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Content

RESEARCH ON THE DESIGN AND DEVELOPMENT OF AN EXPERIMENTAL MODEL OF A ROBOTIC SYSTEM FOR SOME PHASES OF MOLD ASSEMBLY.

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The purpose of this scientific paper is to conduct a case study on a workstation within a company and to automate it. In this context, the starting point is the manual process of assembly and the goal is to develop an experimental robotic assembly system.

1. Introduction

This scientific paper aims to present an automated alternative for the metallic inserts assembly process. The study begins with the injection process, material preparation, homogenization, manipulation of the piece from the mold, and its takeover by the operator. Then, the Poka Yoke Vision system is studied, which ensures the correct and complete assembly of the inserts on the piece. An analysis of the automation requirements is performed, along with Finite Elements Analysis (FEA) and physical analyses using a force transducer. Next, the 3D modelling part is initiated, including sketches, prototypes, and electrical schematics, and available alternatives are explored. The next stage involves the additive manufacturing of some parts and conventional manufacturing of a semi-finished product on a milling machine, through processes such as drilling, centering, and milling. In parallel, work is being done on an image analysis program aimed at recognizing certain surfaces of the piece and converting pixels to millimetres.

2. Current Stage

The chapter is divided in several components, as follows:

2.1 Image Analysis

In order to perform image analysis and precise measurements, a ruler with a fixed length of 10 cm was used as a measurement unit, along with a 6-axis Kinova Gen 3 lite robotic arm presented in both Figure 2.1.1 and Table 2.1.1, and a webcam. Photographs was taken at different camera positions, represented by different values of the arm's Z parameter, and the distance between the centre of the camera and the subject being photographed will be measured in pixels.

Fig 2.1.1- Kinova Gen 3 lite Articulated Robotic Arm [1]

Table 2.1.1. Kinova Gen 3 lite parameters [1]

Information	Values
Degrees of freedom	6
Payload weight	0.5 kg / 1.1 lbs
Total weight	5.4 kg / 11.9 lbs
Maximum reach	760 mm
Maximum speed	25 cm/s
Motor rotation range	± 155 to 160°

To calibrate the system, 30 photographs were taken, five for each value of Z between 0 and 0.25 meters (Fig 2.1.2, 2.1.3), selected using a five-point sampling method. The average number of pixels corresponding to a length of 10 centimetres were be calculated for the 30 photographs and presented in both pixel units and millimetres.

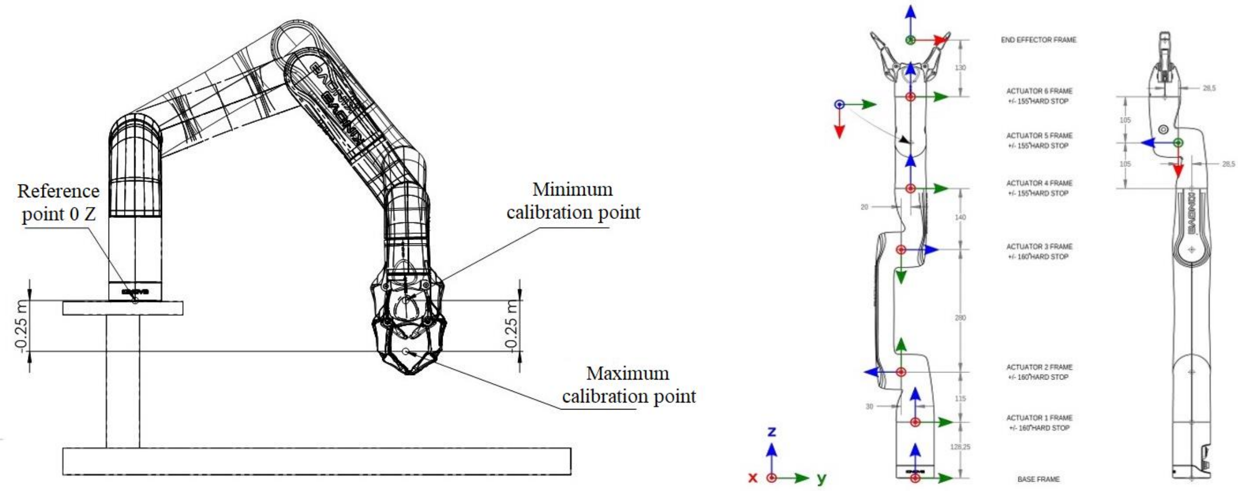

Fig 2.1.2- Calibration principle diagram [2]

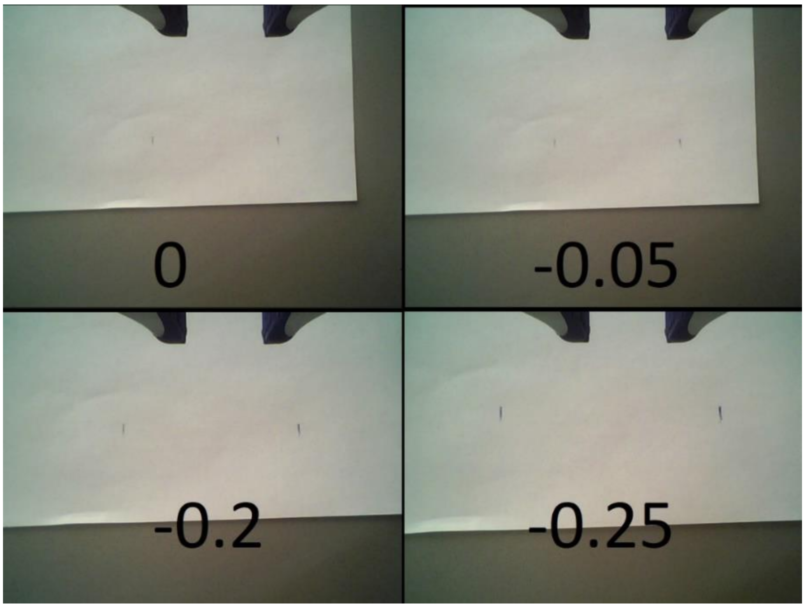

Fig 2.1.3- Images taken by varying the Z parameter

The *Measure* command from NI Vision Assistant was used to determine the distance in pixels between the two lines, as shown in the following figure.

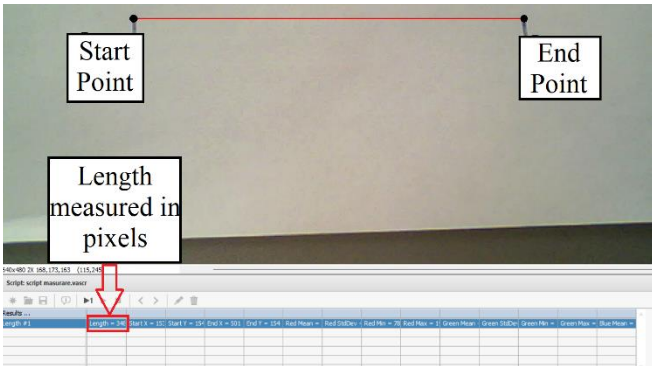

Fig 2.1.4- Pixel measurement method

The following table shows the measurement results.

Table 2.1.2. Pixels measurement results

Z	Pixels per 10cm						Pixels per mm
[meters]	1	2	3	4	5	Average	Average
0	156	155	156	157	157	156.2	1.562
-0.05	175	176	175	176	175	175.4	1.754
-0.1	198	199	199	199	199	198.8	1.988
-0.15	232	232	232	230	232	231.6	2.316
-0.2	277	279	278	279	278	278.2	2.782
-0.25	348	346	347	348	347	347.2	3.472

The equation of the line was calculated using the Curve Expert program, in order to obtain the scaling factor and transform the measurements into real length units, such as millimetres. The "Calculate a nonlinear regression" function was used to obtain the regression line equation, as the points are not arranged on a straight line (Fig 2.1.5). All available nonlinear calculation models were selected, and based on the score obtained from the analysis, the most suitable equation for our data was chosen.

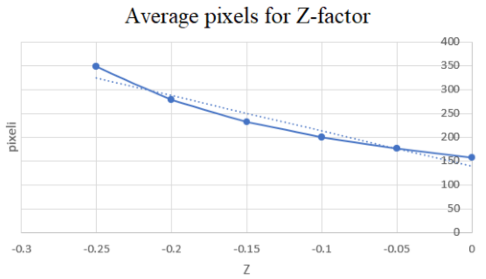

Fig 2.1.5- Nonlinear graph of pixels for the 10 cm unit.

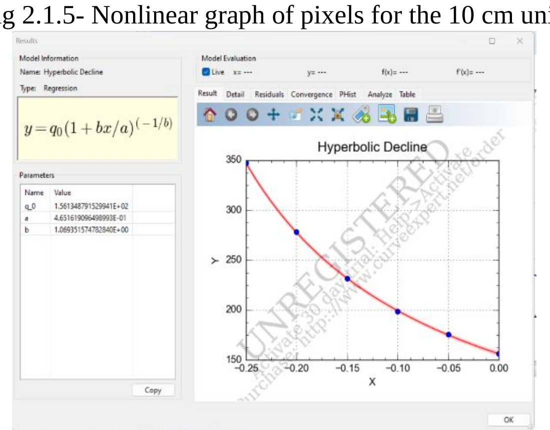

Fig 2.1.6- Presentation of the chosen function

The scaling formula was implemented in the LabVIEW programming environment so that measurements can be transformed into real length units using the "Hyperbolic Decline" function (Fig 2.1.6), which is defined by the parameters "q0", "b", and "a", and the variable "x", which represents the number of pixels. When controlling the system, the height of the object and the fixation device are also taken into account, specifically by adding the parameter "hT" to the formula.

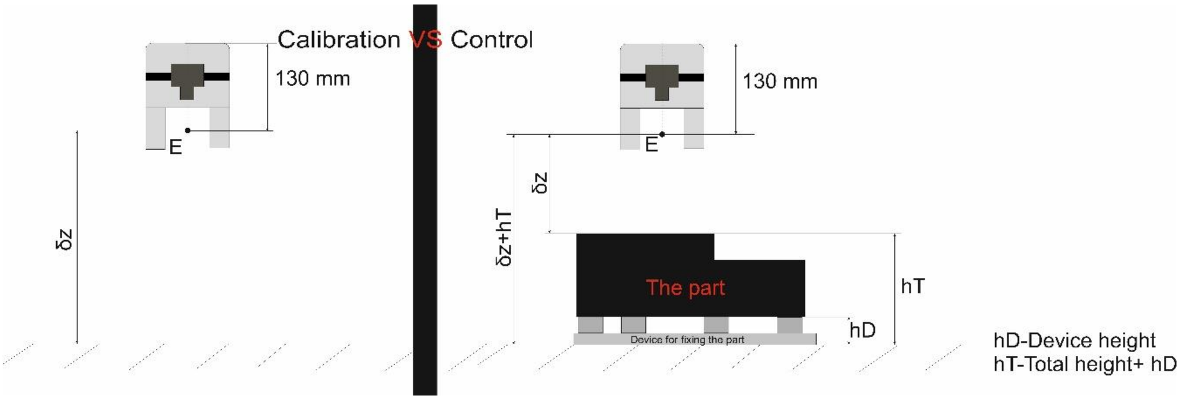

Fig 2.1.7- Calibration vs control with the part

So, image analysis becomes a simple geometry problem as shown (Fig 2.1.8), where C is the camera centre, B is the camera resolution, and D is the centre of the detected object.

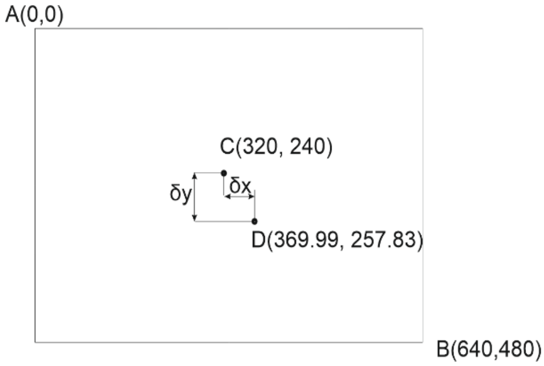

Fig 2.1.8- Converting an image into mathematic representations

Demonstration of pixel to mm conversion:

To reach the centre of the element, we need to move a certain value on the x-axis and another value on the y-axis, according to the following calculations:

The difference between the x-coordinate values of the centre of the element (369.99) and the current position x-coordinate is: $\delta x = 369.99 - 320 = 49.99\, pixels$.

The difference between the y-coordinate values of the centre of the element (257.83) and the current position y-coordinate is: $\delta y = 257.83 - 240 = 17.83\, pixels$.

Thus, to reach the centre of the element, we need to move 49.99 pixels on the x-axis and 17.83 pixels on the y-axis.

To convert the units to millimetres, we applied the conversion formula starting from the relationship of 1 ppm (pixels per millimetre) equal to 1.28666 pixels/mm. For example, to convert the displacement of 49.99 pixels on the x-axis, we multiplied this number by the conversion ratio of 1 mm to 1.28666 pixels, obtaining the value of 38.89 mm. Similarly, for the displacement of 17.83 pixels on the y-axis, we used the same formula and obtained the value of 13.86 mm.

$1\, ppm = 1.28666\, pixels/mm$ (factor calculated by the program for Z = 0 and piece height of 100 mm)

$49.99\, pixels * (1\, mm\, /\, 1.28666\, pixels) = 38.89\, mm$

$17.83\, pixels * (1\, mm\, /\, 1.28666\, pixels) = 13.86\, mm$

The next step is to move the camera centre to the gripper centre, and this is done as follows: we need to calculate the coordinates of the point E (End Effector) relative to the centre of the image sensor C.

It is known that the distance between the two points is 55 mm on the X-axis, so the coordinates of point E can be calculated using the formula:

$$E = C - 55\ mm \qquad (1)$$

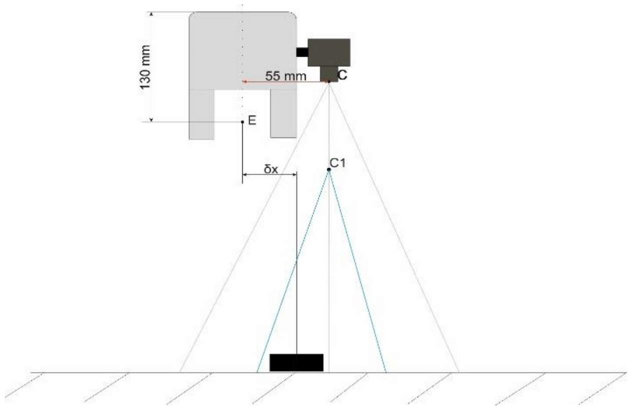

Fig 2.1.9- Moving camera centre to end effector

2.2 FEA analysis vs reality

A FEA analysis was performed using Ansys software to determine the required clamping force of the insert, while simultaneously a real test was conducted with a force transducer. The accuracy of the results obtained is 86.57%. The analysis resulted in a value of 15.149N, while the force transducer indicated a value of 17.5N. This difference is considered to be due to the material used for the insert, Ovako 51CrV4, of which the composition is not fully known.

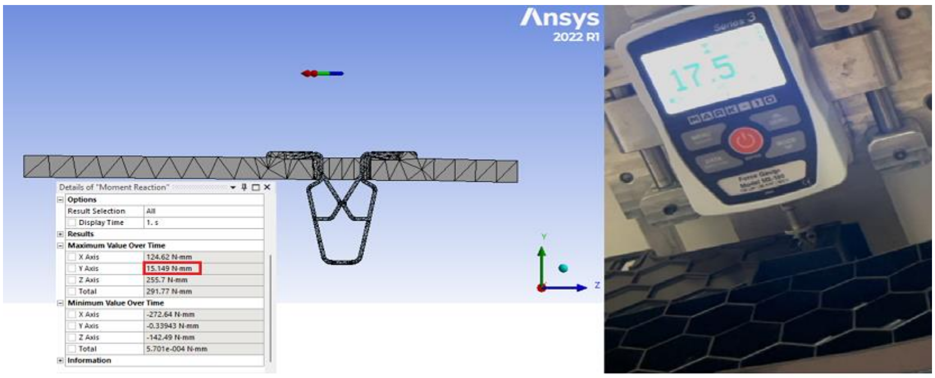

Fig 2.2.1- Interpretation of FEA analysis vs. force transducer

2.3 Device for fixing the part

A complex fixing system has been developed, which was designed through planning five production batches, each comprising 110 assemblies, in an industrial environment. This system was created by building a 3D model and a CAM model, and was successfully manufactured. The purpose of this system is to take over the degrees of freedom of the parts and fix them in a corresponding position.

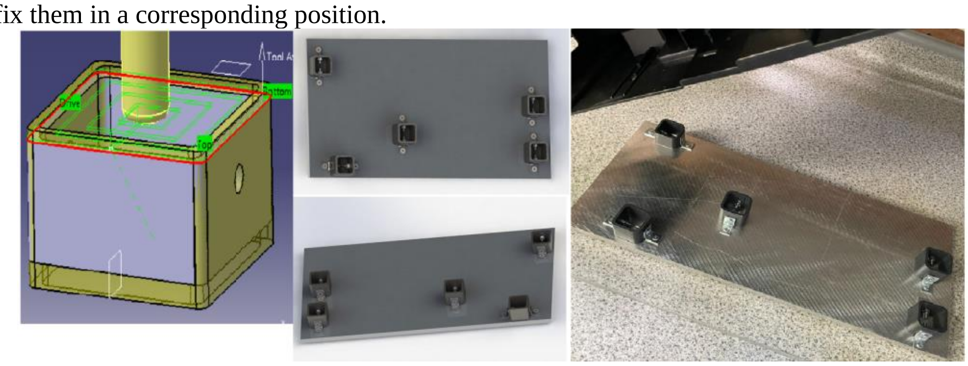

Fig 2.3.1- Device for fixing the part, CAM, rendered, real life

2.4 Inserts sorting device

A complex system has been developed that includes creating a 3D model and printing a sorting device. The purpose of this device is to facilitate the activity of the robotic arm by picking up the inserts. To activate the device, three different trigger solutions were developed: magnetic sensor, proximity sensor, and vision system.

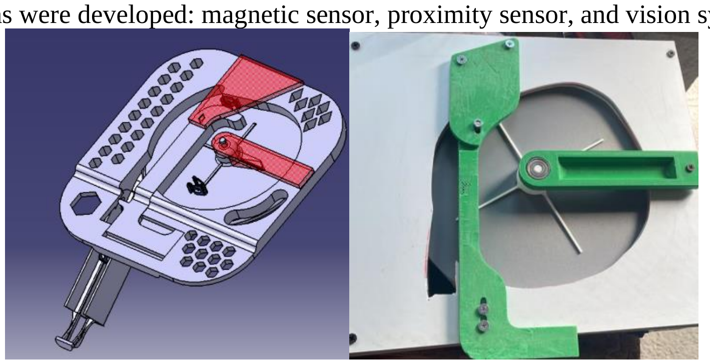

Fig 2.4.1- Insert sorting device CAD vs prototype

2.5 Protective glove for gripper

A complex system has been developed for grasping inserts that will come into contact with a rubber area of the gripper. To facilitate this activity, a special fixture has been designed which has two zones: an inner one that conforms to the shape of the effector, and an outer one that facilitates grasping the insert. This fixture will be used to protect the contact area between the gripper and the metal insert, which can cause damage or wear.

Fig 2.5.1- Protective glove for gripper VS Alternative to 3D printing, silicone mold

3. Conclusions

This research article describes the design and development of an experimental robotic system for certain phases of mold assembly. The manual assembly process is analyzed, an automated Vision system is developed to ensure correct and complete assembly of parts, and physical and engineering analyses are performed using a force transducer, 3D models, prototypes, and electrical schemes. A semi-finished product is processed through milling processes, while simultaneously, an image analysis program is developed to recognize certain surfaces of the part and convert pixels to millimetres. Future research directions may include implementing the robotic system in a real production environment, improving the image analysis program, and exploring other production methods. Additionally, machine learning algorithms can be implemented in the robotic system to improve its accuracy and efficiency.

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DESIGNING AND BUILDING AN EXPERIMENTAL MODEL OF A ROBOT THAT MEASURES DISTANCES IN A ROOM

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Abstract: This paper presents the design, construction and programming stages of a robot that can measure distances in a room. In the first stage, each component was designed using 3D software, followed by assembly for testing. In the second stage, the parts were manufactured using 3D printers and electronic components were acquired. The third stage involves testing the electronic components, with the final stage being the assembly of the robot and testing its performance.

KEYWORDS: robot, sensor, measurement, manufacturing

1. Introduction

This project presents the design and assembly stages of a robot that can measure distances in a room. This project can be useful for understanding the process of designing and building a robot, as well as developing programming skills.

The objectives of this project are to familiarize with the functioning of the robot, to adapt the robot to any kind of enclosure, to understand and develop applications to perform necessary tests, to control the robot and to improve and optimize the system. In order to achieve these objectives, various design and programming methods were used for the robot, and the optimal solution was chosen.

2. Current status

There are several technologies and methods currently used for distance measurement with the help of robots, such as the following examples:

• Ultrasonic distance sensors - they work by emitting sound waves with a very high frequency and measuring the time it takes for the waves to bounce back to the sensor after encountering an object [7];

• Lidar - is a sensor technology that uses lasers to measure the distance to an object. This technology has been implemented mainly in self-driving vehicles and autonomous robots [8];

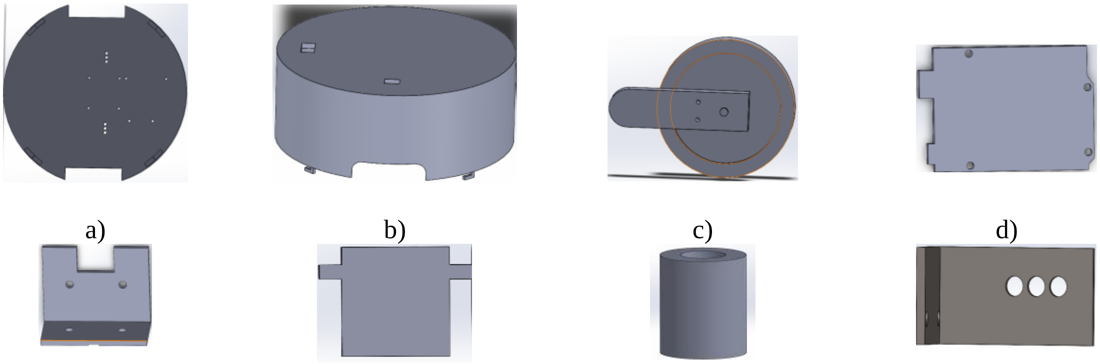
• Infrared distance sensors - they emit and detect infrared radiation, and the distance to an object can be calculated based on the time it takes for the radiation to bounce back to the sensor[9].

The technologies and distance measurement methods presented are very advanced and are used in a wide range of applications. However, the continuous development of artificial intelligence and other technologies could lead to the improvement of these approaches.

3. Designing and building the robot

The prototype of the measuring robot was made using specialized software. The first objective of the project was to take the measurements from the datasheet of the components that were placed on the chassis, and then design them to simulate the assembly.

The modeled components are shown in Figure 1.



a) b) c) d)

e) f) g) h)

Fig. 1 Modeled components: a) bottom casing, b) top casing, c) wheel and motor, d) Arduino Uno R3, e) sensor holder, f) SG90 servo motor, g) spacer, h) motor holder

The figure bellows shows the assembled robot containing the components presented in Fig. 1.

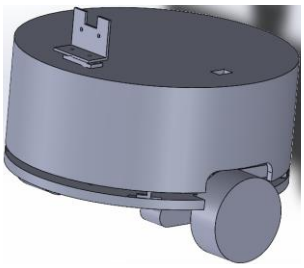


Fig. 2 The final assembly of the robot

4. Additive manufacturing

The next objective of the project was to 3D print the components using the most optimal printing method. To configure the settings and choose the printing material, the Z-Suite program was used (Fig. 3a). In terms of cost and printing time, PLA (Polylactic Acid) material was chosen for the print.

a) b)

Fig. 3 Bottom casing: a) part presentation on the printer, b) physically produced casing (finished product)

After manufacturing the bottom casing, the next step was to verify the closure of the top casing. A sample was created to check the closure of the lid on the chassis, as shown in Fig. 4.

After testing, the settings for the top casing were adjusted, and different 3D printing technologies were compared to choose the best one in terms of cost, printing time, and strength.

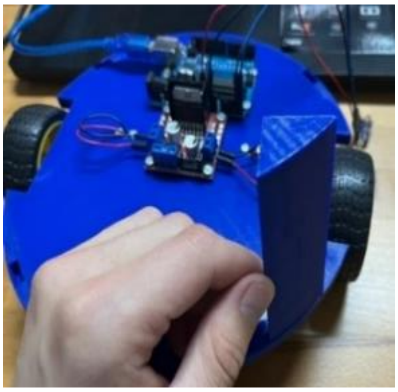
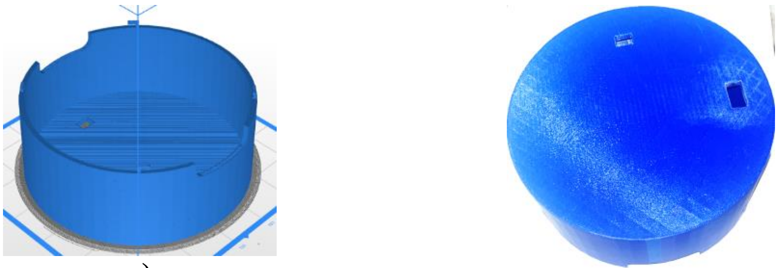


Fig. 4 Sample test for closure

The printer used for manufacturing the components is Zortrax M300 Dual, and the material chosen after the study was PLA.



a) b)

Fig. 5 a) Part presentation on the printer, b) Physically produced top casing (finished product)

The next step after printing the casings was the acquisition of the electronic components presented in Table 1.

Table 1. The components

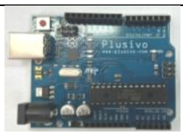
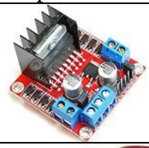
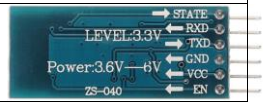
No.	Category	Quantity	Representation	No.	Category	Quantity	Representation
1.	Whell	2		4.	Sensor VL53L0X	1	
2.	Motor	2		5.	Battery case	1	
3.	Plusivo controller	1		6.	Battery	2	

Table 1. The components (continued)

No.	Category	Quantity	Representation	No.	Category	Quantity	Representation
7.	L298N	1		10.	Breadboard	1	
8.	Servomotor SG90	1		11.	Motor holder	2	
9.	Start/Stop button	1		12.	Bluetooth module hc-05	1	

5. Testing the DC motors and servomotor

The next stage consists of testing the functionality associated with both the DC motors and the servomotor – as shown in Table 1. The DC motors are responsible for providing a means for locomotion for the robot, by engaging the two wheels presented in Figure 9b, and the servomotor is tasked with controlling the position of the VL53L0X sensor [4].

5.1 Testing the DC motors

The first step was to create a program that would be very easy to use for testing the DC motors. To use the Plusivo board, compatible Linx and Arduino modules were installed. The program in Fig. 6 shows the use of the Linx module. On the left and right side of the While loop, the connection is opened/closed. The While loop is used to continuously run the program until the user presses the STOP button. Inside the loop, three functions are used to start the motors and set their speed.

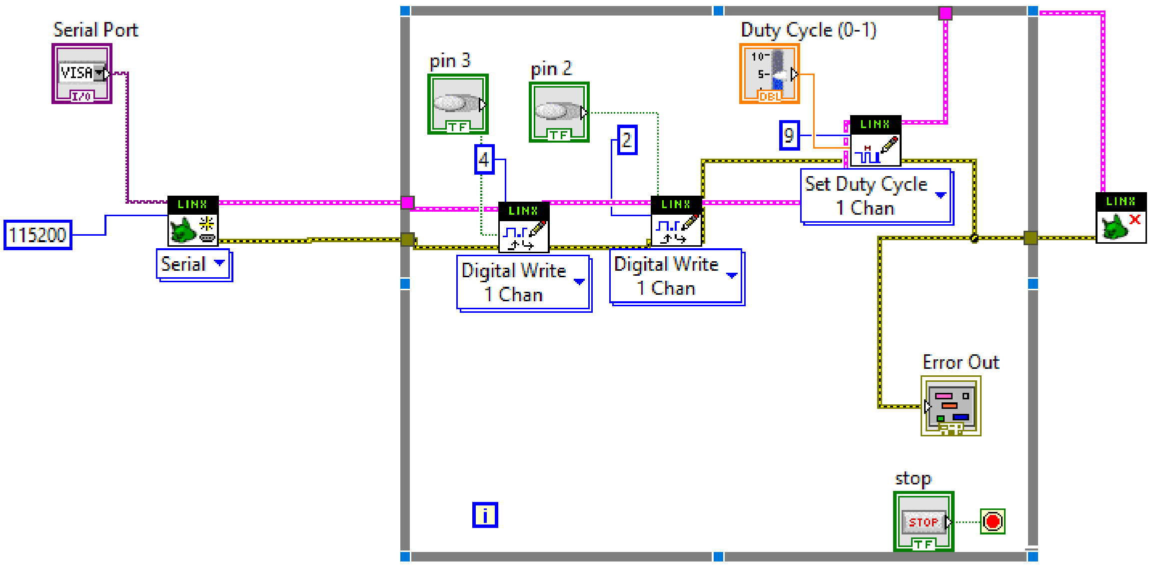


Fig. 6 DC motor programming schematic

5.2. Testing the SG90 Servomotor

The second step is to create a program for testing the SG90 servomotor, for which a sub VI was developed. This subprogram was designed to continuously run the servomotor until the STOP button is pressed. To establish the connection between Arduino and the specialized software, the Linx function can be used. The program's open/close functions are located outside the While loop. Also, outside the loop is the Servo Open One Channel function, through which the servo sends data to Plusivo board, via digital pin 10. Inside the While loop in Fig. 7, calculations are made to rotate the servo from 0 to 180 degrees with a delay of 10 ms.

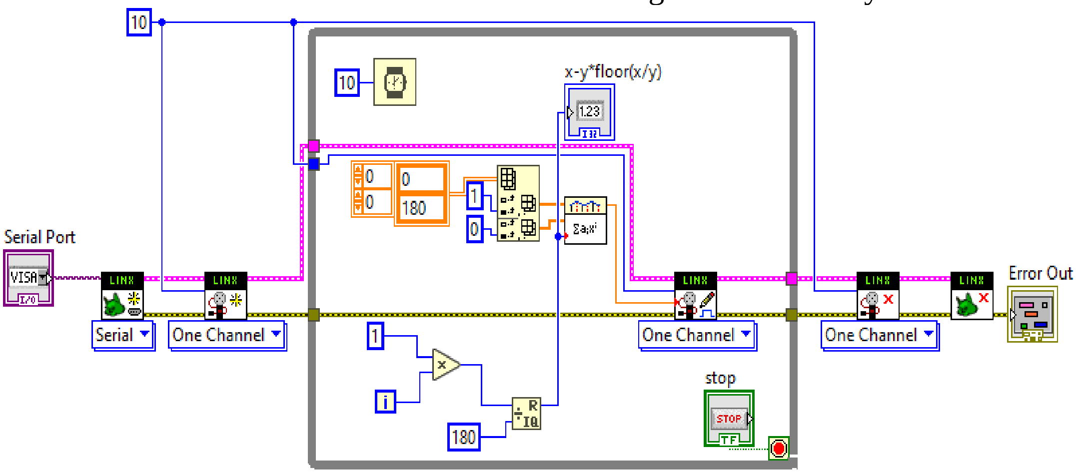


Fig. 7 Servomotor Program schematic

6. Robot assembly and connection diagram

The first step in assembling the electronic components of the robot was to create the connection diagram presented in Figure 8. In this figure, the connection mode between the motors, servomotor, sensor, Bluetooth HC-05 module, and Arduino Uno R3 board can be identified.

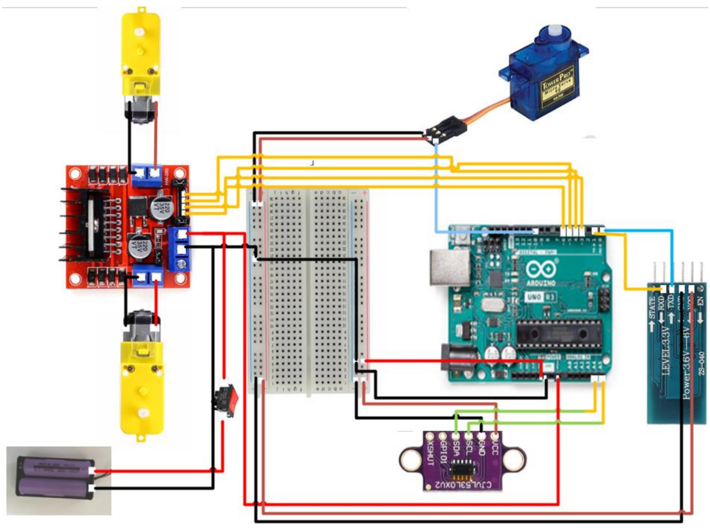
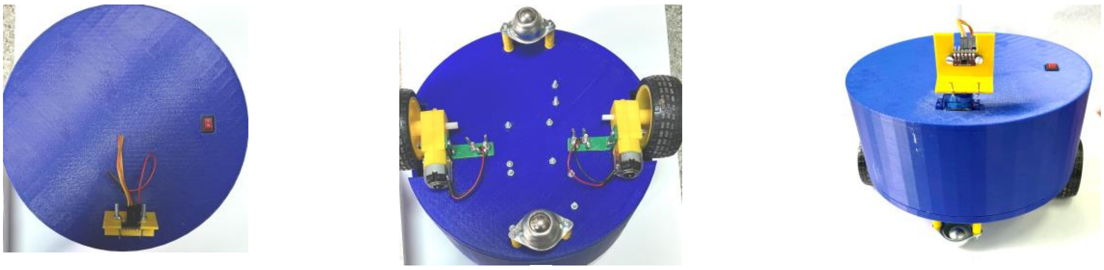


Fig. 8 Electrical diagram

In Figure 9 the final assembly of the robot can be seen. When constructing the electrical diagram from Figure 8, the component parts presented in Table 1 were taken into account.

The third step involves developing a program necessary for controlling all of the electronic components. Following the completion of the tests, a program was developed that measures distances in a room and runs continuously until the user presses the STOP button.



a) b) c)

Fig. 9 Bottom case: a) top view of the robot, b) bottom view of the robot, c) front view

7. Conclusions

In conclusion, this project has practical applications in various fields, such as construction industry and land surveying. The project involved the development of a robot capable of measuring distances in a room. The work that went into developing the prototype included the use of a VL53L0X sensor, DC motors, and servomotor in a practical context – distance measurement. Practical concerns also regarded the use of additive manufacturing for physical prototyping, sensor calibration for measurement accuracy in order to achieve an autonomous operation of the robot.

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DEVELOPMENT OF AN ALGORITHM FOR THE DOSING OF POLYMERIC MATERIAL IN INJECTION MOULDING

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SUMMARY:

The proposed software solution will calculate the amount of granules to be injected into the mould by comparing real-time values transmitted by a series of sensors with ideal values from a database. This system will monitor key parameters such as injection pressure and time, cooling time, melting temperature, etc. By analysing these parameters in real time, the software solution will dose the ideal amount of granules that are required for injection, thus ensuring that the part fits the desired specifications. The computer system will also take into account the type of material used as well as the injection volume. In this way, manufacturers will increase the efficiency and accuracy of the injection process, reducing the amount of residue and ensuring product quality.

1. Introduction

In-mould injection technology has advanced significantly over the years, including the use of innovative software solutions that have revolutionised the industry.

The use of computer-aided design software is one of the most important innovations in the field of injection moulding. Engineers can use CAD software to create complex 3D models of their products, which can then be translated directly into mould design. This technology has significantly reduced the time needed to create moulds, while allowing for more precise and accurate design.

Another significant advance is the use of simulation software such as Moldflow Analysis. Engineers can use simulation software to predict how the plastic will behave during the injection moulding process, allowing them to optimise mould design and process parameters. This reduces the number of design iterations required and reduces the risk of end-product defects.

Throughout production experience, it has been observed that an injection programme made at one point in time does not achieve its initial results as time goes by, regardless of the time of day or season.

This is due to disturbing factors acting on the injection process such as ambient temperature fluctuations, different material batches, cooling water temperature fluctuations, non-return valve closing behaviour and others. Therefore, periodic intervention is required to compensate for these disturbances through small periodic program adjustments (switch point, pressures, speeds).

Given these facts, a pertinent solution that could improve the injection process would be a computer system that adjusts the dosage of polymeric material in real time from injection to injection.

2. Current status

In order to understand how to approach this problem, a detailed analysis of the injection unit is necessary. It serves to plasticise the material, to pressurise it into the mould and to maintain the pressure in the compression stage. In its composition, there are the following elements:

- **Nozzle** (the fitting at the head of the injection cylinder through which the plastic material passes from the cylinder into the injection mould);

- **Screw** (the active part of the injection moulding machine and is built in several versions);

- **Cylinder** (ensures the heating and homogenisation of the material as well as the generation of the necessary pressure);

- **Hopper** (is placed on the injection moulding machine cylinder in the area of the feed hole);

- **Injection moulding machine table** (the mechanical assembly on which the entire injection unit is mounted);

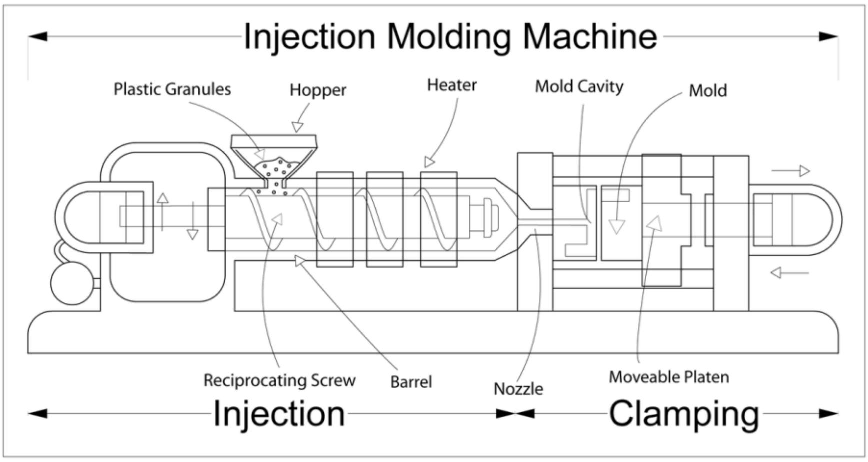

Fig. 1. Injection screw

The injection moulding screw is a basic component of an injection moulding machine that melts and injects plastic material into the mould cavity. It is divided into three distinct zones, each of which has a specific purpose in ensuring optimal plastic processing. These zones are known as the feed zone, the transition zone and the metering zone.

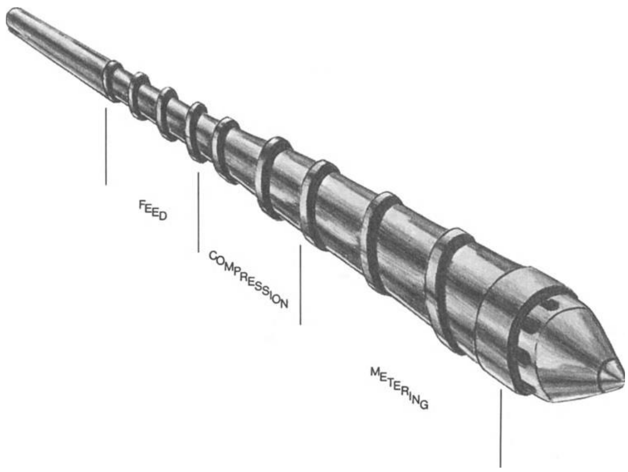

Fig.2 Injection screw. [2]

- **Feed zone**

The feed zone is located near the back of the screw and is responsible for picking up and transporting the solid plastic granules to the heated cylinder. The plastic granules are gradually compressed and transported forward in this zone. The main objective of the feed zone is to maintain a consistent and continuous flow of material, preventing bridging or uneven feeding.

- **Compression zone**

As the next area after the feeding area, this is where the plastic granules begin to melt and become molten material. The temperature gradually rises in this zone until the melting point of the plastic is reached. The screw design is optimised to generate the shear and pressure required for efficient melting. In the transition zone, the molten plastic transforms from a solid to a viscous, molten state.

- **Metering zone**

This area is the final section of the screw, closest to the die. Its function is to precisely control and measure the amount of molten plastic to be injected into the mould cavity. The depth and compression of the screw gradually decreases in this zone, allowing precise volume control. The screw rotates at a constant speed, ensuring that the molten plastic is injected into the mould in a constant and controlled manner.

The three-zone configuration of the injection screw allows optimal processing of the plastic and ensures that the molten plastic is delivered evenly and consistently during the injection process. Temperature, screw speed and other parameters in each zone can be adjusted to suit different plastic types, viscosities and injection requirements.

This zone will be the starting point in solving the dosing problem. Injection size in the mould injection process refers to the volume of molten plastic injected into the mould cavity during each cycle. It plays a crucial role in determining the quality and characteristics of the final product. Injection size is usually measured in grams and depends on a number of factors, including the size and complexity of the part as well as the type of material used and the capabilities of the injection moulding machine.

The proposed software solution consists of three main components: the database, the sensors and the algorithm. The database stores the ideal values of various parameters such as mould temperature, injection pressure and melt temperature. The sensor measures the real-time values of these parameters during the injection process. The algorithm compares the real-time values with the ideal values and calculates the mass of plastic to be injected to achieve the desired quality of the injected part.

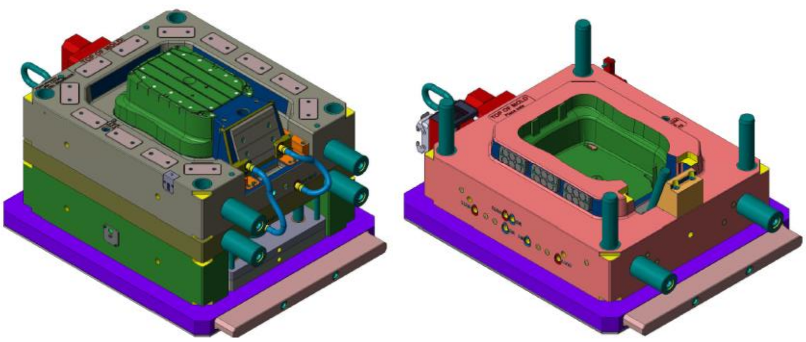

Fig.3. Movable part and fixed part of the injection mould.

It will be implemented using the Python programming language. The user interface is designed using the Tkinter library, which provides a simple and easy-to-understand user interface. Sensor data is acquired using the PySerial library, which allows communication with the sensor via a serial port. The algorithm is implemented using the NumPy and SciPy libraries, which provide very useful mathematical and statistical functions.

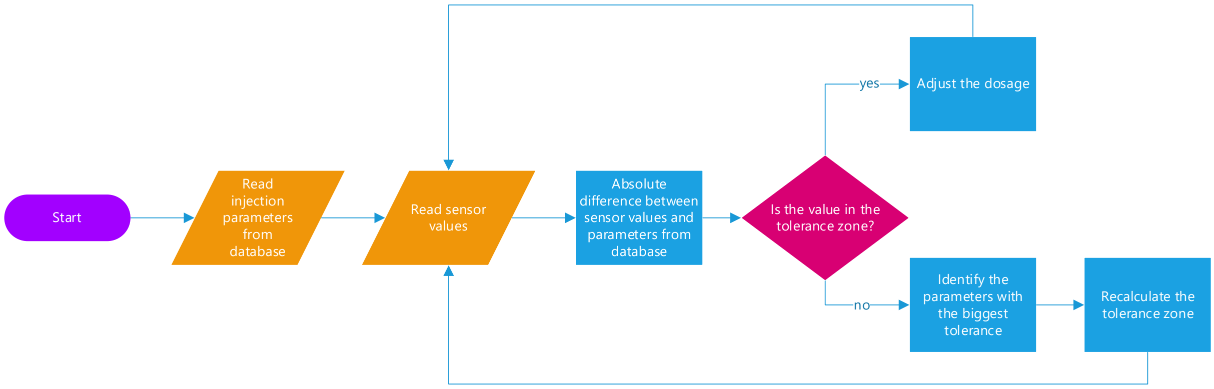

Fig. 2 Recursive algorithm diagram for dose calculation.

3. Contents

To determine the quantity of material, the mathematical model will start from the volume of the product. In this case, the volume of the product is specified. The calculation of the cavity volume in the mould will also be taken into account. The mould cavity volume is the space inside the mould that will be filled with plastic to create the product. It is usually larger than the part volume to account for factors such as shrinkage. The injection mould cavity volume (V_c) can be calculated by multiplying the part volume by a factor, usually between 1.2 and 1.5.

$$V_c = V_p \cdot F_c \tag{1}$$

The next important element is the fill factor which takes into account the additional volume required to compensate for the shrinkage of the material during the cooling and solidification stages. This is usually expressed as a percentage. To calculate the fill factor (U_F), the formula is used:

$$U_F = 1 + (\frac{P_c}{100}) \tag{2}$$

In that way, we obtain an initial formula for the dosage :

$$D_i = V_c \cdot U_F \tag{3}$$

Subsequently, the injection pressure (P_{inj}) and volume (V_{inj}) as well as the dosing rate (D_v) are integrated into the equation:

$$D = D_i \cdot \left(\frac{V_{inj}}{P_{inj} \cdot D_v}\right) = V_c \cdot U_F \cdot \left(\frac{V_{inj}}{P_{inj} \cdot D_v}\right)$$

(4)

In order to confirm the principle, values for the parameters in the formula will be entered according to the test injections performed.

Table 1. Testing values obtained from the injection test process.

Nr.	Parameter	Value	Unit
1.	Product volume	933.352	[cm^3]
2.	Cavity factor	1.2	-
3.	Shrinkage	0.75	[%]
4.	Compensatory injection volume	459.39	[cm^3]
5.	Injection pressure	1450	[bar]
6.	Dosage speed	0.55	[mm/s]
7.	Product mass	1120 ± 5%	[g]

Applying the formula based on the parameter values, we obtain :

$$D_{test} = 933.352 \cdot 1.2 \cdot (1 + 0.75) \cdot \left(\frac{459.39}{1450 \cdot 0.55}\right) = 1129.05 \quad [g] \tag{5}$$

After applying the formula with the real parameters obtained from the test injection, we can see that the mathematical model is correct and falls within the error margin of the product mass value.

$$1064 \leq 1129.05 \geq 1175 \ [g] \tag{6}$$

4. Conclusion

This project presents a software solution that optimises the injection process, allowing real-time adjustment of the plastic supply to meet desired specifications. The algorithm compares actual sensor values with ideal parameters and then adjusts this plastic dosage to ensure that the finished product meets the desired quality standards.

One of the main advantages of the software is the user-friendly interface, which allows the user to enter ideal values for each parameter and monitor the injection moulding process in real time. The interface displays sensor values and ideal values as well as a graph of the injection parameters in real time. This feature allows the user to monitor the performance of the injection process.

This computer system reduces the amount of wasted material and improves product quality by optimising the process. The software solution ensures that plastic material input is adjusted to meet desired specifications, preventing the production of defective parts and reducing material waste.

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5. Notations

- V_c : Cavity volume [cm^3]
- V_p : Product cavity[cm^3]
- F_c : Cavity factor
- U_F: Fill factor
- D_i : Initial dosage [g]
- D : Dosage [g]
- V_{inj} : Injection volume [cm^3]
- P_{inj} : Injection pressure [bar]
- D_v : Dosing speed [mm/s]

AUTOMATIC HARVESTING SYSTEM FOR RIPE TOMATOES

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ABSTRACT: This paper presents some of the existing work on this topic, the calculations used to select the appropriate motors for robot functionality, and some examples of ripe tomato detection.

KEYWORDS: algorithms, tomatoes, autonomy, detection

1. Introduction

Artificial intelligence (AI) represents the ability of a system or robot to mimic the human mind as closely as possible, make decisions, and achieve goals in the most efficient way possible.[1]

AI analyzes existing data and can predict future actions, thus becoming autonomous. It operates similarly to humans by learning new things, applying them, and adapting along the way to become as efficient as possible.[1]

Agricultural work has shown its disadvantages with climate change and with the professional preferences regarding the jobs that humans want to do, resulting in a considerable decrease in the number of people engaged in harvesting various crops. Additionally, the working conditions offered by the environment/greenhouse are difficult to tolerate, which can affect human health, reduce performance and productivity, and even lead to additional medical expenses.

Given the above, the purpose of this paper is to develop an autonomous robot that harvests ripe tomatoes, with a minimum operating time of 8 hours, high accuracy in detecting ripe tomatoes, and a efficiency at least equal to that of humans in terms of the number of tomatoes harvested per minute. The objectives will be achieved with carefully selected components, offering system rigidity, necessary speed of operation, and precision of functionality. The detection of ripe tomatoes will be done using the Roboflow and Google Colab websites, a USB camera connected to a Raspberry Pi, and the OpenCV library in the Python programming language.

2. Current stage

In this chapter, the current progress of the paper and the 3D model of the system will be presented.

In terms of algorithms used for programming the system, only the code for detecting ripe tomatoes and the code for detecting distance using ultrasonic sensors exist.

In terms of the prototype, the mechanical and physical components are present, printed, and modeled up to 90%. After researching existing projects, analyzed by specific parameters such as the duration of operation, robot autonomy, harvesting speed, sensors used for detection and movement, mode of locomotion, effector type, and size dimensions, the 3D model of the autonomous robot was designed and created.

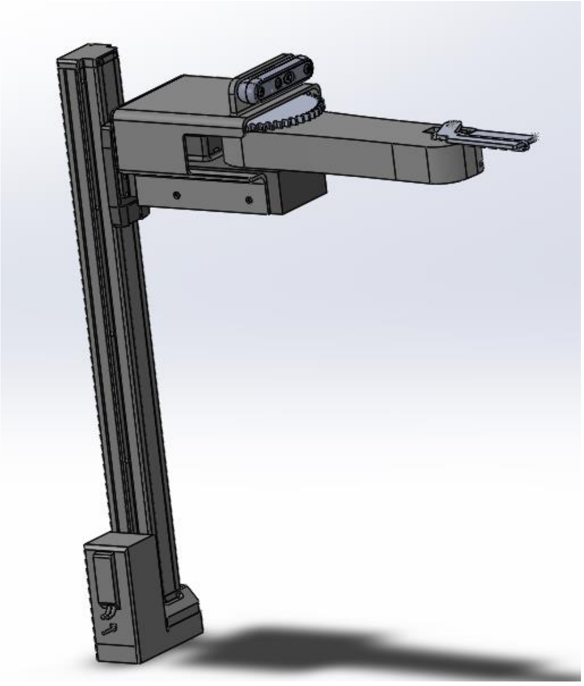

Fig. 2.1 - 3D model of the robotic harvesting arm

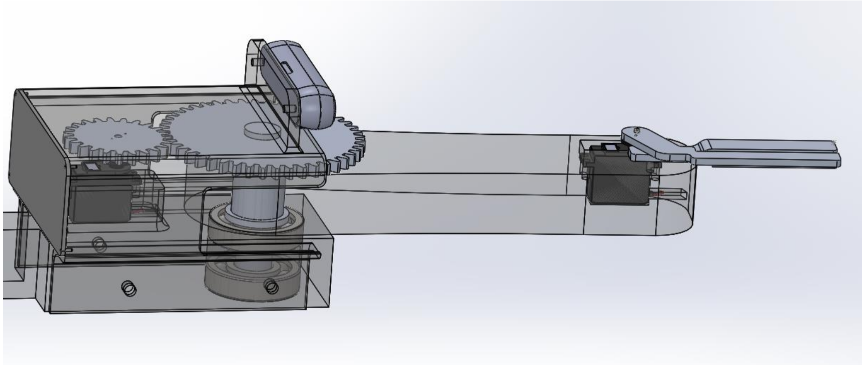

Fig. 2.2 - 3D model of the robotic arm - interior view

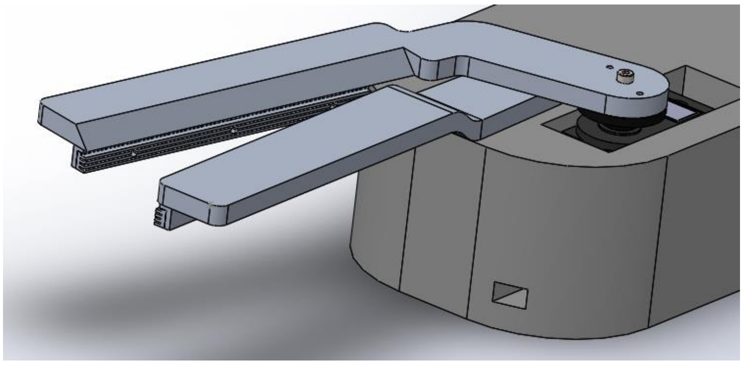

Fig. 2.3 - The effector - designed to grip the stem after cutting

3. Technical report

In this chapter, calculations for the motors used to rotate the arm and the cutting tool are presented.

3.1.1 Calculation of the rotating arm motor - To avoid the high load directly applied to the motor shaft, a gear wheel transmission mechanism was used, thus making the rotation of the robotic arm possible."

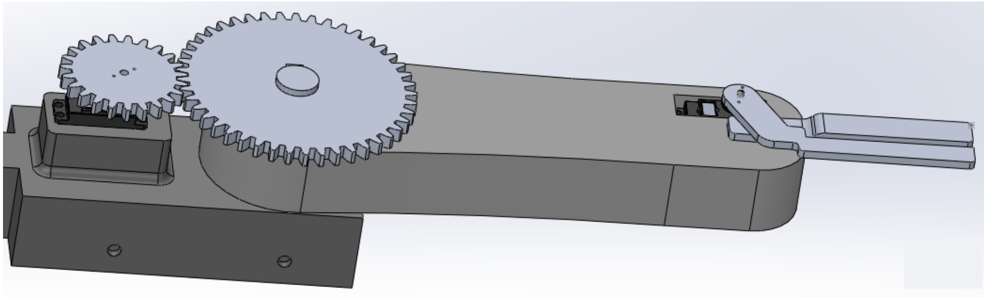

Fig.3.1.1 – Gear wheel transmission, 3D representation

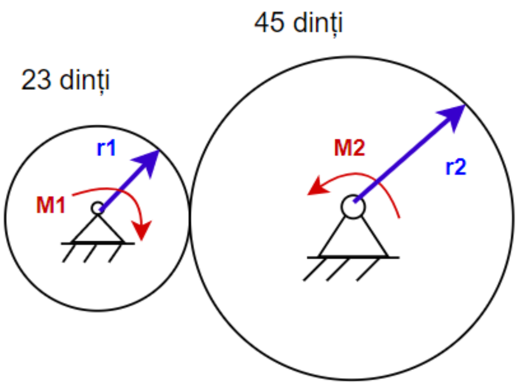

Fig.3.1.2 – Strength diagram for the gear transmission

Moments of inertia: (grams * square millimeters)
Taken at the output coordinate system.

Ixx = 3718398.09	Ixy = 30288.99	Ixz = -5429829.49
Iyx = 30288.99	Iyy = 39167810.17	Iyz = -41349.40
Izx = -5429829.49	Izy = -41349.40	Izz = 37526816.90

Fig.3.1.3 – Moment of inertia to be overcome by the motor (obtained from SolidWorks program)

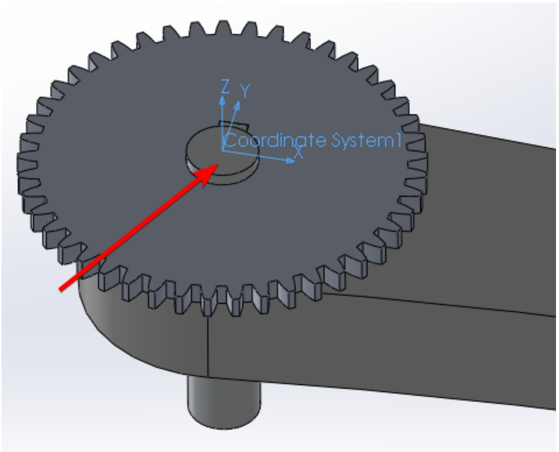

Fig.3.1.4 – Moment of inertia calculated around the OZ axis

$$Z1 := 23 \qquad Z2 := 45 \qquad i := \frac{Z2}{Z1} = 1.957$$

$$J := 0.0375\ kg \cdot m^2$$

$$t := 0.1\ s \qquad \eta := 10\ rpm \qquad r1 := 37.5\ mm \qquad r2 := 70.5\ mm$$

$$w1 = 2 \cdot \pi \cdot \frac{\eta}{60} = 1.047\ \frac{rad}{s} \qquad w1 := 1.047\ \frac{rad}{s}$$

$$w2 := \frac{w1}{i} = 0.535\ \frac{rad}{s}$$

ε = angular acceleration

$$\varepsilon_2 := \frac{w2}{t} = 5.351\ \frac{rad}{s^2} \qquad M2 := \varepsilon_2 \cdot J = 0.201\ N \cdot m$$

$$M1 := \frac{M2}{i} = 0.103\ N \cdot m \qquad M1 = 1.046\ kgf \cdot cm$$

Fig.3.1.5 - shows the calculation of the torque required for the servo motor in the gear transmission assembly

To move the robotic arm, the 'OKY8107 SPRINGRC' motor from SpringRC company was chosen.[2] It was selected with a higher torque because we have considered a big safety factor to compensate for the natural phenomena that were simplified. The torque is 3kg/cm at a supply voltage of 6V, which means a torque of 0.294Nm.

Fig.3.1.6 - The motor selected for the gear wheel mechanism[2]

3.2 Calculation of the motor for the cutting blade

Moments of inertia: (grams * square millimeters)
Taken at the output coordinate system.

Ixx = 2490627.28	Ixy = 3053160.23	Ixz = 4686846.11
Iyx = 3053160.23	Iyy = 32264874.41	Iyz = 735345.60
Izx = 4686846.11	Izy = 735345.60	Izz = 32232675.99

Fig.3.2.1 – Moment of inertia to be overcome by the motor (obtained from SolidWorks program)

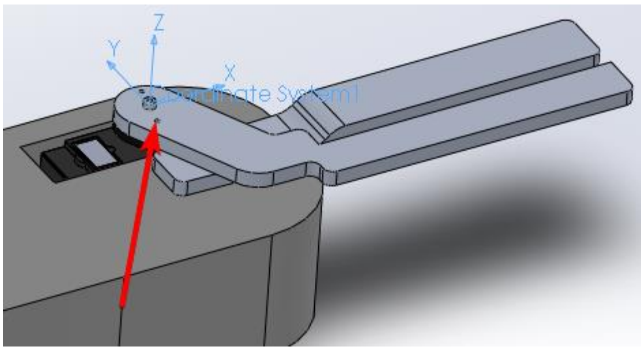

Fig.3.2.2 – Moment of inertia calculated around the OZ axis

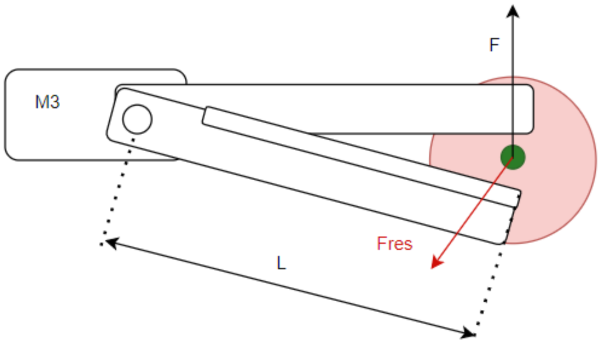

Fig.3.2.3 – The resistance diagram of the scissors

$t := 1\ s \qquad \eta := 0.3\ rpm$

$w = 2 \cdot \pi \cdot \frac{\eta}{60} = 0.031\ \frac{rad}{s} \qquad w := 0.031\ \frac{rad}{s}$

ε = angular acceleration

$\varepsilon := \frac{w}{t} = 0.031\ \frac{rad}{s^2}$

$J := 0.0322\ kg \cdot m^2 \qquad L := 134.4\ mm$

$m := 4.1\ kg$

$F - Fres = 0 \qquad Fres := m \cdot g = 40.207\ N$

$F := Fres$

$M := F \cdot L + J \cdot \varepsilon = 5.405\ N \cdot m \qquad M = 55.114\ kgf \cdot cm$

Fig.3.2.4 – Calculation for the motor needed to cut the stem

The motor chosen after the calculations is the "Servo Power HD WH-65KG" produced by PowerHD[3] with a torque of 65 kg*cm at a supply voltage of 8.4V.

Fig.3.2.5 – The motor chosen for cutting the stem [3]

4. Algorithm for detecting ripe tomatoes

As mentioned in the introduction, automatic fruit detection was achieved by adding sets of images to the program provided by Roboflow[4], where they were labeled as ripe-tomato or unripe-tomato, and then trained. The data was then entered into Google Colab[5] for detailed GPU training, and the final files were added to the Python program, OpenCv with Darknet. The results obtained can be seen below.

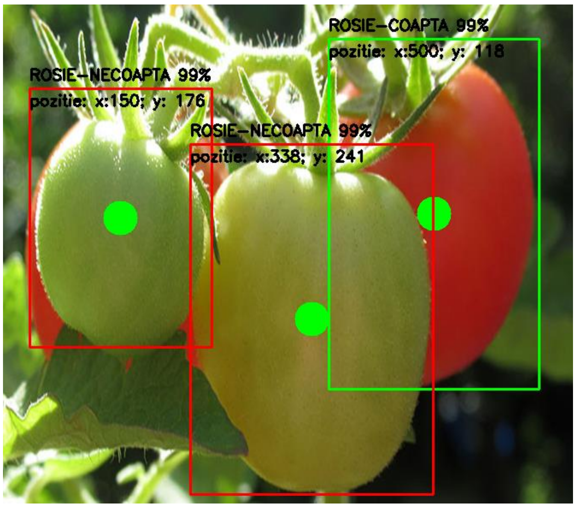

Fig.4.1 – The detection of the tomatoes -1

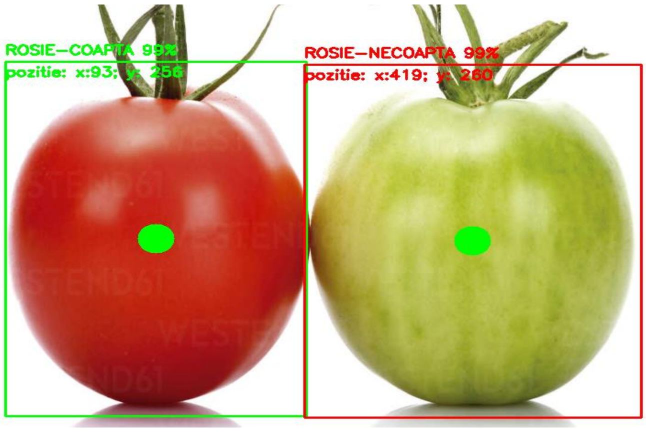

Fig.4.2 – The detection of the tomatoes -2

5. Conclusions

Based on the calculations presented above, an Arduino code will be developed to perform the rotation and translation movements of the robot. Knowing what types of motors are needed, the complete 3D system of the robot will be designed and assembled with the electrical components. Regarding the detection aspect, we can observe that the confidentiality is high but suffers from some omissions. To improve the prototype of this work, the following two options will be considered:

1. The room will exclusively contain tomatoes and will be properly lit.
2. The dataset will be expanded to differentiate between other fruits such as apples.

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[3]https://www.monsterhopups.de/Power-HD-WH-65KG-Servo-65-kg-HV-fuer-1/5-1/6-Metallgetriebe-Wasserdicht-Kugellager
[4] https://roboflow.com/
[5]https://colab.research.google.com/drive/1mzL6WyY9BRx4xX476eQdhKDnd_eixBlG

RESEARCH REGARDING THE DEVELOPMENT OF A SMALL WIND TURBINE

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ABSTRACT: In the past couple of years, the transition to green energy has become one of the goals of the European Union, with the aim of ensuring an improvement in the people's quality of life, while considering the need to protect the environment. With this in mind, innovation in the past couple of years had strived to improve and bring forth solution which are friendly to the environment, and furthermore, even reinvent what we perceive as power sources, in order to use accessible resources without creating more waste. In this context, this paper studies an experimental model of a small wind turbine powered by wind currents generated from intense traffic on highways. The goal of the proposed prototype is a green alternative to energy production that can help light posts along the road or provide electricity for potential charging stations. The proposed methodology is the result of a combination of the study of the need for such a solution in the current market context and the design and implementation of the proposed solution.

KEYWORDS: Vertical Axis Wind Turbine, Wind energy, Green energy, Renewable energy, Alternative source of energy.

1. Introduction

Wind turbines can generate energy that can be fed into grid systems or used to power homes and businesses. Most of the wind systems that are used to generate power are large wind turbines that average over 30 meters in height and are generally installed in fields, outside cities and offshore, far from shore.

Small vertical axis wind turbines are wind power generators that are small compared to wind power generators used on an industrial scale. They are designed to convert the kinetic energy of the wind into electrical energy. They are usually composed of a rotor, a gearbox, an electric generator and a support structure. The rotor is the part that captures the wind energy and is made up of several blades (usually between 2 and 6). These blades are designed to rotate around an axis in the direction of the wind. When the wind hits the blades, the rotor spins and the kinetic energy of the wind is converted into mechanical energy via the gearbox. The gearbox is located between the rotor and the generator and has the role of increasing the rotation speed of the rotor and transmitting mechanical energy to the electric generator. The generator then transforms mechanical energy into electrical energy, which is then transferred to consumers or the public grid.

Small vertical axis wind turbines are designed to operate at lower wind speeds because the wind is less constant and weaker in urban and rural areas than in open sea or plain areas. Therefore, the rotor blades are smaller and lighter than those of large wind turbines, and the maximum rotation speed is lower. They are also designed to be more compact and easier to install and maintain. They are typically used to provide electricity in isolated areas or to power small consumers such as homes and small businesses and street lighting. Upon a closer study of the differences between industrial wind turbines and small ones, we can note some of the advantages of using the latter for this work. At the moment, there are discussions regarding the negative effect of large turbines both on the environment due to the noise produced and the destruction of the habitat for animals and birds, and on the security of the airspace due to the disruption of radars. In addition, this type of wind system required a significant financial effort due to installation, maintenance and monitoring during the operating cycle, in addition to the logistical effort regarding the network and transport infrastructure.

In comparison, small vertical axis wind turbines are more environmentally friendly, generating less noise, and by nature of small size design, no longer a factor affecting the life of surrounding animals or air traffic. Also, another aspect that supports the premise of this work refers to the possibility of placing the turbines closer to the grids or current consumers, which would require lower infrastructure costs and would also represent an advantage for transport and maintenance costs.

2. Current stage of research

The vertical axis wind turbine industry has grown in popularity in recent years, as it offers significant advantages over traditional large-scale horizontal axis turbines. While horizontal axis turbines are the most widespread in the market, vertical axis turbines have several advantages. Historically, they have been relegated to fulfilling a small niche market in commercially available wind turbines due to their design. Current projects lag their horizontal axis wind turbine counterparts in terms of efficiency, measured by their power coefficient. However, new research suggests that these types of turbines may be more suitable for wind farm installations than previously thought.

One of the major advantages of these turbines is that they can be installed in tighter spaces and can be positioned closer to the ground. This makes them ideal for use in urban environments where space is limited, and wind conditions are often weaker. While they do not achieve the performance of horizontal axis turbines at greater heights, they are ideal for use in rural communities, for powering residential and small buildings, and even for road infrastructure and street lighting projects. While not yet as widespread as other methods of generating electricity, vertical axis turbines have high potential to provide a sustainable and energy-efficient alternative for a wide range of applications.

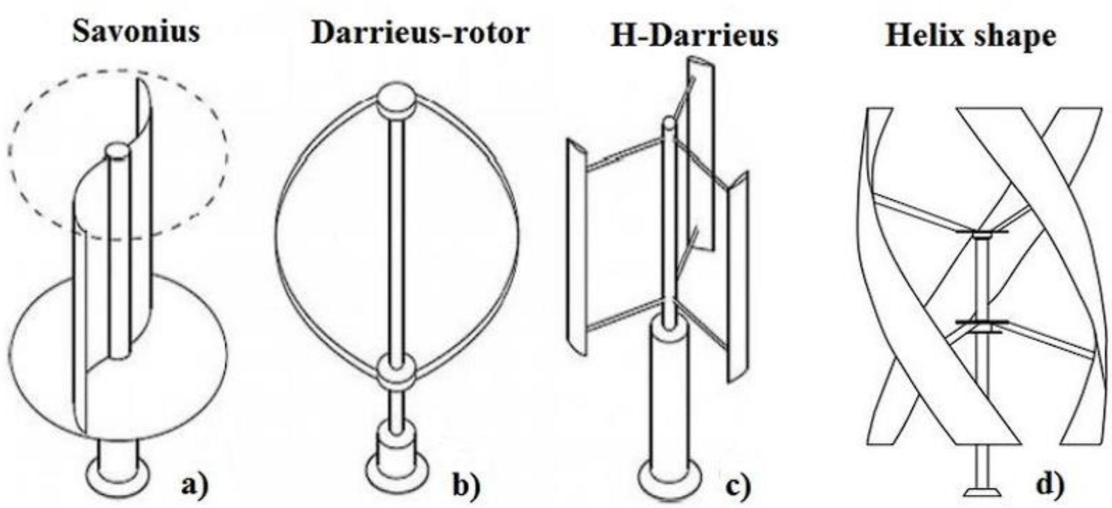
Vertical axis wind turbines (VAWTs) are typically small wind turbines characterized by a rotation axis perpendicular to the ground. As a result, VAWTs can operate independently of the wind direction, which is a major advantage for applications where the wind direction can change rapidly. The two primary models are derived from either Darrieus or Savonius rotors.

Table 1. Vertical axis wind turbines [2]

Manufacturer	Model	Area (m^2)	Power (kW)	Rated speed (m/s)	Cut-in speed (m/s)	Cut-out speed (m/s)	Noise
WePower,	Falcon 1.2	3.5	1.2	13.0	2.7	49.6	32
Quietrevolution	qr5	13.6	3.3	11.0	4.5	19.0	58.0
Turby		4.9	2.5	14.0	4.0	14.0	N/A
Urban Green Energy	Eddy	2.1	0.65	12.0	3.5	32.0	36.0
Windspire Energy	Windspire	7.4	1.2	10.7	3.8	N/A	6.0
Windside Oy	WS-4A	4.0	0.24	18.0	1.9	N/A	N/A
Urban Green Energy	UGE-4K	12.5	4.0	12.0	3.5	25.0	38.0

The Darrieus design has the shape of an eggbeater and uses long airfoil-shaped blades to extract energy as the wind strikes the blades perpendicularly. There are several variants on the Darrieus rotor, including some with straight blades or more advanced models including those based on silence. In ideal low-turbulence wind environments, Darrieus turbines tend to be less efficient than horizontal axis turbines; but in high turbulence conditions, such as wind with directional fluctuations in an urban setting, Darrieus machines can perform better and produce more energy than horizontal axis machines.

The Savonius design features a turbine whose blades have an "S" shape in cross section. Because of their curvature, the concave surface has greater resistance than the convex surface, forcing the rotor to



spin when the cups are exposed to wind.

Compared to horizontal axis turbines (HAWTs) and the Darrieus design, Savonius models rotate slowly but with high torque. Although they have low cut-in speeds, resistance-based turbines are generally not considered good for electricity generation. Additionally, Savonius turbines use more material than Darrieus machines and achieve significantly lower aerodynamic efficiency.

Supporters of vertical-axis turbines identify several advantages over horizontal-axis turbines for urban applications. Firstly, they are considered preferable for rooftop applications because they can handle wind from all directions and can perform better in turbulent conditions than horizontal-axis turbines. Secondly, they tend to operate at lower rotational speeds and have fewer moving components, such as no yaw system to orient the turbine into the wind, which theoretically can reduce maintenance costs. Thirdly, due again to the lower rotational speeds, they can emit less noise, which can be a major issue for wind turbines near residential areas. Finally, vertical-axis turbines are considered more aesthetically pleasing and more capable of being integrated into the built environment as an architectural feature.

However, despite these capabilities, some analysts in the wind industry believe that this type of wind energy extraction is not a viable solution for wind energy in cities. The biggest reservations are that their relatively lower efficiency cannot yet justify the high costs of production and maintenance. Until small-scale vertical axis turbines become more cost-effective, it is unlikely that they will have a major presence as a method of generating electric power compared to solar panels, which are becoming increasingly cheaper and regulated in the European market.

3. Proposed solution

The experimental model presented in our paper aims to convert the wind and air currents produced by highway traffic and beyond into renewable energy that can be used for local road lighting and, in the future, to power charging stations for electric vehicles. Additionally, due to its design and quiet nature, they can be installed in large numbers between the median barriers of the highway. Moreover, due to their sustainability and proposed design, maintenance teams would benefit from reduced costs due to their placement on highways.

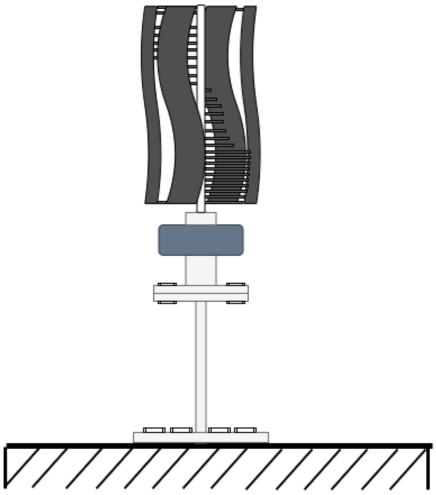


Fig. 2 Experimental model diagram

The proprietary solution represents an experimental model achieved by combining the H-Darrieus and Savonius turbine design with a spiral one in order to obtain a new, innovative product with high efficiency and benefiting from all the main features of established wind turbines. The purpose of this turbine is to generate electricity primarily based on the wind currents generated by moving vehicles on the highway, as well as the natural wind currents in those areas. Thus, the experimental model aims to be part of an array of turbines of this kind, so that the power generated by them can have multiple applications such as:

a) Powering street lighting within the highway, lighting which is currently non-existent due to the lack of a nearby electrical power source or due to complicated logistics and high implementation costs.
b) Source of energy for electric vehicle charging stations.

c) Source of energy for refueling stations for alternative fuels.

d) Transmitting excess electric current to the public grid as an ecological method of generating electricity and more; a method that generates electric energy using "polluting" traffic, thus providing a significant contribution to combating CO2 emissions.

To determine whether such a solution is feasible and more importantly viable, the entire length of the A2 Sun Highway will be used as an experimental example. Knowing that lighting poles are installed at 50m, such vertical-axis turbines will be installed at a distance of 100m in series along the entire highway, so that for every kilometer there will be 20 lighting poles and 10 small wind turbines. Thus, the necessary number N to cover the entire highway is:

$$N = \frac{(Kilometers\ of\ highway)}{Distance\ between\ turbines} = \frac{201{,}800m}{100m} = 201.8 \quad (1)$$

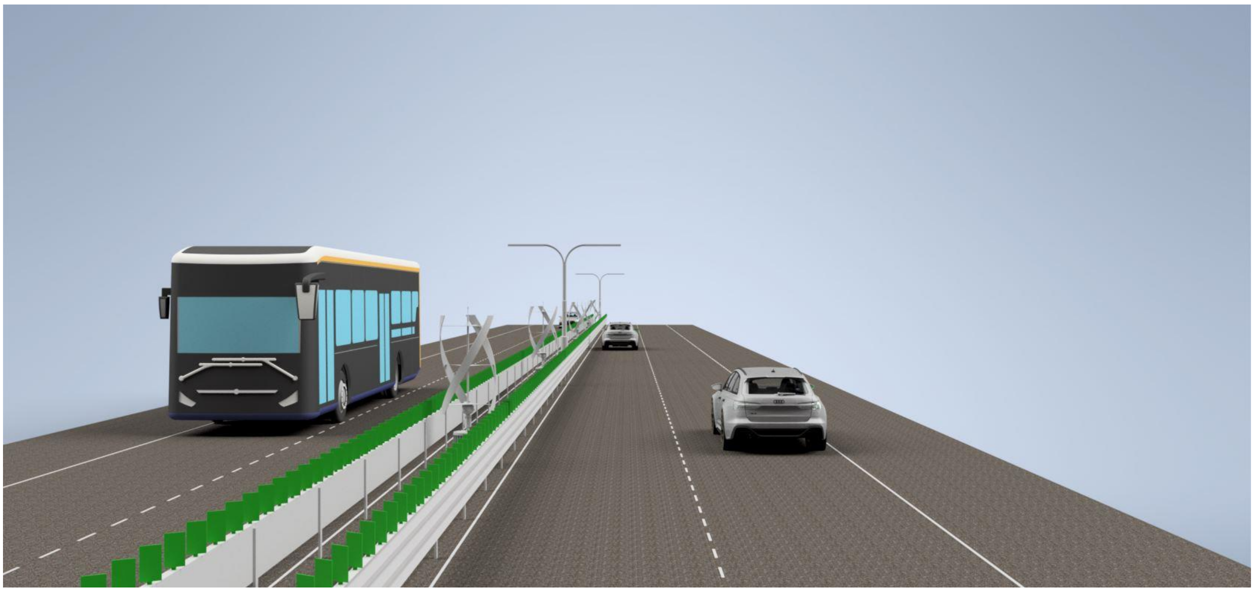


Fig. 3 Rendering of application model respecting the principle of A2 Highway

To determine the energy capacity that they will be able to produce in a normal regime, knowing that the capacities of turbines already on the market that meet the necessary characteristics range between 0.5kW and 3kW, it will be established that the power of a turbine will be 2kW under ideal conditions and 0.9-1.1kW in constant real regime.

Thus, we obtain the following data.:

$$E(kWh) = P(kW)x\,T(h) = 0.9 - 1.1kW\;x\;1h = 0.9 - 1.1kWh \quad (2)$$

$$E(totală) = 0.9 - 1.1\;x\;201.8 = 162.81 - 221.98\;kWh \quad (3)$$

To ensure constant operation for 24 hours of all turbines under real operating conditions, a power output between 4.6 and 5.6 megawatts can be obtained. Using Ohm's Law, we can obtain:

$$R = \frac{201800W}{220V} = 917A \quad (4)$$

To determine if this number is feasible in order to support the applications, we must also know the energy requirements for each consumer. Thus, following the market studies conducted personally, the following have been established:

Table 2. Energy consumption of potential consumers

LED street lighting pole	60– 100Wh	0.45 A
Electric vehicle charging station	3.7 – 22kWh	32A
Fuel stations	7 - 28kwh	32A

Knowing that to illuminate the entire highway, lighting poles will be installed at 50m between them, we obtain the total number needed as follows:

$$S = \frac{(Kilometers\ of\ highway)}{Distance\ between\ poles} = \frac{201.800}{50} = 4300 \quad (5)$$

To determine if the entire system can sustain street lighting under real conditions for 12 hours, the intensity of electric current produced by the turbines will be divided by the intensity of electric current required by the poles, knowing that 1 wind turbine is responsible for powering 2 street poles.

$$A = \frac{\text{Current intensity produced by 1 turbine}}{\text{current intensity consumed by 2 streetlights}} = \frac{\frac{1000W}{220V}}{0.45 * 2} = \frac{4.54}{0.9} = 5.04 \tag{6}$$

After the calculation, we can establish that the system can support street lighting, with one turbine being able to power at least 5 streetlamps at maximum capacity.

The primary goal of wind turbines will remain the priority of powering public lighting. Based on the above calculations, their high potential allows for the remaining produced energy to be used for other possible consumers listed earlier. Therefore, to determine the maximum number of electric vehicle charging stations and/or fuel stations, we will use the following formulas:

$$Er = 4.54A - 0.9A = 3.55A \tag{7}$$

$$\Pr \min = 3.55A * 220V = 781W \tag{8}$$

$$\Pr total = 781W * 201 = 156.9kWh \tag{9}$$

$$Tec\ max = \frac{156.9kWh}{22kwh} = 7.13 \tag{10}$$

$$Tec \min = \frac{156.9kWh}{3.7kwh} = 42.40 \tag{11}$$

$$Tsc \max = \frac{156.9kWh}{7kWh} = 22,4 \tag{12}$$

$$Tsc\ min = \frac{156.9kWh}{28kWh} = 5.60 \tag{13}$$

Er - Remaining electrical energy;
Pr min - Minimum remaining power;
Pr total - Total power remaining after street lighting;
Tec max - Maximum number of recharge stations that can be powered;
Tsc max - Maximum number of fuel stations that can be powered;

5. Conclusions

Following the calculations and the direct addressing of these products for use as a source of non-polluting energy, the idea can be concretized that small vertical-axis wind turbines represent a promising technology for generating electricity using the wind created by highway traffic. This technology can be used to reduce energy costs and contribute to reducing greenhouse gas emissions.

As a result of this study, the question may arise as to why this method of generating electricity would be more efficient than solar panels. For this, the following arguments exist:

1. Small vertical-axis wind turbines are more efficient under the specified conditions (existence of tunnels, viaducts or passages in the highway design significantly increases their efficiency compared to solar panels, which are dependent on areas with strong sun and clear skies. Solar panels also produce much less, or no electricity at all, during the night and are greatly affected by cold periods.

2. Solar panels require a much larger surface area and a higher implementation cost in order to generate the same amount of electricity as a wind turbine.

3. Maintenance: Small vertical-axis wind turbines have fewer moving parts and can also be easily monitored and maintained through automated control systems.

4. Service life: Compared to solar panels or photovoltaic parks, small wind turbines have a relatively long service life, usually over 20 years. Their components are designed to be durable and resistant to wear, and their simple design reduces the risk of failures and the need for costly component replacements.

The use of small vertical axis wind turbines can be successfully integrated into existing infrastructure, which can reduce installation and maintenance costs. Moreover, these turbines are less sensitive to wind direction and speed, making them more suitable for areas where air currents are variable. In addition, these turbines are much more compact and quieter than horizontal axis turbines, making them even more suitable for use in urban areas or on highways.

It is important that the implementation of these turbines is done carefully, and their design is thoroughly analyzed, considering all specific installation conditions to ensure optimal performance and maximum durability. If implemented carefully, these wind turbines can be an efficient and sustainable solution, contributing to reducing the negative impact of road transport on the environment.

In conclusion, small vertical axis wind turbines are a promising technology for generating electric power using wind created by highway traffic, but it is imperative to consider all specific conditions and conduct a comprehensive cost-benefit analysis before implementation.

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RESEARCH ON THE DEVELOPMENT OF A WINDOW CLEANING ROBOT

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ABSTRACT: Through the years, the evolution of technologies brought the world the opportunity to have new gadgets for ease living. Cleaning large windows on multi-story buildings is normally an extremely risky process even for those who are working in this domain, that is why robots have been developed to help or replace humans in such cases. The window cleaning robot is a smart device for those who are living in a multi-story building, or they are afraid of heights.

Key words: robot, window, cleaning, innovation

1. Introduction

Cleaning large windows on tall and multi-story buildings is a time-consuming and risky task. Outside, it can be done with hoisting machines and manual cleaning, or, in very rare cases, with sophisticated, complex, large, heavy, and very expensive automatic cleaning machines that are operated manually from the ground floor. [1]

A compact window-cleaning robot (WCR) was created specifically for use in a household setting. The robot climbs onto the surface of the window glass using suction cups and washes the surface with a revolving wiper at the same time. WCR is distinguished by its low weight and small size. The robot's navigation will be aided by the sensing system. This window robot will have 2 suction cups used as an adhesion system and it can travel independently around the surface of a building office window while cleaning and washing it thanks to the water spray nozzle that can spray it evenly on the glass. The robot will complete the work of window cleaning in a specified pattern helped of an app after it is attached on window. It can move freely on window surfaces indoors and outdoors, thanks to an internal vacuum motor, and a microfiber cloth. Because it is working on multi-surface, the robot can overcome small air leaks and move well on rough surfaces thanks to a vacuum pump that consistently supplies negative pressure. [2]

2. Current state

After we did short research to see what already exists on the market and what we must improve and innovate for our products, the two concepts were developed.

The assembly has three main objectives: to clean the window, to support and sustain the water for the cleaning process and to detect the window's edges.

Some parts will be fully 3D printed, while other components will be purchased to insure the motion of the assembly, as all the electronic components.

The first concept of the robot is composed of 5 different parts, while the second concept has 4 different parts:

1. Support
2. Main body
3. Water tank
4. Cover for the water tank
5. Pump with spray nozzle

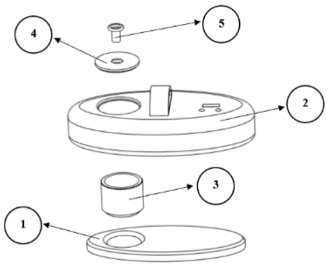


Fig. 1. First concept (sketch)

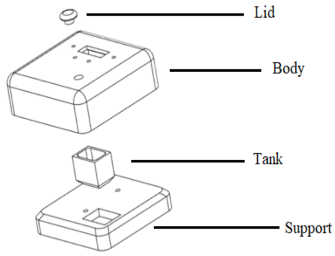


Fig. 2. Second concept (sketch)

The 3D design of the two concepts were designed in Autodesk Inventor Pro [8] and they are represented in Fig. 3 and Fig. 4.

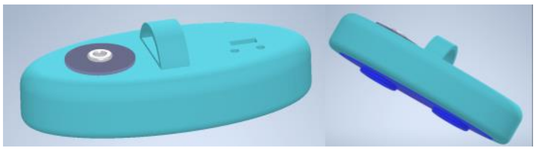


Fig. 3. 3D design of the first concept [6]

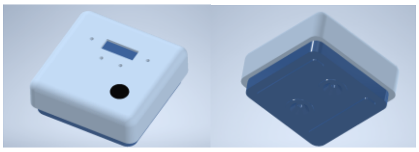


Fig. 4. 3D design of the second concept [6]

After designing the components, the additive manufacturing step must be completed in order to choose the best 3D printing machine [3]. We will utilize one of the 3D printing machines, which are accessible at the Industrial Engineering and Robotics Faculty, so in this case we do not need to utilize a complicated manufacturing process to print such components.

Fused Deposition Modelling (FDM) is utilized to print all the pieces and the material chosen for 3D printing is ABS (Acrylonitrile Butadiene Styrene) because it is lightweight and has good impact strength. Also, it is abrasion resistant and affordable [3].

BCN3D CURA [9] as software and SIGMAX as the main equipment and ZSUITE [10] as software and ZORTRAX M300+ as the main equipment will be used to compare the results.

Putting all components of the robot in one 3D printing machine, we will reduce the time of the printing. The main additive manufacturing principals which were used in the design of the parts are: supported walles, holes, connecting/moving pars and horizontal bridges [3].

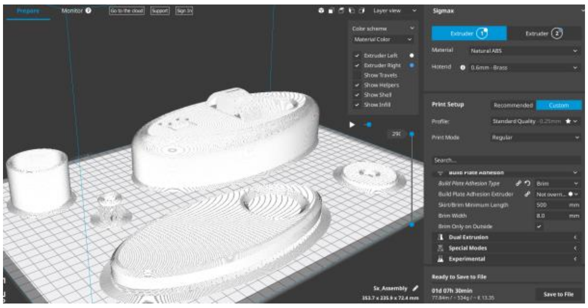


Fig. 5. The results in BCN3D CURA for the first concept

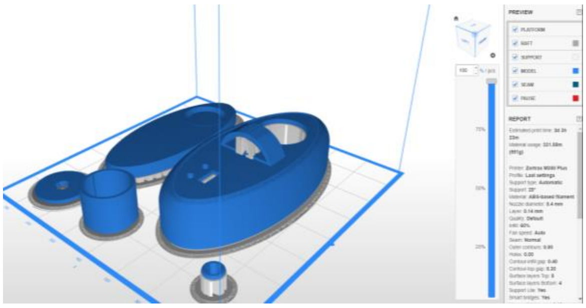


Fig. 6. The results in ZSUITE for the first concept

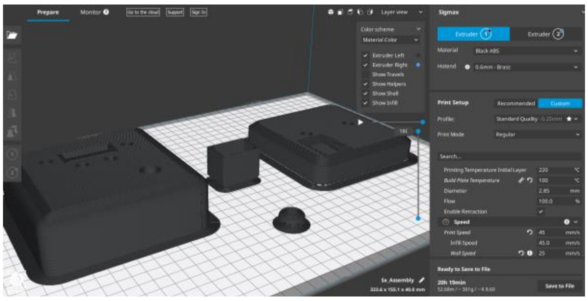


Fig.7. The results in BCN3D CURA for the second concept

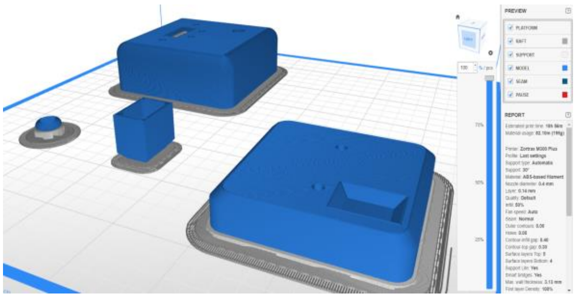


Fig. 8. The results in ZSUITE for the second concept

The data available in the figures show that the expected printing time is almost the same, the Sigmax material cost is chipper, but when it comes to material utilization, the Zortrax M300+ uses less material than the Sigmax.

As we can see, the Sigmax, will be choosen as the 3D printing machine for the first window cleaning robot designed and the Zortrax M300+ will be selected as the 3D printing machine for the second robot designed.

The following are the main steps in the manufacturing process for the parts of the first product that will be manufactured [4]:

1. The Autodesk Inventor software was used to design the parts.
2. The BCN3D Cura software was used to set the parameters for 3D printing.
3. The Sigmax 3D printer was used to print the parts.
4. Post-processing of the parts.
5. Assemble the parts.

The primary processes in the manufacturing process for the pieces of the second product that will be made are as follows [4]:

1. The Autodesk Inventor software was used to design the parts.
2. The ZSuite software was used to set the parameters for 3D printing.
3. The Zortrax M300+ 3D printer was used to print the parts.
4. Post-processing of the parts.
5. Assemble the parts.

The rest of the components will be purchased in order to insure the motion of the assembly, as all the electronic components. The main electrical components for the products are presented in Table 1.

Table 1: Components [2]

Name of the Component	Manufacturing technology	Price
Arduino Uno	Purchased	107.70 RON
Breadboard	Purchased	22.61 RON
DC Motor	Purchased	226.28 RON
Micro servo	Purchased	28 RON
Motor drive	Purchased	58 RON
Red Led	Purchased	0.73 RON
Green Led	Purchased	1.59 RON
Resistor	Purchased	7 RON
Ultrasonic distance sensor	Purchased	164.62 RON
LCD display	Purchased	51.67 RON

Potentiometer	Purchased	4.10 RON
Wires	Purchased	6.31 RON
H-bridge motor drive	Purchased	34.76 RON
Pushbutton	Purchased	14.34 RON
Suction cups	Purchased	206.77 RON
Vacuum pump	Purchased	141 RON
Pression sensor for vacuum	Purchased	15.20 RON
IR sensor and remote	Purchased	7.07 RON
Hobby gearmotors	Purchased	15.17 RON

The circuits of the two product concepts were designed in Autodesk TINKERCAD [11] software, where all the components are connected to each other [5].

For the first concept of the product is composed of 2 different circuits:

1. First circuit is for displaying different text on an LCD when you open the robot, then you have to choose which cleaning program do you want.
   The components used for this circuit are: Arduino Uno, two Breadboards, Wires, 220 Ω Resistor, two 10kΩ Resistors, two pushbuttons and a Potentiometer.

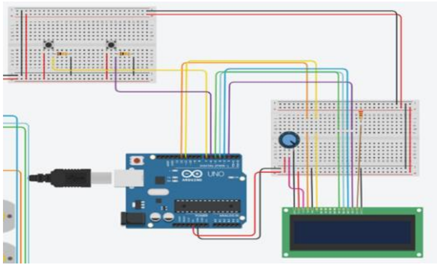


Fig. 9. First circuit [11]

2. The second circuit is for establishing the direction of the robot using an Arduino uno with a ultrasonic distance sensor, a potentiometer and micro servo for the angle, with 2 DC motors for the wheels connected by a H-bridge motor drive, a pushbutton with 2 Led in order to know when the robot is ON and OFF, 4 resistors of 220Ω and 10Ω resistor, wires and 2 breadboards.

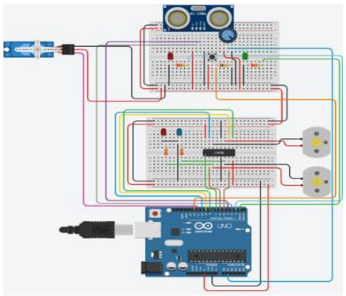


Fig. 10. Second circuit [11]

3. The two circuits are connected to each other with a GND wire and 5V wire (see Fig.3.4).

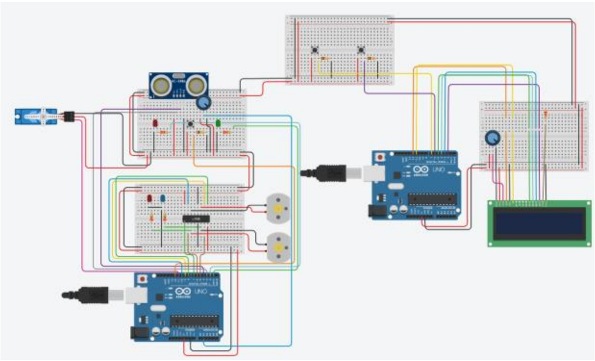


Fig. 11. The final TINKERCAD circuit [11]

For the second concept of the robot, an automated system for a cleaning robot will be designed. The robot can detect an obstacle with the help of the ultrasonic sensor, which automatically bypasses it to the left. The programs will be selected with an IR sensor and remote. It also, has an LCD display in order to show you different messages [6].

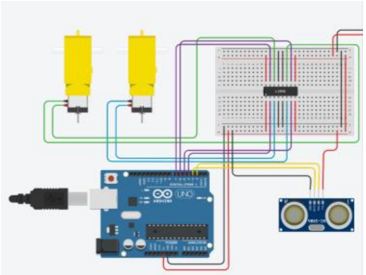


Fig. 12. The first circuit [11]

1. The first circuit represents the 2 gearmotors connected to the H-bridge motor drive and an ultrasonic distance sensor which calculates the distance between the robot and an object to avoid it.

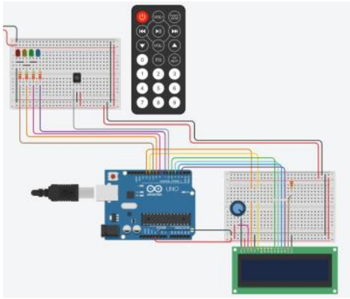


Fig. 13. The second circuit [11]

2. The second circuit is for the LCD display and the IR remote. The robot will be controlled by an IR remote having multiple comands.

3. The two circuits are connecting to each other in order to make the final circuit.

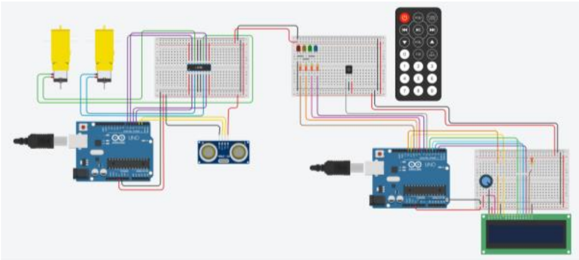


Fig. 14. The final circuit of the second concept [11]

3. Business plan

For our business we will have a registered company that will manufacture the products and sell them [6].

A. General data

1. Full name of the company: Cleannyhobo SRL

2. The location of the enterprise:

• Social headquarters: XYZ Street, No. 5

• Operational headquarters: XYZ Street, No. 5

• Working point: XYZ Street, No. 5

• Offices: XYZ Street, No. 5

3. Unique registration code: RO23456789

4. Legal form of incorporation: SRL (Limited liability company)

5. Date of establishment / Trade Register Number: J40/2233/2022

6. The main activity of the company and the related CANE code: Creative industries * - without CAEN code 6201

7. The value of the share capital: 10000 Lei

8. Contact person: Maria Monica CHISELEFF

9. Associates, main shareholders:

Table 2: Associates, main shareholders [6]

Physical person	Address and phone	Nationality	Capital shares (%)
Maria Monica CHISELEFF	ABC Street, No. 2	Romanian	50%
Robert Sebastian BRATU	DEF Street, No. 4	Romanian	50%

10. SME category: Micro

B. What is the mission statement?

• We are a new company founded by a young but ambitious team eager to make a difference by bringing technology closer to people with the goal of making their lives easier. Our products are for those who are living or have offices in multi-story buildings, or they are afraid of heights [6].

• The product is made up of two major components: an electronic component and a mechanical component. The mechanical component's primary function is to keep the supplies and electronic components running. The electrical component of the product ensures that the product moves correctly.

4. Process of selling the product

This part was done by using IBM WebSphere Business Modeler Advanced [12] to create business model [7].

Fig. 15 represents the process map starting from the moment the client places an order to the point where the order is delivered with all the steps involved along the way.

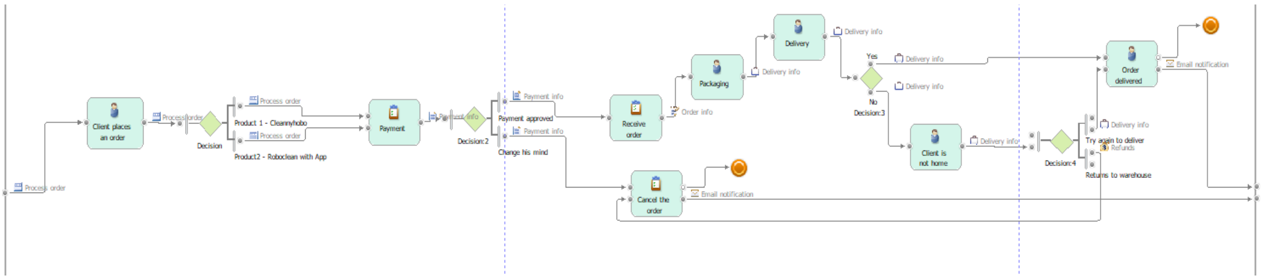
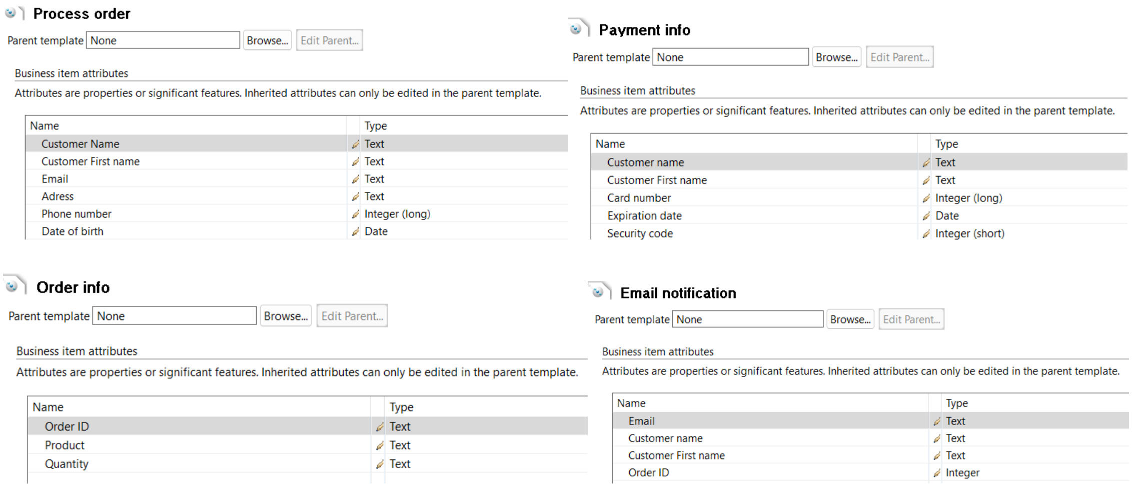


Fig. 15. Process map [12]

Because this program is as a database, different business items will be created (Fig. 16), resources and roles, shifts (Fig. 17 and 18).



Process order

Parent template None

Business item attributes

Attributes are properties or significant features. Inherited attributes can only be edited in the parent template.

Name	Type
Customer Name	Text
Customer First name	Text
Email	Text
Adress	Text
Phone number	Integer (long)
Date of birth	Date

Payment info

Parent template None

Business item attributes

Attributes are properties or significant features. Inherited attributes can only be edited in the parent template.

Name	Type
Customer name	Text
Customer First name	Text
Card number	Integer (long)
Expiration date	Date
Security code	Integer (short)

Order info

Parent template None

Business item attributes

Attributes are properties or significant features. Inherited attributes can only be edited in the parent template.

Name	Type
Order ID	Text
Product	Text
Quantity	Text

Email notification

Parent template None

Business item attributes

Attributes are properties or significant features. Inherited attributes can only be edited in the parent template.

Name	Type
Email	Text
Customer name	Text
Customer First name	Text
Order ID	Integer

Fig. 16. Business items [12]

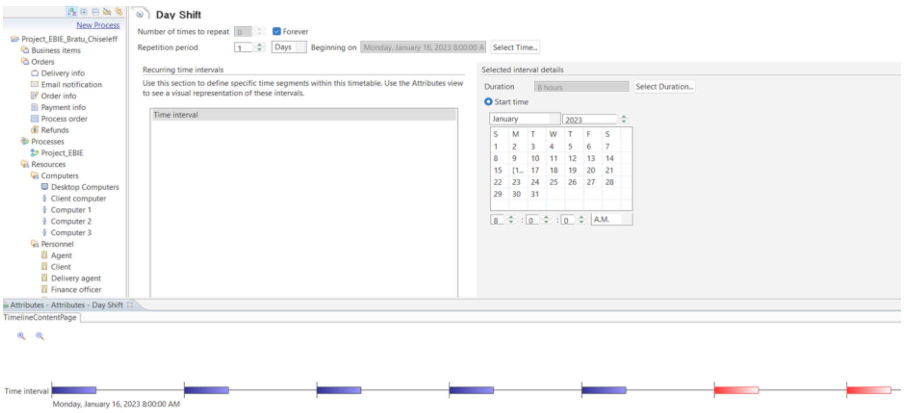


Fig. 17. Day shift [12]

5. Conclusion and future developments

To sum up, the two concepts of product were developed using the software Autodesk Inventor Pro [8], then the 3D printing machines were chosen to be the best for each robot to reduce time, money, and material. Then a business plan was created because to sell and manufacture a product, a registered company must exist.

The future developments are as follows:

- Purchase the needed materials;
- Produce a prototype of each concept and test them;
- Make the right modifications (if needed) and test them again;
- Register the trademark, and the industrial design at the national and international level (OSIM and EUIPO) [1];
- Register the company and hire the right employees.

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[10]. ***, ZSUITE, user manual and software.
[11]. ***, Autodesk TINKERCAD, user manual and software.
[12]. ***, IBM WebSphere Business Modeler Advanced, user manual and software.

7. Notes

The next notes are used throughout the work:
WCR = window-cleaning robot;
FDM = Fused Deposition Modelling;
ABS = Acrylonitrile Butadiene Styrene;
SME = Small and medium-sized enterprise;
OSIM = State Office for Inventions and Trademarks;
EUIPO = European Union Intellectual Property Office.

SOLAR POWERED MULTIPURPOSE PLATFORM, ASSEMBLY AND FURTHER PROGRESS

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ABSTRACT: The solar powered multipurpose platform is a product that delivers green energy both to USB ports and an accumulator assembly, while being connected to an Arduino UNO board that reads temperature, humidity, and light intensity in real time, the product having a buzzer attached to the circuits that will buzz to announce when the temperature is too high or there is too much light for the product to generate energy, also the LED or LEDs will turn on or off based on the temperature level. The product uses 100% green energy and does not require any external energy. The product is being built with materials and components into a factual prototype. The electrical components undergo different building, development, and improvement stages, during 3 different prototypes, which help understand the best way of solving the challenge of circuitry and additive manufacturing. The parameters will be stored and taken into consideration for the final product.

KEY WORDS: Arduino UNO, Prototypes, Circuitry

1. Introduction

The solar powered multipurpose platform is a product that delivers green energy both to USB ports and an accumulator assembly, while being connected to an Arduino UNO board that reads temperature, humidity, and light intensity in real time, the product has a buzzer attached to the circuits that will buzz to announce when the temperature is too high or there is too much light for the product to generate energy; Also, the LED will turn on or off based on the temperature level. The product then sends this accumulated information to a website that will register all the information in graphs and display it accordingly. The product uses 100% green energy and does not require any external energy. In the 2 years in which the product was developed, it went through distinctive design and improvement stages that helped the product innovate itself. At first it was a simple idea, about the existence of a product that would produce enough energy to charge simple products such as smartphones, portable devices or power on a computer that measures some information, that information being sent to a website where it could be visible at any time from the same IP with the correct username and password. The research went underway and resulted that the market was lacking an affordable product which would be both easy to use and provide a user-friendly interface. The stages that the product went through, from an idea to an actual product: Initial stages of production from the assembly design to the current stage, used the exact measurements of the actual components used in the prototype, to assure the least error and challenge possible.

2. Actual Stage

In present, the product is being built with materials and components into a factual prototype. This stage will help seek out the best way to solve the challenge of building it. The components that the prototype will be built with are fulfilling, as follows, either structural roles or industrial use of electrical, technical, and software-based roles. Solar rays will be captured from the monocrystalline and then using the photovoltaic panel, will be transferred safely to the solar charger.

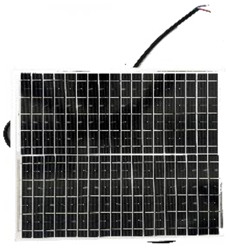

Fig. 1. Photovoltaic panel

The solar panel will be connected using the cables to the charger, the charger has the role to collect all the energy that the photovoltaic panel generates and either store it into the accumulators or use the USB Hub to power up some energy to the ports connected to it (if needed). The charger's display also operates and indicates different information and is helpful to indicate the status of the product and its photovoltaic panel.

Fig. 2. Solar charger

The accumulators have the role of storing the power generated by the photovoltaic panel and distributed by the solar charger. When the charger has a demand of energy, the accumulators will send the stored energy to the charger which then chooses how it will make use of it.

Fig. 2. Accumulators

Arduino UNO and Arduino UNO Components:

Fig. 4. Arduino UNO

"When building your Arduino projects, you use resistors to limit the amount of current going to certain components in the circuit, such as LEDs and integrated circuits. To calculate the resistance, you should use a modified version of Ohm's Law." [1]

The product will take use of 2 types of resistors: 220 Ohm will be connected to the RGB Led and a 10k Ohm will be connected to the Piezo buzzer and to the photo sensitive sensor.

Fig. 5. Resistors

The circuits used in Arduino projects are used for creating ways of transportation for the energy between the Arduino UNO and the components.

Fig. 6. Circuits

The photosensitive sensor is used to receive and read the level of light that reaches its surface.

Fig. 7. Photosensitive sensor

The temperature and humidity sensor are used to measure read and indicate the exact levels of humidity and temperature.

Fig. 8. Temperature and Humidity sensor

The piezo buzzer is used as an alarm for tracking attention to the user, in moments in which the user has no attention over the product, to alert the user that the temperature is too much, or the humidity is too much or that the light is not bright enough.

Fig. 9. Buzzer

Building the Solar Powered Multipurpose Platform:

According to the operating manual for the charger, firstly the accumulators need to be connected to the photovoltaic charger positive and negative ports, as first connecting the solar panel would result in complications such as: the solar panel would transfer energy to an inexistent source, the charger then not being able to read a source, would result in transferring the energy back to the photovoltaic panel, this resulting in a "bottleneck" [2], this bottleneck, could cause serious damage to the charger.

Secondly, the solar panel cables are connected into the ports of the solar charger, the exact order needed for this operation is the following: first circuit cable connected is the positive pole, afterwards the negative pole is connected to the solar charger's ports. The photovoltaic panel would then display the current voltage stock of the accumulators. As soon as the monocrystalline receives any sort of light, being either artificial (under certain conditions) or natural light (either through a window or directly from the sun), the solar charger's display would show a solar panel that sends the energy to a set of batteries, and the set of batteries that sends the energy to connectable ports, while also displaying the exact voltage that the controller has at the time.

Arduino Uno is able to receive the code needed for compiling and running the exact program sketch through a special cable, an USB B with a male connector to USB A male connector cable, this connector having the ability to send big packages of information from a computer to the Arduino, using the Arduino IDE software, which compiles and runs the program firstly in a software based "test site" that assures there are no errors, then sending the package to the hardware, the Arduino UNO. The Arduino UNO assembly and the breadboard with the different components connected, are then carefully introduced in the special encasing solar cover. Solar Cover board assembly is custom created, designed and improved especially for this product, as it serves the role of keeping the Arduino UNO device and components safe from environmental conditions.

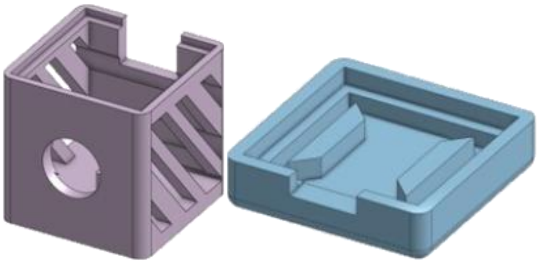

Fig. 10. The Solar Encasing Assembly

3. Prototype tests

For the prototype product, the Arduino UNO LED components will be slightly modified to 3 different LEDs as opposed to the RGB LED found in the sketch. This change will determine more accurate results, coding processes and experience. After the final prototype tests, when moving on to the construction of the product, the LED present in that assembly would be an RGB LED and not 3 different LED components.

Test 0 for the prototype

To evaluate the prototype product 0, a computer mouse is connected to the output USB port of the charger, measuring the voltage that the product is generating and checking if the USB port sends the needed energy to the computer mouse.

The test is a success, the computer mouse lights turn on, this means that it receives the needed energy.

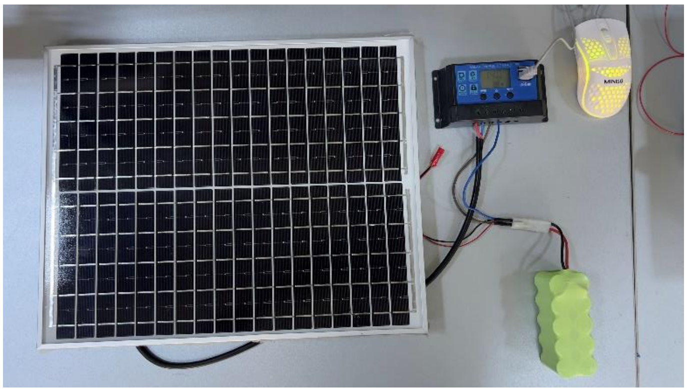

Fig. 11. Prototype 0

Test 1 for the prototype

While the photovoltaic panel was set inside a classroom that received solar light through a window, the monocrystalline was partially covered with a hand, to see the differences, it would make in charging voltage. The results were that the photovoltaic panel on the display of the charger disappeared, meaning that if 60% of the monocrystalline would be covered, and the main source of sun would touch that exact spot, then the photovoltaic panel’s monocrystalline would not be able to generate any green energy from the remaining 40% of its surface.

The test was a success, the prototype assembly only displays the photovoltaic panel on the solar charger’s display while at least 50% of the monocrystalline is not covered.

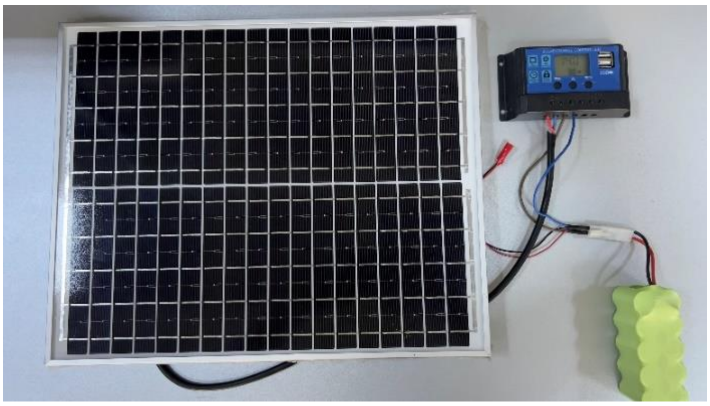

Fig. 12. Prototype 1

Test 2 for the prototype

While the Arduino UNO is connected to the charger and receives the needed energy to work, the board will signal by lighting an LED if the temperature is constant and not rising or falling above or under the limits set. The LED will blink from 5 seconds to 5 seconds, indicating the constant temperature. If the temperature changes dramatically, the other LED will light up, indicating changes of temperature. This prototype assembly would not have the light sensor connected as in this case, would not serve any purpose.

The test results in a success, the LED lights signal the consistency in temperature, and signal it every 5 seconds.

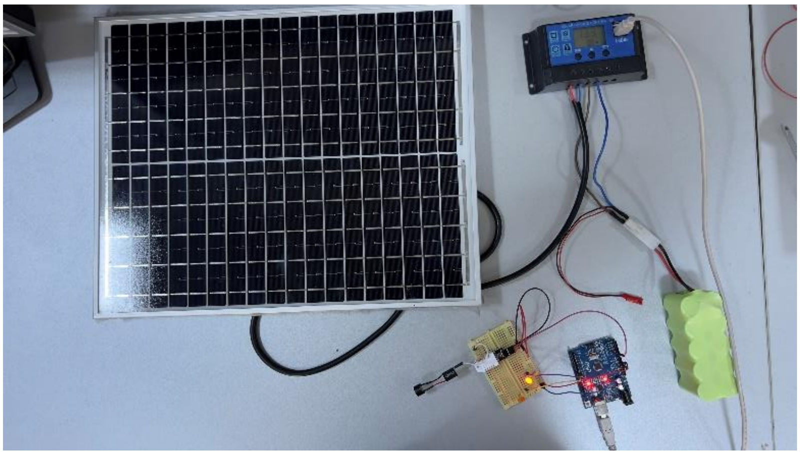

Fig. 13. Prototype 2

Test 3 for the prototype

The third prototype has all the Arduino UNO components, and, while running the code, the light sensor receives the data that the light level is either neutral (no LED turned on), more than the needed amount (the right LED turned on) or less than the needed amount (the left LED turned on). Even if the sensor observes this light level as less than the needed amount, the photovoltaic panel's crystalline will still receive energy if the needed amount is not an exact 0 (or the monocrystalline is not entirely covered)

This test lights up the right LED as the third prototype Arduino UNO received the desired data amount of the needed limit, lighting up the LED at a low level first, afterwards it lit up instantly.

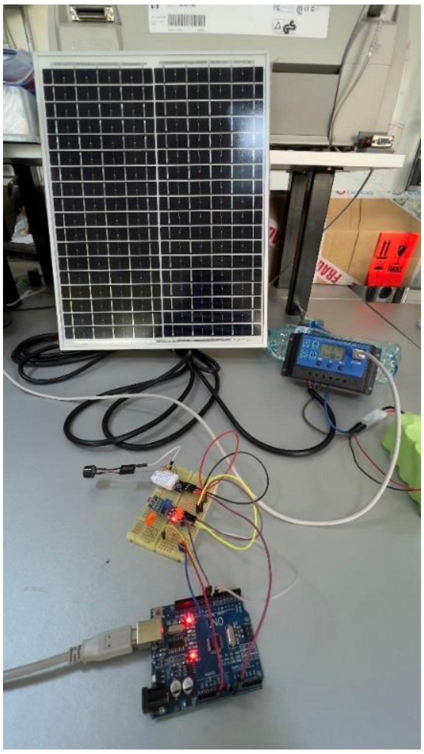

Fig. 14. Prototype 3

4. Printing of the Solar Powered Multipurpose Platform's Solar Encasing Assembly

The manufactured parts, the solar case cover, and the solar case, would be 3D printed using the available resources for the printing process, some design improvements would be taken into consideration and done, under exceptional circumstances for the prototype.

Prototype 1

For this prototype, the parts will be printed at a 75% smaller scale to observe form needs and improvements. The parts were printed in the prototype stage using PLA material due to convenience of stock.

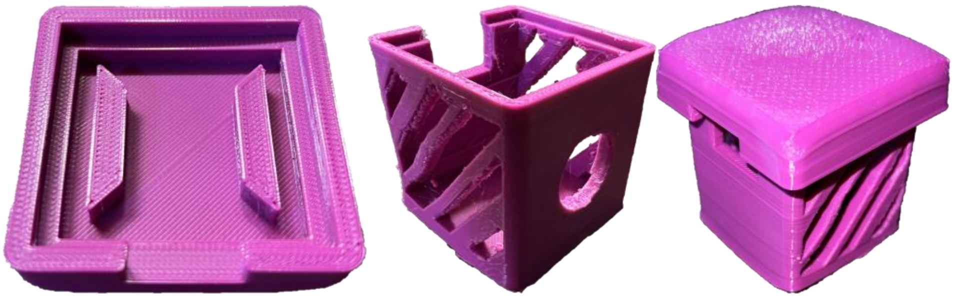

Fig. 15. Prototype 1 Printing of the Solar Encasing Assembly

Table 1. Printing observations

Observation	*Solar Case*	*Solar Case Cover*
Software	On Shape + Ultimaker CURA	On Shape + Ultimaker CURA
File size	130 KB	540 KB
Time	2 hours 12 minutes	1 hour 14 minutes
Grams	13	9
Material	PLA	PLA

5. Conclusions

Each prototype served its own purpose without any failures or problems.

The 3D printing process and prototype of the manufactured components reached its goal of finding the existence of differences between the initial measurements and the final measurements (solar case cover and solar case).

In conclusion, the prototypes used for the assembly of the product will help serve the purpose of creating a development curve that has the important role in understanding the challenges, creating new goals and achievements, fixing any existent errors and time scheduling the process for the finished product to an almost precise accuracy (taking into consideration various other errors that may surface and are unforeseen).

6. Words

Bottleneck= "In engineering, a bottleneck is a phenomenon by which the performance or capacity of an entire system is severely limited by a single component. The component is sometimes called a bottleneck point. The term is metaphorically derived from the neck of a bottle, where the flow speed of the liquid is limited by its neck." [2]

Arduino UNO= "The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc" (…) "is equipped with sets of digital and analog input/output pins that may be interfaced to various expansion boards and other circuits." [3]

Prototypes= "A prototype is an early sample, model, or release of a product built to test a concept or process" [4]

Circuitry=" the circuits that an electrical or electronic device contains, considered as a single system" [5]

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STUDIES ON THE DEVELOPMENT OF TRUNK PRODUCT FOR DESIGNER CLOTHING AND SHOES WITH INTEGRATED SECURITY SYSTEM

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ABSTRACT: The main objective of this project is to research the design requirements in order to make a trunk for designer clothes and shoes with an integrated safety system that is consistent with the requirements of potential customers. A thorough market study will be carried out where the products already on the market and their related patents will be analyzed in order to determine the major new functions. The scientific importance of the theme is given by the two research directions of the creation and implementation of the new product: ***conceptual design*** *– where the main functions will be determined, research based on existing patents, systematic exploration and product architecture;* ***detailed design*** *– where the 3D model will be made according to the proportions, dimensions and related tolerances, taking into account the ergonomic and anthropometric aspects, the definition of the design elements and the materials used.*

KEY WORDS: trunk, conceptual design, detailed design, analysis, 3D design.

1. Introduction

This paper aims to research the new design requirements for creating a multifunctional trunk for designer clothes and shoes, in order to meet the demands of potential customers. The identified functions will help us develop the new requirements that the product must adhere to, in order to satisfy customer needs.

Furthermore, the analysis of existing trunks on the market and their patents is pursued in order to address existing issues and improve the existing functionalities of these products.

Moreover, the product architecture will be developed based on the functions identified to meet the needs and desires of consumers, enabling us to start creating the 3D model and identify any potential issues before the product reaches the production stage.

Once the main functions have been determined, the detailed design stage will commence, where the 3D model will be created according to the specifications, while simultaneously checking for any issues alongside the main functions. After this is accomplished, the product will be analyzed from an ergonomic and anthropometric perspective. If the product meets all these criteria, the 3D model will be finalized by incorporating the design elements that relate to the final architecture of the product.

Once the final 3D model is completed, a thorough analysis of the materials available on the market will be conducted to determine which ones meet our requirements and can be sent for production.

The certification, use, commercialization, and recycling of the product also play an important role in this process. All these stages are closely linked to the economic analysis.

The final stage involves creating the product manual, which will be extremely useful for the user to understand exactly how the product functions and how to resolve any potential errors that may arise.

Thus, the purpose of this project is to determine whether the product is practical and meets all the needs of potential customers. The most important aspect is for the product to provide the user with the best quality and ensure the safety of the stored items.

2. Conceptual design

2.1 General function and component functions

Starting from the identified need and customer requirements, it has been determined that the general function of the developed product is storage and safekeeping of clothing items. The general function undergoes an analysis process, which results in identifying the main functions and then the secondary functions. The main functions are characteristics of the product that determine the general function. The secondary functions, resulting from the interaction between the main functions, are referred to as internal interactions. Additionally, there are interactions between the main functions and the environment in which they operate, which are called external interactions.

The main functions of the "Trunk for designer clothes and shoes with integrated security system" product are presented in Table 2.1.

Table 2.1 Main functions of the product

No. Function	Main functions of the product
$Ø_{11}$	Maintaining the safety of the items
$Ø_{12}$	Storing clothing items
$Ø_{13}$	Signaling the operational status of the security system
$Ø_{14}$	Easy transportation
$Ø_{15}$	User-friendliness
$Ø_{16}$	Increased durability
$Ø_{17}$	Luxurious and ergonomic design

From the previously established main functions, a list of critical functions has been compiled, presented in Table 2.2, which determines the commercial success of the product. These critical functions correspond to dimensions and requirements with maximum relative importance.

Table 2.2 Critical function of the product

No. function	Critical function of the product
$Ø_{11}$	Maintaining the safety of the items
$Ø_{12}$	Storing clothing items
$Ø_{13}$	Easy transportation
$Ø_{14}$	Increased durability

The system of phenomena used in the development of the general function - "Allows for the safe storage of clothing items" - is further analyzed:

Table 2.3 Applicable effects

No. function	Critical function of the product	Possible effects
$Ø_{11}$	Maintaining the safety of the items	adsorption, chemisorption, coating layer, electrochemical deposition
$Ø_{12}$	Storing clothing items	deformation limiters, adsorption, coating layer, electrochemical deposition
$Ø_{13}$	Easy transportation	gravity, inertia, vibrations, friction
$Ø_{14}$	Increased durability	shape memory effect, mechanical fixation, absorbtion

2.2 External research to identify known constructive solutions

To establish the known conceptual solutions for the development of the main functions, we conducted a bibliographic study that primarily considers invention patents related to similar products.

The objective of this invention, as shown in Figure 2.1, is to overcome the difficulties faced by the traveling public. The series of drawers that usually occupy half of the wardrobe trunk are, according to this invention, housed in a detachable frame. This frame is arranged in such a way that it has smooth contact with the walls of the trunk in which it is housed, thus not practically losing any extra space in the trunk and not compromising its appearance in any way. [1]

When the trunk with its detachable frame is brought on board an aircraft or into a hotel room, the frame carrying all the drawers can be easily removed and stored under the bed or in any convenient location, while the trunk itself can be stored until it is needed again.

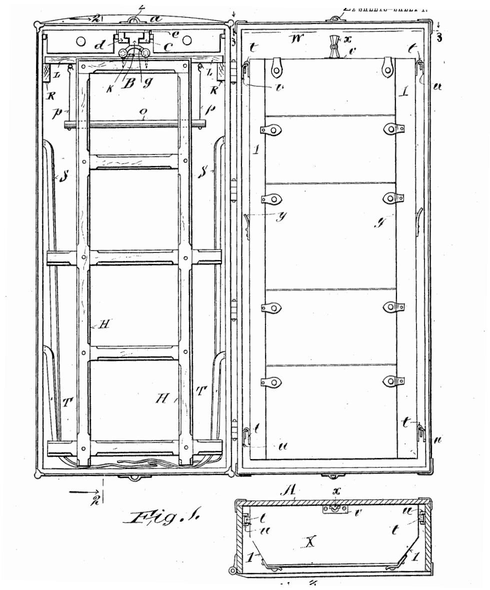

Fig. 2.1 Wardrobe trunk [1]

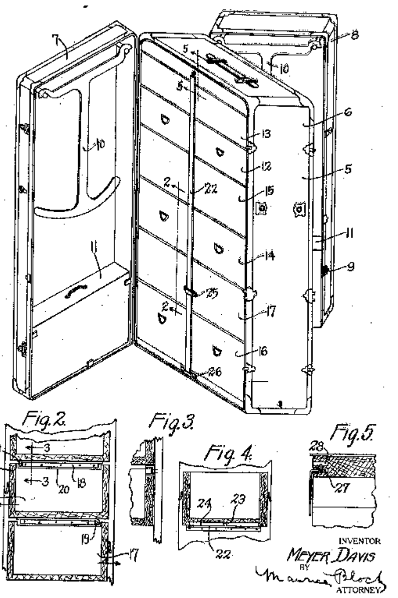

Fig.2.2 Wardrobe trunk [2]

The invention presented in Figure 2.2 refers to improvements in a wardrobe trunk. The purpose of the invention is to construct a wardrobe trunk that can be used as a practical closet for storing clothing items in the same way a regular closet is used. Another object of the invention is to arrange multiple interior parts of the trunk, used for storing clothing items, in such a way that the garments can be easily and securely held in their appropriate places when the trunk is intended for travel purposes. [2]

2.3 Internal research for new constructive solutions

In order to create the product, several technical solutions have been found that can easily fulfill the critical functions. The solutions found for the designer clothing and shoe trunk with an integrated security system are listed in the table 2.4

Table 2.4 Technical and conceptual solutions

Ensuring the safety of the items	**Storage of clothing items**	**Easy transportation**	**Increased resistance**
Integrated security system	Adequate compartments	Retractable wheels Handle	Superior quality of materials Post-sale warranty

2.4 Systematic exploration

To conduct a systematic exploration, a rigorous method of selecting relevant research is necessary, as well as a critical evaluation of their quality and relevance. After identifying relevant research, they should be evaluated based on criteria such as the methodology used, sample size and participants, as well as the obtained results and their relevance to the research domain.

Upon compiling the database of known conceptual solutions for the product's main functions, we have identified a number of technically feasible solutions through the combination of concepts. However, given the specific objective specifications established in previous works, certain conceptual solutions are excluded due to their incompatibility.

2.5 Product architecture

During the product architecture process, several key factors will be considered, including consumer needs and desires, available materials, available technology, and production costs. Additionally, it is important to evaluate the product's market viability and existing competition to ensure that the product has real chances of success.

The image below depicts the chosen concept for the product design:

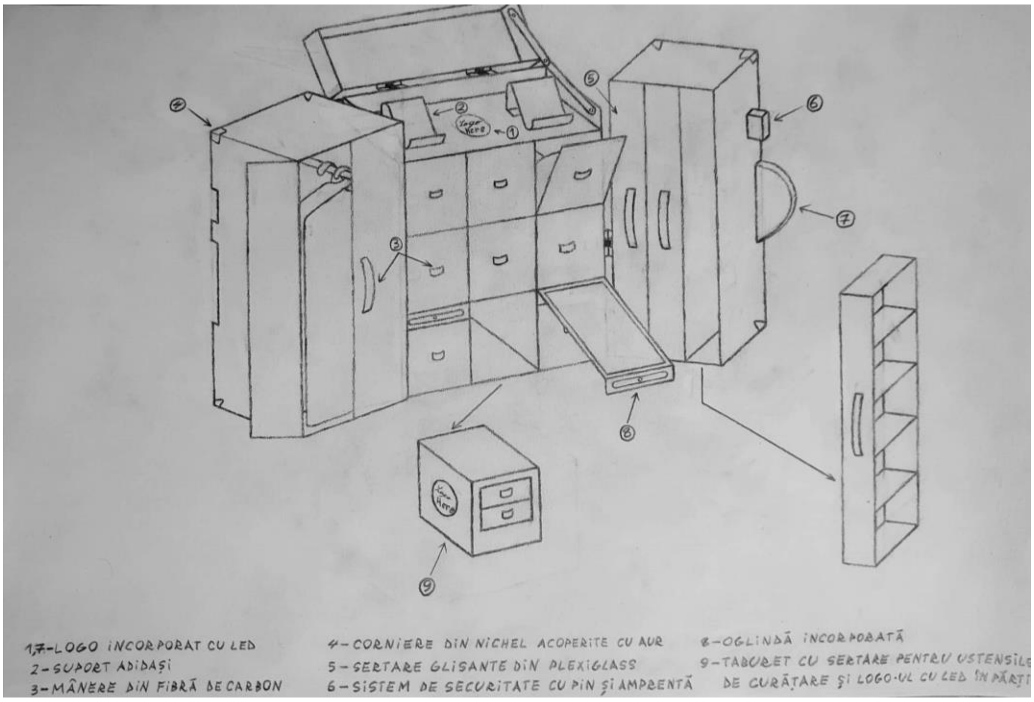

Fig. 2.3 Trunk sketch [3]

3. Detailed design

3.1 Proportioning, shapes, dimensions, and tolerances

- Proportioning: The overall dimensions of the trunk are 100x80x150 cm (L x W x H).
- Shapes: The shapes used in the construction of the trunk are quite common, including circles, rectangles, and curved forms for certain elements.
- Tolerances: Tolerances will primarily be applied to the drawers to ensure ease of use, with a tolerance of ±0.3 mm.

3.2 Determining ergonomic and anthropometric conditions

- Ergonomics

Ergonomics plays an important role in designing the trunk for the user to benefit from optimal conditions of use. The product must be made so that the user does not develop physical problems along the way due to proportional causes or due to certain elements inside the trunk.

- Anthropometry

Anthropometry, as well as ergonomics, plays an important role for this product, because the trunk must have a suitable height for the user to be able to use this product as easily and efficiently as possible.

3.3 Defining design elements

The main design elements used are the following:

- Brand logo placed on multiple parts of the product;
- Mirrors for viewing shoes and clothes;
- Display supports for shoes;
- Metal elements in the corners of the trunk to prevent hitting;
- The stool with mini drawers;

Fig. 3.1 Logo SEB'NDIA full color [4]

3.4 Determining materials and treatments

- **Cedar wood**

Cedar is resistant to weathering, rotting, does not require treatment before use, making it ideal for the trunk skeleton.

- **Plexiglass**

The side drawers for the individual pairs of shoes will be made of Plexiglas, because it is durable, weighs half as much as glass and can be found in any color.

- **Carbon fiber**

This material will be used to cover the trunk because it is durable, modern, and does not attract moisture from the air to damage the inner skeleton.

- **Velvet**

This material will be used for subtle accents inside the trunk as it is a slightly reflective material and gives the trunk a subtle tint.

- **Brass**

With its lower copper content, CW508L is a single-phase material that is still very good for cold forming. Therefore, this alloy is very suitable for stamping, riveting, crimping and edging. Therefore, this material will be used for the outer corners of the trunk and for the inner support.

3.5 3D modeling, development of overall and execution drawings

Following the specifications, functions, shapes and colors determined, the 3D model for the designer clothes and shoes trunk was made:

Fig. 3.2 Model 3D – rendering 1,2 [5]

4. Approval, use, marketing and recycling of the product

- **Homologation:** As part of the technical preparation for the manufacture of new products, the execution and homologation of the prototype as well as the zero series is a very important requirement. In order to proceed with the homologation phase, it is aimed to check whether the new product corresponds to the documentation (technical-economic study, design theme, specification, etc.) and to certify the manufacturing technology within the established technical-economic indicators.

Homologation, however, represents the confirmation activity, based on tests and tests, to which the prototype with the zero series is subjected to attest that the product corresponds to the designed one. Homologation is carried out in two stages, namely:

1. **Preliminary approval** – of the prototype;
2. **Final approval** – of the zero series product;

- **Usage:** After the product has reached the market and is publicly accessible, its use depends on the buyer and how they develop their day-to-day business. Of course there are certain concepts already anticipated, namely: **Fashion designers, artists, businessmen, ordinary people.**

- **Marketing:** The marketing of the trunk will be carried out through several channels, depending on the marketing strategy adopted and the targeted market segment, and thus we have: **online store, luxury stores, fashion events, influencer marketing, direct sales.**

- **Product recycling:** After the product has reached the end of its life and can no longer be used due to defects, excessive wear or inconvenience, it can be returned to the brand for recycling for a certain amount of money. Once the used product reaches recycling, it will be separated into components and types of materials that will then be properly recycled to allow their future use.

5. Elaboration of the product book

The product book is an important tool in the development, production and sale of a product. The product book should provide a detailed description of the product and answer any questions or concerns potential customers may have. This can be distributed electronically or in print with the product and used as a marketing tool to increase customer trust and satisfaction.

In the case of a clothing trunk, the product book might include the following information: what's in the box, product overview, specifications, quick start guide, applicable repairs and fixes, important safety information, and consumer warranty.

6. Conclusions

The purpose of this scientific research is to develop a new and modern product, namely a trunk for designer clothing and shoes. This product is innovative and highly relevant in today's market.

The product incorporates many new elements that provide greater confidence and a much stronger impact among people. However, during the development of this product, regardless of its nature and type, various issues can arise. These problems can be of different types and can stem from various reasons. Examples include material selection, product weight that may hinder transportation, and so on. Additionally, technical issues such as safety system failures or improper functioning can also occur.

The most important aspect of this trunk for designer clothing and shoes is to ensure that customers receive a high-quality product. Thanks to the chosen materials, design, weight, and advanced safety system, potential customers can benefit from a qualitative, modern, and affordable product.

Furthermore, similar products are already available on the market, such as those from Italian brand Gucci and French brand Louis Vuitton, which are competitors. However, there are some aspects that put them at a disadvantage, such as dimensions and the lack of an integrated safety system.

The main objective of this project is to research the new market requirements in order to create a trunk for designer clothing and shoes. It involved a detailed analysis of the requirements and the factors that influenced the design of the new product. Nowadays, higher-quality materials are being used, continuously improving, and the models are more complex and sophisticated. The developed product benefits from these aspects, and in addition, it features an integrated security system with fingerprint and PIN.

The original contributions of this work lie primarily in the design, the materials used for the product, and the integrated safety system.

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[3] Personal sketch

[4] Personal logo

[5] Personal renders

RESEARCH ON THE DEVELOPMENT OF A HUMANOID ROBOT HEAD

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ABSTRACT: The purpose of this research is to develop a humanoid robot head. For this, several concepts were made, regarding the components, their location and the design of the product. In order to obtain the model, an analysis of competition and one of concepts was performed, being chosen the optimal concept for the realization of the product. Finally, the 3D components were modeled and printed and the mechatronic system was made, and then tested. Based on the information obtained, a prototype of the product was developed and some conclusions regarding it and future research directions.

Key words: humanoid, head, prototype

1. Introduction

Humanoid robots have made significant technological and artificial intelligence advancements in recent years. People's desire or need for common and recognizable characteristics in their surroundings served as the catalyst for this humanization transition.

As a result, engineers and programmers are continually attempting to create robots that are as human-like as possible by giving them human abilities, such as the capacity to move, move their arms, and engage when sensors detect another human. These characteristics enable users to start conversations and interactions with robots [2].

The goal of this research is to create a humanoid robot head that mimics human gestures and can communicate with humans.

2. Current state

To create a specific product, it is necessary to understand the demands of the intended audience and the conceptual approaches that will best address those needs. It is also necessary to analyze the market that will be introduced.

The life and advancement of man and society are impossible without meeting certain prerequisites known as needs [3].

This humanoid robot head will enable remote communication with a variety of people by mimicking some facial expressions during a conversation.

3. Conceptual model

An overview of future trends in robotics is provided in reports based on the quick development of technology and new robot models, which offer a diversity of information and viewpoints. They can offer predictions about where technology is headed and what effects it might have on the economy, employment and interpersonal relationships.

The needs of humans, including the integration of robots in various processes and the facilitation of interaction with humans through them, are reflected by the construction of such a humanoid robot head. These demands were determined utilizing a Google Forms questionnaire with clear, short questions that might give us useful information.

Following a market analysis of the intended market for the product, which included the identification of rival products and their features as well as the determination of product functions, numerous concepts were developed based on the questionnaire. An ideal notion for the actualization of the robot head was selected after a more thorough investigation of them, as it can be seen in Figure 1.

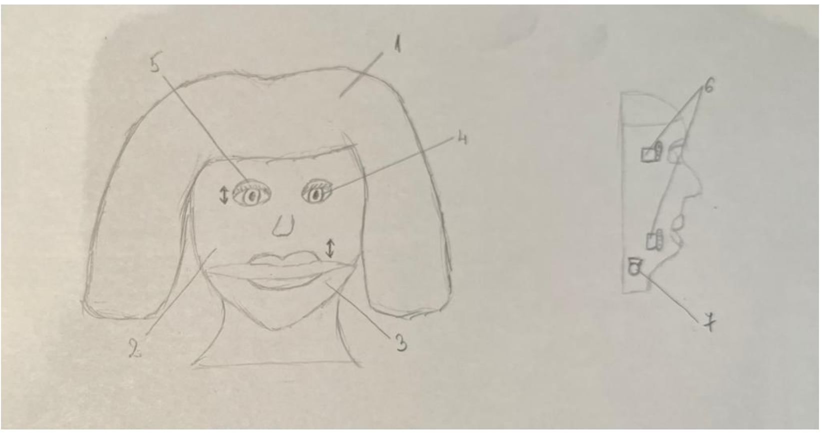

Fig. 1. The concept chosen for the realization of the robot head

A plastic face structure (2) is present on the robot head. Attach the maxillary (3) to it, fix the eyes (4), and arrange the eyelids (5). The actuator (6) conducts a top-down action. They move vertically thanks to two actuators (6), which are used to move them. For recording and issuing words, a voice module (7) is incorporated. The wig (1) is also affixed to give it a human appearance.

4. 3D modeling and printing of components

A thorough examination of the face's features is necessary to create a humanoid robot head, as is the creation of places for the integration of various operating circuits. Additionally, anthropometric measurements are taken to give the product a realistic appearance.

The robot head's 3D model was created with the help of the SolidWorks program. The product's constituent parts have been modeled within it. These are depicted in figures 2 - 6.

Fig. 2. 3D Eye Model

Fig. 3. 3D Eyelid Model

After the component 3D models were created, they were saved in STL format so that they could be used to create printing-related codes. These codes, which determined the parameters of the printing regime for each component, were produced using Z-Suite software. They were then employed as Z-HIPS printing materials and printed on Zortrax M300 Plus printers.

Fig. 4. 3D maxillary model

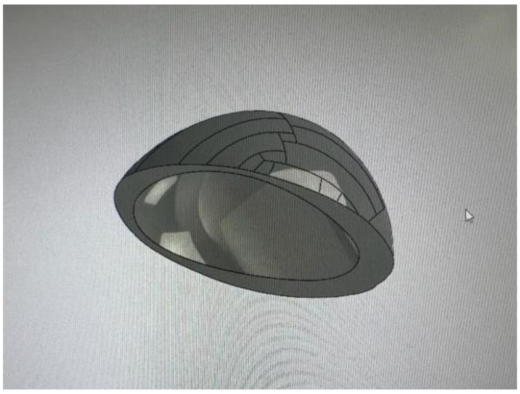

Fig. 5. 3D cap model

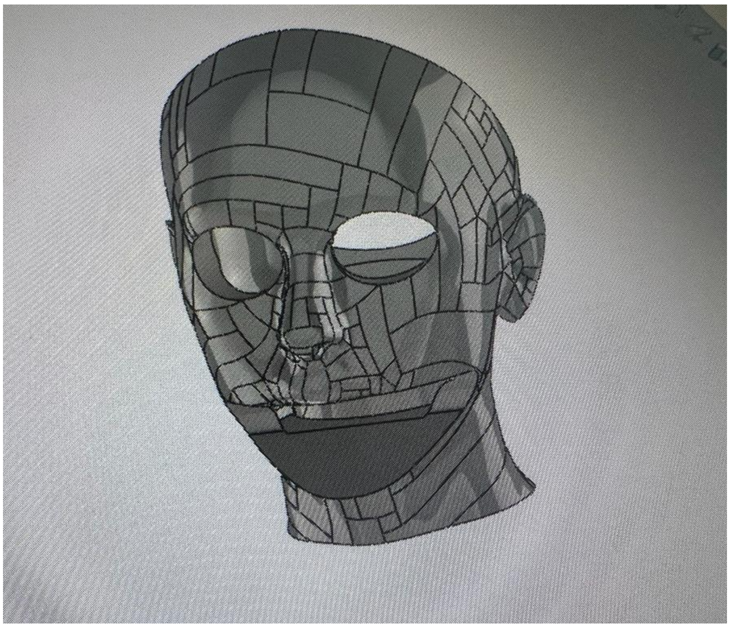

Fig. 6. 3D head model

A kind of styrene is high impact polystyrene (HIPS). In limonene, a solvent obtained from citrus trees, it dissolves. HIPS can dissolve in d-Limonene when used as a support material, erasing any traces left behind by removing the support and leaving the print intact. HIPS is a great option for pieces that need to be lighter because it is more dimensionally accurate and lighter than ABS. Since this filament is relatively new, using it is still in the testing phase [4].

Table 1 contains printing parameters for 3D models.

Table. 1. Printing parameters

Parameter	Value
Layered height	0,19 mm
Number of exterior walls	2
Filling pattern density	30%
Filling pattern	Line (patern 1)
Printing temperature	250° Celsius

Table. 1. Printing parameters (continuation)

Parameter	Value
Printing bed temperature	80° Celsius
Printing Speed	40 mm/s
Addition of support material	No Yes - support material density 15%
Adhesion to the printer bed	Raft

Figures 7 and 8 show the 3D-printed parts and their assembled counterparts.


Fig. 7. Printed cap


Fig. 8. Printed and assembled components

5. The mechatronic system

The robot head was designed as a mechatronic system in order to be interactive. The mechatronic system consists of actuators and modules that replicate user-transmitted language and human movements. Table 2 lists every element of the mechatronic system.

Table. 2. Mechatronic system components

Component name	Number of pieces
Arduino board	1
Breadboard	1
Actuator	3
Voice mode	1
Father-father wires	11
Mother-father wires	5

The Arduino Uno board was linked to the breadboard in order for the circuit to function, and then the other components were joined to it using the mother-father and father-father connections. When using an actuator, the connection is made as follows: a father-father wire connects the red pin of the actuator to the line on the breadboard connected to the Arduino Uno board's 5V port, another father-father wire connects the white pin to the plate's digital pin, and a third wire connects the actuator's black pin to the line on the breadboard connected to the board's GND port.

In the case of voice mode, a father-father thread connects the red pin of the module and the line on the breadboard connected to the 5V port of the Arduino Uno board. A second thread connects the voice module's black pin and the line on the breadboard connected to the GND port. The remaining four pins are connected to the digital pin of the plate using father-father threads.

Making the necessary code using Arduino software is the final step in the operation of the mechatronic system. Declaring the variables and their types was followed by performing a code sequence for each servomotor and the speech module, which was then combined at the end to produce the whole code.

Component libraries are part of the source code. Then, a declaration of the components and pins to which they are attached follows. Figure 9 depicts a few of these.

```
#include <Servo.h>
Servo servomotoro1;
Servo servomotoro2;
Servo servomotoro3;
int j;
int i;
#define REC 2
```

Fig. 9. Adding bookstrings, declaring variables and pins

The void setup section of the code contains a declaration of the variable types, and the void loop section contains the operating instructions for each component. Part of this code can be found in figure 10.

```
void loop() {
 for(j=10;j<=50; j+=10){
    servomotoro1.write(j);
    delay(1000);

  for(k=10; k<=40; k+=30){
     servomotorg.write(k);
     delay(1000);
 }
```

Fig. 10. Sequence void loop

6. Functional prototype

They came back together to create the first prototype after finishing the realization and testing of the circuit and assembling the robot head. Figure 11 depicts it in visual form.

Fig. 11. Initial prototype

In order for the system to work, two actuators are used to move the eyelids, and a third actuator is used to move the jaw when the voice module makes sounds.

7. Conclusions

In conclusion, following the development of concepts, the choice of the optimal one, the design of components related to the concept, their printing and the realization of the mechatronic system, the first functional prototype of the product was obtained. Within it are features very close to human ones and gestures similar to a person's behavior.

In future research, it is intended to create another functional, improved prototype that reflects as much as possible the final product.

Thus, the humanoid robot head to be developed as a final product is intended to provide an image as close as possible to reality, can be used in various ways and facilitating fast distance communication.

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RESEARCH ON THE DEVELOPMENT OF A CLOTHES IRONING DEVICE

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ABSTRACT: Having as a starting point the need to iron any type of clothing item in the best possible quality and in the shortest possible time, it is proposed to develop a product named an clothing ironing device.In order to carry out the work, the essential steps are presented: business strategy, competing concepts, development of the chosen technical solution for the purpose of obtaining and developing the product, which has a semi-automatic system with air transmission, through a fan and technology generated by air voltage warm.

Key words: iron, product, development, air, transmission.

1. Introduction

In order to choose a product that would minimize the customers time in household chores, a number of five ideas were analyzed, after which it was decided to continue the project with the clothes ironing device (Baloon Air-oning).

This paper deals with relevant aspects regarding the development of a product intended for ironing clothes through a hot air system.

The need that led to the development of this work is to iron clothes in a short time and with little human effort. The purpose of the device is to iron textile products such as skirts, trousers, blouses, shirts. Being an innovative product that fulfills its ironing function, with the help of a hot air system, but also by means of a balloon, it evens out the clothes to be ironed.

The objectives pursued in this work are: the analysis of the entire life cycle of the product, the planning and development of the possible technical solutions for the realization of the optimal concept and the realization of the technical solutions for the selected product and the prototyping of the product.

2. Business strategy

Need analysis

Marketing aims to achieve in the best conditions the satisfaction of consumers and implicitly the profitability of the company, within a dynamic company-consumer process. To make an analysis of the need, it started first of all from the long time and the high human effort.

A questionnaire was made to identify the needs of users of the ironing device, this questionnaire being made up of 18 questions, these being divided into two parts "Buyer classification", to find out which category the product was addressed to, respectively "Buyer's opinion" to provide concrete information on the ironing process, but also on its improvement, which is related to the theme proposed in the questionnaire. Therefore, an analysis of the need was carried out according to certain criteria for their identification and characterization.

The identification and characterization of the need is presented in Table 1.

Table 1. Specific needs

No.	Need	Parameter	Value
1.	Be easy to use	Mechanism	Button operation
2.	Make it durable	Material	nylon (balloon)
3.	Be efficient while ironing	Smoothing wrinkles Optimum level of reliability	80-85%
4.	To be ironed quickly	Ironing time Duration	Shirt-7-10 min Blouses- 7-10 min T-shirts- 5-7 min Pants- 10-15 minute Skirts- 7-10 minute
5.	Have a reduced size	L x l x h	Dimensions (with the top during operation): cca 60 x 20 x 100 cm Dimensions (with the bottom during operation): cca 60 x 20 x 120 cm Weight: cca 2,2 kg
6.	The clothing product that is still wet can be ironed	Temperature	4 programs: Cotton- 204 °C Polyester-148 °C, Nylon-170 °C Silk-148 °C
7.	The need to sanitize clothes and smooth out wrinkles	System with a hygienic role of eliminating bacteria from the surface of fabrics	Air jet program; Air jet pressure - minimum 5 bar, maximum 8 bar Steam jet 170g/min
8.	Adjustable in height and width	Specific balloon/rod/hanger dimensions	4 dimensions (sizes can be found in the tables below): • S • M • L XL
9.	Pleasant appearance	Design	-
10.	Have an automatic shut-off system	Automatic warning/stop system	The automatic shutdown function is activated when the device detects
11.	Low noise level		60-65 decibeli

Functional analysis of the need

In order to establish the existence of the need for the device, it is necessary to know who the device serves, on whom the system acts and for what purpose this device exists.

The device serves the man who in the present case is the user to provide quality to the clothes to be ironed, being also the main function, and the goal is to reduce ironing time and human effort.

The product functions are presented in table 3.1, and environmental elements and the interfaces of these elements with the clothes ironing device are shown in figure 3.1.

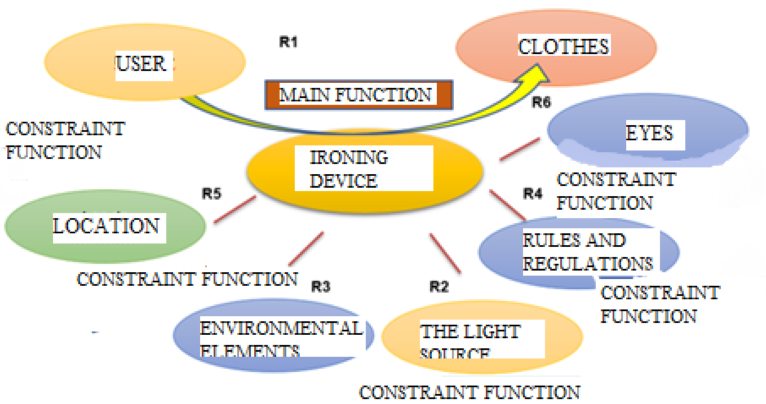

Fig. 1 Functional analysis

Table 2. Product functions

Environmental elements	**Actions of the environment element (functions)**
User	It helps to achieve the main function
Clothes	Allows the user to change the state of the clothes
Location	The product adapts to the location
Environmental elements (dust, humidity, temperature, vibration)	The device to withstand environmental elements
The energy source	The device connects to the power source
Rules and regulations	The device must comply with the rules and regulations in the field
Eyes	Let it be aesthetic

R1- Main function = The product allows the user to change the state of the clothes

R2- Constraint function = The product can affect the condition of the floor

R3- Constraint function = An environmental element can affect the state of the product

After the analysis, it emerges that the first function, the one that allows the user to change the condition of the clothes, is the most important. For the realization of the concepts related to this project, this function was respected with priority.

Competing Products (Competitive Analysis). In order to determine which features can be implemented in the new model of ironing device, the main features, advantages and disadvantages of these types of products on the market were analyzed. The analyzed products are presented in the following table.

Table 3. Specifications comparison

No.	Existing products	Characteristics	Benefits	Disadvantage	Applied prices
1.	The Aero360 hot air inflatable [8] 	Contains inflatable balloon Power: 1800 W Supply voltage: 220 - 240 V	Easy to use and store. Adjustable in height and width. Automated. Includes clothes drying program. Suitable for almost all sizes.	Only t-shirts/shirts can be ironed. It can only be powered from the socket. It does not have an anti-limescale system.	399 lei
2.	Tefal Pro Style IT3440E steam iron [9] 	Power: 1800 W Variable steam: 30 g/min On/Off function Steam adjustment levels: 3 The anti-limestone system	Fast and precise. User friendly. Fast heating Refreshes and sanitizes. Anti-calc solution. Provides a flat surface to keep clothes still.	It is pressed by hand. It has no clothes drying process. It can only be powered from the socket. It needs water.	365 lei
3.	The MaxxMee inflatable [10] 	Contains inflatable balloon Power: 1000 W Supply voltage: 220 - 240 V Maximum weight supported: 2.5 kg	Steam ironing function. Small dimensions and easy storage. Easy to use and store.	Only t-shirts/shirts can be ironed. It can only be powered at the socket. It does not have an anti-limescale system.	299 lei

4.	TUBIE - clothes drying and ironing robot [11] 	Contains inflatable balloon Power- 3200 W Supply voltage: 220 - 240 V Weight- 15 kg Cable length- 3m Material: Stainless steel	Hot air ironing function Manual adjustment of temperature / material. Small dimensions and easy storage.	Heavy weight. It can only be powered at the socket. Only t-shirts/shirts can be ironed. High price.	6499 lei

In conclusion, according to the previous table, some information was obtained about the current market and the main characteristics of a product similar to the one that was developed, this helps that there are new improvements that can be brought to the market to capture an audience as larger.
The main competitors for our product were analyzed in order to be able to observe the size of the market. So, in table 4. the main competitors for the ironing device are presented:

Table 4. The main competitors

No.	Producer	Headquarters	No. employee	Fiscal value
1.	TEFAL	France	>100	3 300 700
2.	Cleanmaxx	Turkey	50	2500 000
3.	TUBIE	Germany	>100	2440 800

Market segmentation. Through market segmentation, the aim was to identify groups of consumers with common needs, in order to adapt the products and their marketing in an effective way for those groups. The objective of market segmentation is to minimize risk by determining the products that have the greatest chance of gaining a share of a target market, which will help determine the best way to offer the products to the market, to buyers.

From a demographic point of view, the profile of potential customers was analyzed, resulting in a target group consisting of people aged between 18 and 50+ years.

Also, an analysis was carried out on the gender of the people, from which it emerged that most of the people who completed the questionnaire are of the female gender.

From a psychographic point of view, the results show that more than half of people iron clothes according to need, this helps to create the ironing product and improve the ironing process because we are addressing a wide target audience.

Following the analysis of some jobs performed throughout the country, close percentages emerged, but the highest percentage is within the legal-administrative field, being also imposed a certain elegant outfit that requires a special and impeccable ironing of the clothes.

Target customer profile. To create the target profile, an analysis was carried out taking into account the previously mentioned interest segment. Demographically, the user's age is 18-50 years old, predominantly female, time-stressed, and their workplace may be office, field, or a combination thereof.

3. Technical solution development and prototyping

A product concept is a rough description of the technology, the principles of operation and the form of the product [1].

Next, two conceptual options will be presented that fulfill the functions established for the product to be developed.

Concept A. The first product concept that meets the established need features 2 detachable parts, namely, 2 nylon balloons. The first balloon is specially designed to place t-shirts/shirts/blouses and the second one is suitable for trousers.
This concept requires more human effort to use as it involves the effort of swapping heads and lining up the garments. Catia V5 software was used for the 3D design of Concept A.

In table 5 shows the component elements as follows:

Table 5. The functions of the component elements

No.	Component elements	The functions of the elements
1	Motor	It converts electrical energy into mechanical energy
2	Timer	It measures the ironing time
3	Telescopic rod	Support function
4	Support legs	Support+support function
5	Fan	It generates an air flow
6	The ventilation holes	Ventilation function (casing ventilation)
7	Mounting flange	Mount/Assembly function
8	Clips with elastic cord	Grip function
9	Collar section	Support function
10	Blouse-type nylon balloon	Ironing function (role in placing clothes)
11	Nylon trouser balloon	Ironing function (role in placing clothes)
12	Microcontroller	Information storage function
13	LED screen	Display information
14	Thermostat	Temperature measurement function
15	Electrical resistance	Heating function
16	Power cable plug	Power supply function
17	Control panel	Program management function/light indication
18	220V to 5V transformer	Electric current conversion function
19	Relay	
20	"PUSH" type button	Electric circuit activation function
21	Temperature and pressure sensor DTH	Temperature and pressure measurement function

Concept B

The second concept is the mannequin type, where two clothing items such as a blouse and trousers can be ironed simultaneously. Its efficiency is much higher by the fact that time is saved and human effort is reduced. In order to design the 3D concept B, the Catia V5 software was used in Fig. 3.

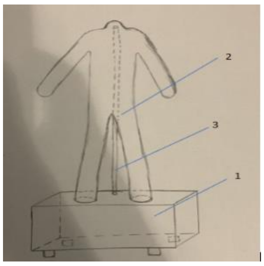

Fig. 2. Concept sketch B where 1. Housing, 2. Dummy balloon, 3. Telescopic rod

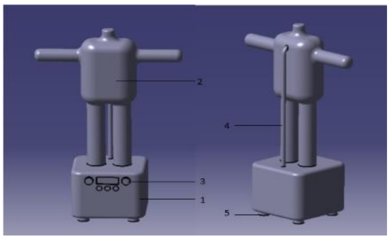

Fig. 3. Design Concept B where 1. Housing, 2. Dummy balloon, 3. Control panel, 4. Telescopic rod, 5. Support legs

The version of the technical solution has been finalized, which includes the following components, divided into the mechanical subsystem, the electrical and electronic subsystem and software.

Following the analysis of the hierarchization of the criteria of the two concepts (production costs, dimensions, ease of use of the product), the analysis of the concepts and their comparison, concept A was chosen for further development, taking into account the expressed needs of consumers the most . The product requires minimal storage and installation space, the emphasis is on ironing clothes according to the need, either pants or blouses, it does not require much assembly time.

Unlike the classic iron, the clothes iron (innovative) ensures a large amount of hot air that penetrates deep into the fabric, so that the clothes will become perfectly smooth without much effort. The warm air circulates through the clothes, gently drying them, leaving a pleasant smell and soft fabrics to the touch. It is equipped with an air ironing function for sanitizing clothes and smoothing wrinkles, with an intuitive control panel with the help of which a timer has been set.

In addition to the impeccable effect brought to the clothes, the large amount of air also has the hygienic role of removing bacteria from the surface of the fabrics. The warm air will inflate the balloon and penetrate the fabric drying the material, while the tension generated by the balloon will smooth out all the creases. The nylon balloon ensures perfect and even drying of t-shirts, blouses or shirts in sizes between S-XXL.

Product functionality

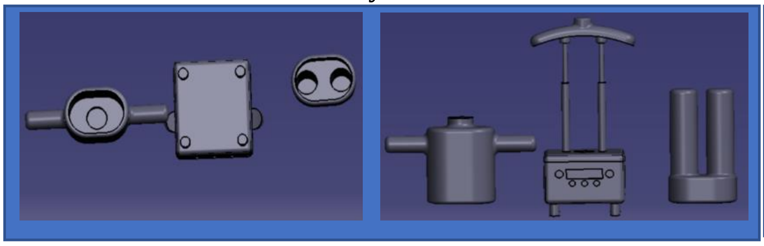

Fig. 5. Concept A

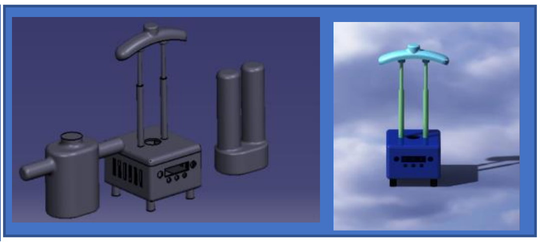

Fig. 6. Ensemble Concept A

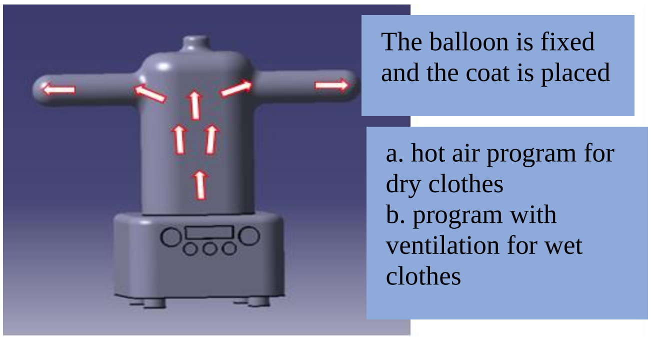

Fig. 7. Product Operation

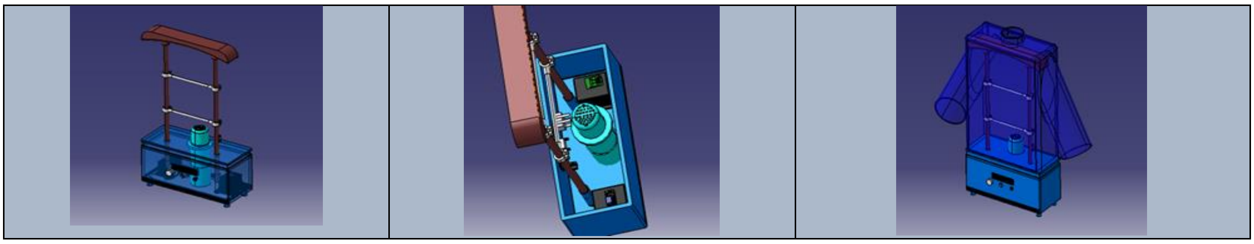

Fig. 8. Final assembly

Experimentation and prototyping

To create the prototype, some experiments of possible functionalities were first carried out.

The first experiment concerns the connection of a temperature and humidity sensor to a micro-controller, with the aim of finding out the temperature and humidity inside the inflatable balloon during the use of the product.

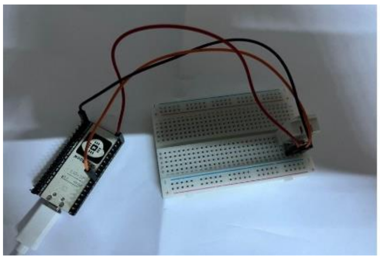

Fig. 9. Testing- temperature and humidity

As a result of the experimentation, the measurement of temperature and humidity was successful, as well as the integration of a WEB server on the ESP32 development board that allows WIFI access to a Web interface that displays the temperature and humidity measured in real time.

The second experiment was carried out by connecting a servomotor to the micro-controller. The experiment was carried out in order to be able to remotely control the actuation of the servo motor by turning it in one direction or another.

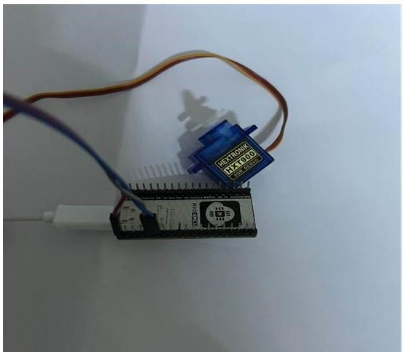

Fig. 10. Electric motor propeller rotation testing

It was possible to operate the rotation of the electric motor propeller in a range of 0-180° to the right or 0-180° to the left.

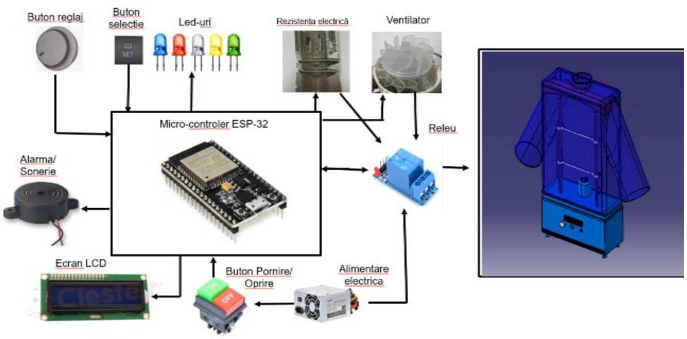

Fig. 11 Electrical system architecture

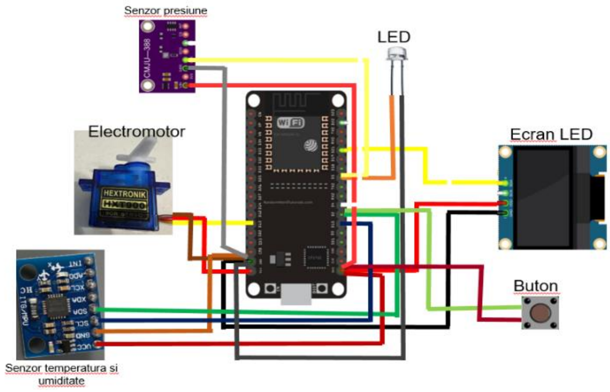

Fig. 12 Diagram with the connection diagram

In order to create the prototype, in the second semester of the academic year 2022-2023, tests and experiments of some subsystems of the product were carried out. In addition to the already existing component elements of an existing device, automated control functionality has been developed through a relay that can command various working modes with different firing times programmed according to the algorithm running on the ESP 32 microcontroller.

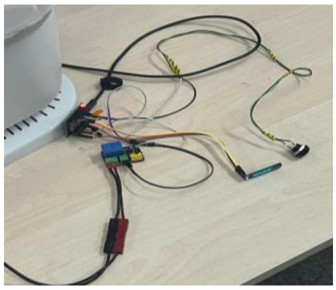

Fig. 13 Elements components

The tests confirmd the possibility of programming by means of the ESP32 microcontroller several working modes corresponding to certain ironing cycles. The correct dimensions of the electrical and electronic components were also confirmed. The potential for the development of intelligent functionalities that could assist the users of such ironing systems was demonstrated.

4. Economic analysis

In order to perform the economic analysis of the product, the cost of the product was realized.
The total unit cost of the product is 223 lei/piece.
The selling price of the product is 306 lei, with a profit margin of 40%.
In order to reach the profitability threshold of our product, it is necessary to sell in one year 1652 pcs.

5. Conclusions and perspectives

The project used numerous analysis methods to objectively choose the functions that the product must have in order to satisfy the needs of the customers. The start of the project was based on a modern method of generating ideas, namely, the brainstorming method.

A number of five ideas were analyzed, after which it was decided to continue the project with only one.

In order to be able to form an overview of the product typology based on an idea like the one we selected, we chose to use the questionnaire method. This method provided enough information to be able to move on to the next step, namely, to research the market, to perform functional analyses, both internal and external, but also to create the profi

In addition, market segmentation was carried out in order to choose the target customer.

To create the product, two concepts were designed with the help of the Catia V5 software.

In order to create the prototype of the technical solution, research was carried out to find the components necessary to satisfy the functions and needs, their compatibility and their realization.

In the next period, the main objective is to finalize the technical solution, to make the product prototype, to test and analyze the results, so as to improve the stage at which it is for placing the product in production, to define the schedules ironing.

To demonstrate the potential of developing intelligent functionalities that could assist the users of such ironing systems.

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RESEARCH ON THE DESIGN AND DEVELOPMENT OF AN ELECTRONIC DEVICE FOR MONITORING AND TRACKING INDIVIDUALS WITH SPECIAL NEEDS

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ABSTRACT: Currently, there is an increasing demand to provide support and assistance to individuals with special needs. In this context, intelligent assistive technologies are becoming increasingly important and can significantly contribute to improving people's quality of life. These technical solutions include wearable devices, environmental sensors, and communication and information technologies that can help in continuous health monitoring and immediate detection of medical issues or emergencies. Furthermore, they can assist in real-time tracking and enhancing the safety of the wearer. The aim of this article is to provide a comprehensive perspective on how monitoring and tracking devices designed for individuals with special needs can be utilized to improve quality of life, along with an analysis of the key challenges that need to be overcome to enable their widespread use.

KEYWORDS: monitoring, tracking, individuals with special needs, assistive technologies, data security.

1. Introduction

This paper aims to examine the importance of intelligent assistive technologies that have the capability of continuous monitoring and real-time tracking, as well as their contribution to improving the quality of life for individuals with special needs. These individuals may include those with neurodegenerative disorders of the nervous system, who experience cognitive and orientation issues (such as Alzheimer's disease, Parkinson's disease, Creutzfeldt-Jakob disease, Lewy body dementia), or young children who are more prone to the phenomenon of wandering.

The article provides an overview of the current situation of individuals with special needs and the challenges they face in their daily lives. It explores how intelligent assistive technologies, such as wearable devices and environmental sensors, can assist in continuous health monitoring and immediate detection of any medical issues or emergencies. The importance of real-time tracking and enhancing the safety of the wearer is emphasized.

Finally, the paper presents the objectives pursued and the approach taken to provide valuable and relevant information for the academic and professional community in the field of assistive technology for individuals with special needs as described above.

2. The current state of assistive technologies for monitoring and localization for individuals with special needs: a statistical study on people with disabilities and recent advances in the field

The safety and well-being of individuals with special needs are major concerns in our society [1, 2, 3], whether it pertains to protecting those with cognitive and orientation issues or young children who are at a high risk of wandering. These individuals face a range of challenges in their daily lives, including difficulties in navigating both indoor [1] and outdoor environments, as well as difficulties in autonomously managing their health. They are often exposed to the risk of accidents or other medical issues, and their care sometimes requires additional efforts from families and caregivers. Despite the daily challenges faced by individuals with special needs, the development of intelligent assistive technologies represents a promising solution to improve their quality of life [2, 3]. Wearable devices, environmental sensors, and communication and information technologies can continuously monitor health status and promptly detect medical issues or emergencies. Real-time tracking can provide increased security for individuals with cognitive and orientation issues. These intelligent assistive technologies can be tailored to the needs and capabilities of each user, regardless of their level of ability or experience, significantly enhancing people's lives and providing them with independence, safety, and comfort every day.

2.1. Statistical analysis of the situation of individuals with disabilities in Romania

In Romania, disability is measured in correlation with the concept of general activity limitation. This concept refers to the limitation of a person's usual activities as a result of health problems experienced in the past six months and is used by Eurostat to assess the level of disability in all European Union member states. According to the latest statistical data **[4]**, approximately a quarter of the population aged 16 and over in Romania has disabilities. Among them, individuals with severe activity limitations represent 6% of the population (1.2 million people). As of December 31, 2019, the total number of people with disabilities reported by the National Agency for the Rights of Persons with Disabilities, Children, and Adoption (ANDPDCA) through the county general directorates for social assistance and child protection, as well as the local sectors of Bucharest, was 846,354 people. Out of this total, 97.92% (828,792 people) were under the care of families and/or living independently, while 2.08% (17,562 people) were in public residential social assistance institutions for adults with disabilities coordinated by ANDPDCA. At that time, the disability rate reported in relation to the population of Romania was 3.82% per 100 inhabitants, with the South-West Oltenia, South-Muntenia, and North-West regions having the highest rates. In terms of counties/municipalities, the highest number of people with disabilities was recorded in Bucharest (69,392 people registered as of December 31, 2019), followed by Prahova County (37,836 people registered at the same date), while the lowest number was registered in Covasna County, with 6,332 people at the end of 2019. Among the total number of people with disabilities, women represent 53.08%, and 72.45% of adult individuals with disabilities are over 50 years old. Specifically, the data analysis by age groups shows that 53.76% are individuals aged between 18-64 years (418,473 people), and 46.24% are over 65 years old (359,947 people).

The degrees of disability are: severe, moderate, mild, and slight. At the end of 2019, the number of people with severe disabilities represented 39.92% of the total (an increase compared to 39.05% in 2018), those with moderate disabilities accounted for 48.80% (compared to 49.75% on December 31, 2018), while those with mild and slight disabilities accounted for 11.28% (compared to 11.20% on December 31, 2018) [4].

Current legislation defines barriers or obstacles as factors in a person's environment that, by their absence or presence, limit functioning and create disability. It also includes factors such as inaccessible physical environments, negative attitudes towards disability, poor services, systems, and policies, as well as the lack of assistive technologies and devices, among the possible barriers [4].

Furthermore, the UN Convention on the Rights of Persons with Disabilities emphasizes that parties should take effective measures to ensure the mobility of persons with special needs. It encourages entities producing assistive devices and technologies to consider all aspects related to the mobility of persons with disabilities [7]. Although there is a national emergency call service for people with hearing or speech disabilities, its use is not monitored, and the personnel involved in emergency interventions are not prepared to meet the needs of persons with disabilities. Emergency action plans of the Department for Emergency Situations (DSU) do not provide specific procedures for people with disabilities, except for delegating individuals responsible for coordinating risk management for this group [5].

Considering the increasing need to provide support and assistance to individuals with special needs to enable them to lead safe and protected lives within the community, the use of intelligent monitoring and tracking technologies, developed in the form of electronic devices, is becoming increasingly important. These technologies can significantly contribute to improving their quality of life and that of those around them [6].

2.2. The current state of development of electronic monitoring and localization devices for people with special needs

Official figures show that in the past 30 years, there have been a total of 83,754 cases of missing persons, including children and adults, out of which 2,418 individuals have disappeared and have not been found. Among the over 83,000 missing persons, over 52,000 were under the age of 18 at the time of disappearance. Almost 400 children have never been found [9]. These alarming numbers highlight the importance of ongoing efforts to develop efficient monitoring and localization technologies to prevent such unfortunate situations and increase the chances of finding missing individuals with minimal effort and cost. As disappearances can have serious consequences for the individuals involved and their families, it is crucial to pay increased attention and properly address such cases, with monitoring and localization devices being useful tools in prevention and resolution efforts.

The current stage of development of electronic devices aimed at improving the lives of people with special needs is continuously evolving. There is a growing demand for current monitoring technologies to include wearable devices with GPS capabilities for location tracking, alongside health assessment devices such as heart rate monitors and smart blood pressure monitors. Additionally, there is an increase in the use of mobile applications and wearable devices for monitoring various parameters [8]. Overall, the development of assistive technologies for individuals with special needs focuses on improving accessibility, autonomy, and independence for users, as well as easing the tasks of caregivers [6].

3. Conceptual and detailed design of the electronic monitoring and localization device for people with special needs

In identifying the main issues and requirements related to the development of an electronic monitoring and localization device for individuals with special needs, several aspects can be highlighted. Firstly, the device users are individuals with extremely limited abilities, which means that the product needs to be accessible and tailored to their needs, with an ergonomic and intuitive design. A suitable solution to meet these requirements could be a bracelet-like device that can be comfortably worn on the wrist. Additionally, an important aspect is the durability and water resistance of the device, as it will be exposed to wear, moisture, and shocks. Moreover, special attention must be given to data security, as the information collected by the device is sensitive and needs to be protected against unauthorized access **[10]**. The accuracy and reliability of the localization system are crucial aspects because the device needs to provide precise real-time information about the user's location. Sufficient battery autonomy is also necessary to enable the device's usage for an extended period. Lastly, another important requirement is the integration of the device with other existing technologies and services, such as mobile applications or data monitoring and management platforms, as well as integration into the national emergency system (e.g., 112).

These are just a few of the major issues and requirements that need to be considered in the development of an electronic monitoring and localization device for individuals with special needs.

3.1. Conceptual Design of the Device

To develop a monitoring and localization device for individuals with special needs, it is advisable to use a combination of methods that take into account the specific needs of the users and the technical requirements of the product. The Six Sigma method or DMAIC (Define, Measure, Analyze, Improve, Control) can be utilized to reduce variability and eliminate errors in the device's production process, ensuring optimal performance. The Failure Mode and Effects Analysis (FMEA) method can be employed to identify and prevent potential risks associated with device usage. Based on three pillars - empathy, ideation, and experimentation - the Design Thinking method is suitable for understanding user needs and creating innovative solutions that address those needs. Additionally, the PEST(LE) analysis can be utilized to evaluate external environmental factors such as political, economic, social, technological (legal and ecological) factors that may impact the product's usage. Last but not least, testing prototypes and beta versions of the device by end-users can provide valuable feedback to consider their needs and adapt the device's design and functionality.

It is important to mention that these methods need to be adapted to the specific needs of the product, and the chosen method should be continuously evaluated to ensure the device is efficient and meets the requirements and needs. Moreover, multiple technological solutions will be implemented to contribute to the development of the electronic monitoring and localization device for individuals with special needs.

Firstly, a detailed analysis of user needs and requirements will be conducted, and appropriate technologies will be identified to fulfill those requirements. State-of-the-art sensors capable of continuous monitoring of movements and accurate localization of the user will be employed to enable real-time tracking. Additionally, a wireless communication system will be developed to transmit data from the device to a control center. This system will utilize cutting-edge technologies and facilitate real-time data transfer without the need for cables or physical connections.

Furthermore, an intuitive user interface will be implemented to allow device customization based on the wearer's needs and the caregiver's preferences. Regarding durability and water resistance, high-quality materials that can withstand daily usage and environmental factors will be utilized. The device will be designed to withstand extreme environmental conditions such as rain and humidity.

All of these technological solutions are implemented with a single purpose in mind: to create an electronic monitoring and tracking device for people with special needs that is durable and easy to use. The end result is a product that meets all user requirements and can be used with confidence in any situation.

3.2. Detailed design of the device

In this section, ideas and specific technical concepts will be explored to develop a monitoring and localization system suitable for individuals with special needs. The detailed design of the product will involve both hardware and software aspects.

To begin with, the identification of hardware components for the monitoring and localization system is necessary, including sensors, communication devices, localization devices, and a data processing unit. Additionally, specific requirements of individuals with special needs must be taken into account when establishing features such as product size, weight, how it will be worn and used, and the interaction of the monitoring and localization device with other medical devices and systems used by the user, such as pacemakers, cardiac stimulators, hearing aids, implantable defibrillators, insulin pumps, implantable pain pumps, neurostimulation electrodes, epilepsy monitoring electrodes, etc. Another key component of the detailed design is the software. This will include the development of monitoring and localization algorithms, user interface, and how collected data is stored and managed. Consideration will also be given to the software's compatibility with other devices and systems. Additionally, security and confidentiality aspects of personally identifiable data collected by the device will be taken into account, ensuring that they are protected and managed in accordance with legal and ethical requirements **[10]**. Finally, the detailed design will involve a series of tests and improvements to optimize the product for the special needs of the individuals who will use it. These tests may include evaluating the reliability, accuracy, and precision of the monitoring and localization device in a variety of different environments and situations.

4. Conceptual and detailed design of the application for the electronic monitoring and localization bracelet for people with special needs.

This chapter presents the conceptual and detailed design of the application for the monitoring and localization bracelet for individuals with special needs. The conceptual design represents the first stage in the development of the application, where key aspects of functionalities and user interactions are detailed. Furthermore, the detailed design is presented, which focuses on the concrete implementation of the functionalities and technical details of the application.

4.1. Conceptual design of the application

This section details the process of conceptual design for the application of the monitoring and localization bracelet for individuals with special needs. This process is divided into two stages: requirements definition and functionality definition of the application. The first stage involves establishing the application requirements based on the goals and specific needs of the assisted individuals. To accomplish this, a detailed study of end users and application use cases is conducted, and the most important security and confidentiality requirements are identified and analyzed to protect personal data in accordance with legal provisions. The second stage consists of defining the functionalities of the application, which will be designed to meet the previously established requirements. Consideration will be given to facilitating access to information, ease of use, and the application's ability to adapt to various specific user needs. Finally, the conceptual design of the application will be carried out, taking into account the latest technologies and software development standards to ensure optimal functionality and user-friendly experience for the end users **[11]**.

4.2. Detailed Design of the Application

Following the conceptual design of the application for the electronic bracelet for monitoring and locating individuals with special needs, we have moved on to the detailed design phase of the application. The detailed design of the application involved a thorough analysis of the requirements and functionalities needed to achieve the established goals. This process entailed creating a coherent and well-structured design that enables users to quickly and easily access the application's functionalities.

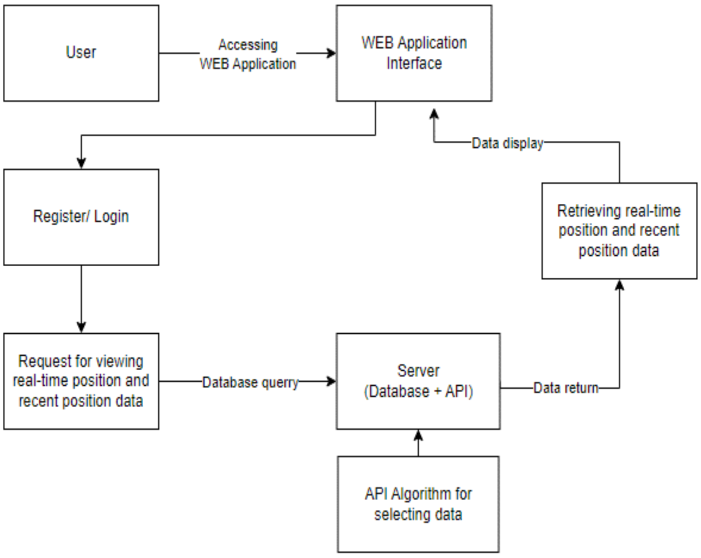


Fig. 4.1 Application architecture.

Firstly, a thorough analysis of the requirements and needs of the end users, specifically individuals with special needs and their caregivers, was conducted. Based on the obtained information, a detailed list of functional and non-functional requirements for the application was developed. These requirements were grouped and prioritized based on their importance to the users.

Based on the established requirements, an architecture diagram of the application (fig. 4.1) was created, and its main functionalities were defined. User interface considerations were taken into account, and an intuitive and user-friendly interface was developed to allow users to quickly access the application's functionalities.

Within the application interface, special sections were designed for different categories of information. These sections are divided into pages as follows:

- Home page, which will contain information about how the system works;
- Register page (fig. 4.2): It will contain a form that users need to fill out with their information;
- Login page (fig. 4.3), which contain a form for user authentication;
- Forgot password page: it will assist users in recovering their password;
- Get data page (fig. 4.4): It will display real-time and recent position information;
- About page: It will provide information about the team that developed the system
- Contact page: It will display contact details.

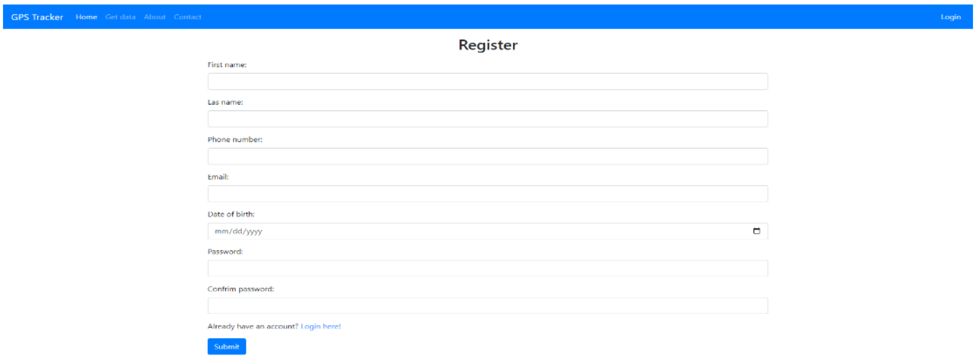


Fig. 4.2 The registration form

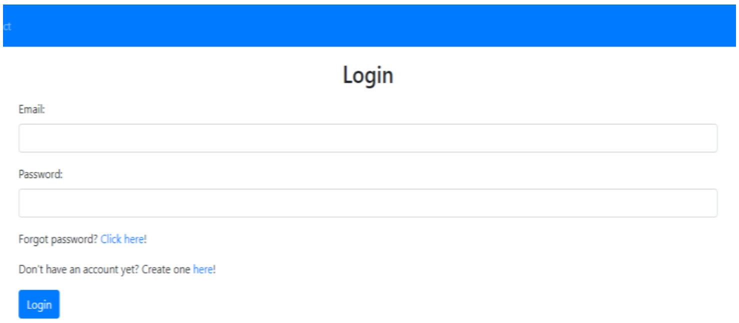
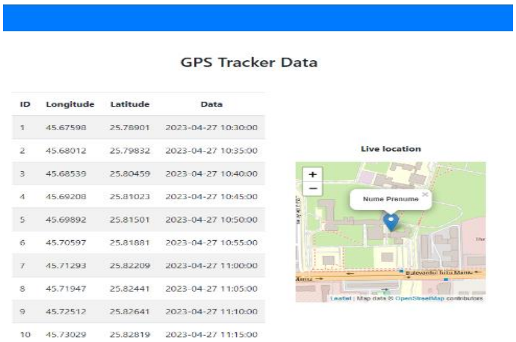


Fig.4.3 The login form



ID	Longitude	Latitude	Data
1	45.67598	25.78901	2023-04-27 10:30:00
2	45.68012	25.79832	2023-04-27 10:35:00
3	45.68539	25.80459	2023-04-27 10:40:00
4	45.69208	25.81023	2023-04-27 10:45:00
5	45.69892	25.81501	2023-04-27 10:50:00
6	45.70597	25.81881	2023-04-27 10:55:00
7	45.71293	25.82209	2023-04-27 11:00:00
8	45.71947	25.82441	2023-04-27 11:05:00
9	45.72512	25.82641	2023-04-27 11:10:00
10	45.73029	25.82819	2023-04-27 11:15:00

Fig. 4.4 Displaying data in the WEB aplication

Furthermore, we have created a detailed plan for the development and implementation of the application, which included prototyping, source code development, and testing the application in various scenarios and usage conditions. Throughout this process, we have employed best practices and utilized the latest technologies available in web application development [11]. Additionally, the detailed design phase also involved the development of algorithms necessary for key functionalities of the application, such as user registration and access management, as well as monitoring and locating individuals with special needs. The detailed design of the application is a crucial process in developing an efficient and user-friendly application that meets the needs of the end-users and contributes to enhancing the quality of life for individuals with special needs and their caregivers. This phase allows developers to implement each functionality of the application in detail, ensuring a smooth and efficient user experience for the bracelet users.

5. Conclusions

This study has highlighted the importance of developing an electronic monitoring and tracking device for individuals with special needs, such as dementia patients and young children. By implementing this device in the form of a wristband, an efficient and easy-to-use solution can be provided for families and caregivers to ensure a high level of protection and safety. One of the main advantages of the device presented in this research is the use of GPS and GSM technology, which allows for precise and real-time tracking of the monitored individual through the wristband. Additionally, the main requirements related to this device, such as durability, resistance to environmental factors, and protection of personal data, have been identified. To meet these requirements, efficient technological solutions have been proposed, such as the use of water-resistant and shock-resistant materials, as well as the implementation of encryption technologies to ensure data security.

In the future, further research is needed to develop and improve this monitoring and tracking device, in order to expand its use globally and adapt it to the specific requirements of different categories of individuals with special needs. Furthermore, the development of new, more advanced security technologies is important to protect the personal data of those who use this product. In this regard, the implementation of user authentication and encryption solutions is possible, as well as the development of artificial intelligence technologies that can prevent risky situations for individuals with special needs. All of these can contribute to improving the quality of life for these individuals and their families, as well as increasing the level of safety in the communities in which they live.

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RESEARCH AND DEVELOPMENT OF AN ASSISTED SYSTEM FOR PERSONALIZATION AND PROGRAMMING OF MEDICINES

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ABSTRACT: A support system for people who need medicines with respect to a preestablished schedule is the result of a research - development process. Based on the defining influencing elements and specific methodology, two main research directions have been followed. Several concepts and design detailed elements are developed as a medicine dispenser, but with a complex structure. Also, an assisted system for personalization and programming of medicines is developed; this includes a simple medicine storage and the distribution of medicine through a web-based application, and is considered a safe system for further development.

KEYWORDS: medicine, product development, web application, nursing, safe system

1. Introduction

The consumption of medicines [6] is an indicator that reflects both the state of health of the population and the efficiency of the health system and services in a country. Romania is a country with a low consumption of medicines, i.e., almost half of the European average. This conclusion is maintained for both prescription and over-the-counter (self-medication) [1].

A smart medicine dispenser helps the patients for taking their medications on time, easilly, without missing pills, and reducing the risk of over/ under dosing. A such of dispenser can inform and alert the patients to take the defined dose at the right time. It assures communication between patients and caregivers, notifying in case the patient missed the pill. Also, it includes an application on smartphone which will allow to remotely manage and control pill schedules and usage data [10].

An automatic dispenser of medicines is realised with the main function of remote and real-time monitoring of the activities of the elderly patients in home environment. It includes alarming whwn the omission of medicines and other critical events take place.The monitoring system consists of wireless sensor nodes distributed in the patient house. The tests demostrated the correct operating and the utility of the system [11].

The main objective of the present paper is to develop and analyse an innovative medicine dispenser, and an assisted system for personalization and programming of medicines, as support for people who need medicines according to a certain schedule.

The assisted system for personalization and programming of medicines is envisaged as accessible to the use of people in need or of the medical staff who care them.

2. Business strategy

2.1. Need analysis

For this analysis, the main needs have been identified. In the same time, a questionnaire was made [2, 4] in order to identify the needs of potential users. The questionnaire was distributed to a sample of 300 people, of whom 182 replied.

The characterization of the expressed needs/ requirements is presented in Table 1.

Table 1. Need analysis

Need	Parameter	Value
To provide treatment for the necessary period	Storage space	28 compartments (14 compartments for storage, 14 for collecting)
Have easy access to medicines in the compartment	The size of the compartments	50 mm x 40 mm x70 mm (bottom compartments are removable)
Have stability	Metal disc/ suction cups	2 units
Have autonomy	Batteries	3300 mAh
Be paired with a smartphone	Mobile app	-
Have a visual alert	LED	1/ compartment
Have audible warning	Buzer	80 dB
Indicate battery level	Lcd Screen	1
Confirm that the drug has been taken	Proximity sensor	Detection distance 4 mm
To announce when the storage space is empty	Proximity sensor	Detection distance 4 mm
Not accessible to children	Locking system	1 unit
Be affordable	Price	< 300 RON
Be easy	Table/ Material	max. 500 g

2.2. Functions and characteristics of potential solutions

A requirement analysis on function – potential solution characteristics has been unrolled, and main results are as presented in Table 2.

Table 2. Functions and characteristics of the potential solutions

	Function	Characteristics of the potential solutions
1	Storage of medicines	Transparent polymer boxes
2	Accessing medicines	Side-closure cover
3	Protection of medicines	Sterile environment, without disruptive factors
4	Managing medicines to the user and informing them	Developing a web application

Certain core system functions have been defined. The system must be simple and easy to physically reach. At the same time, the costs of producing an advanced automated personalization and medication programming assisted system were taken into account.

2.3. Market segmentation

An analysis of different national cultures showed no differences in the habits of taking medication with the help of certain product, and customers who purchased medication personalization and programming assistance systems, regardless of race or religion, used these products in the same way. Therefore, it was concluded that a geographical segmentation of the market for the proposed product is not necessary.

After meeting with professionals in the medical field, the following information was obtained regarding the storage of medications under optimal conditions for their intended use:

- the pills need to be kept in the original packaging for proper hygienic use, but they can be removed from the package and stored in a dry and disinfected place
- pills/ capsules need to be stored at a temperature below 25°C
- syrups/ medicines in glass containers cannot stand in direct light
- the injectable needs to be stored only in the refrigerator
- capsules/ pills may stay in contact with other drugs of the same type.

2.4. Competing products

As a result of the documentation, among the most relevant products comparable to the present idea resulted 3 competing products out of the 30 analyzed both on the Romanian market and in other states, as shown in Table 3 [7, 8, 9].

Table 3. Competing products

No. crt.	Product	Features	Advantages	Disadvantages
1		Material: plastic. Size: variable.	Large partitioning. Simple locking. Compartmentalization is single or divided. Low price: 1.7 euro/pc	Manual safety system.
2	 Ezy Dose (7-Day) Pill	Dimension: 14.5 x 14.5 x 4.2 cm. Material: plastic. Number of compartments 7. Bluetooth.	Setting up is simple, but requires some technical knowledge. The alarm is loud enough to wake up from sleep.	The lid is not easy to close safely. The rotation does not lock, it can rotate freely. Very small compartments.
3	 MedQ Daily Pill Box	Material: plastic. Number of compartments 14.	Provides treatment for 14 days. Visual warning to indicate container.	No locking system for compartments. You can schedule one to two alarms a day. High price/ $ 80.

2.5. Target customer profile

Statistics indicate that both males and females have an equal interest in acquiring personalized drug programming and assistance systems, as they both desire to uphold an organized way of living.

Acquiring revenue is a crucial factor to consider. One valuable market for purchasing personalized and programmed medication systems to save time for nurses are hospitals and nursing homes. Although the centers are the purchasers, the ultimate beneficiaries of this product are the patients and residents receiving treatment.

3. Development of technical solutions

To deal with the intricate process of evaluating numerous product concepts, selection is commonly executed in two stages. The first stage involves sorting out the concepts to quickly obtain some feasible options. This is a rough, preliminary assessment. The second stage is the concept evaluation, a more precise and detailed evaluation of the chosen few concepts. The ultimate goal is to choose a single concept with the highest probability of leading to a successful process [3].

3.1. Development of an innovative medicine dispenser

Different concepts of an innovative medicine dispenser have been created, as presented in Fig. 1.

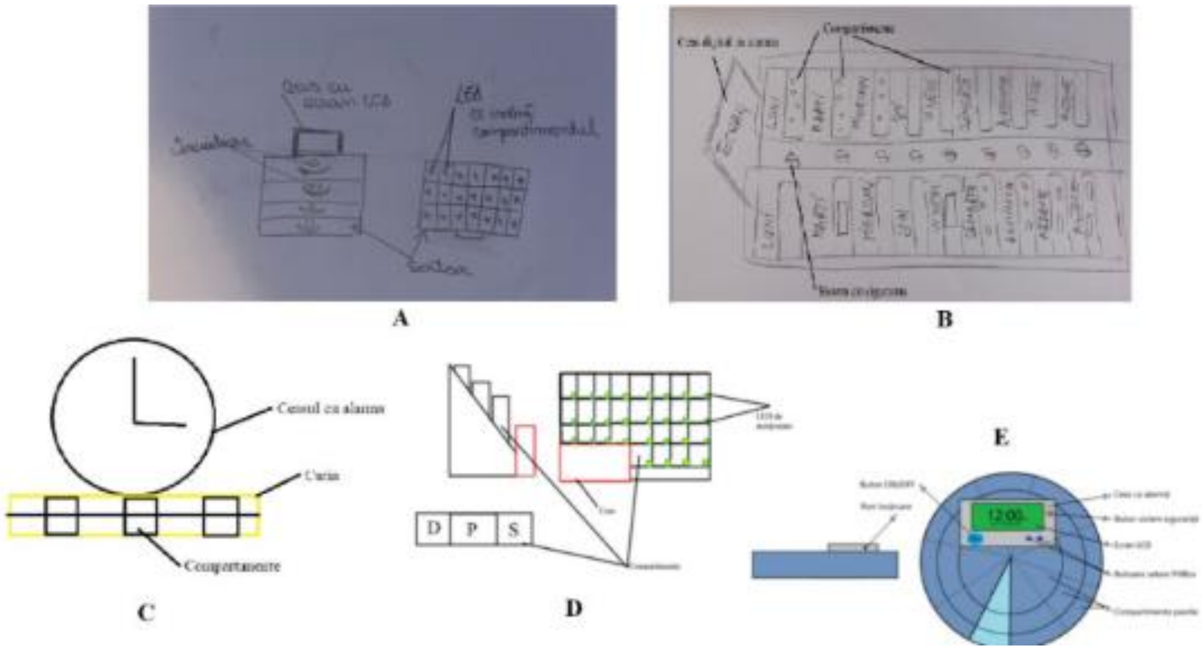

Fig. 1. Concepts on an innovative medicine dispenser

After analyzing and comparing the concepts, the second concept was selected for further development, which best takes into account the needs expressed by consumers. It offers generous compartment divisions and is also designed for primary needs, with mechatronic drive and LCD display. In addition, an automatic security system is included so that the compartments can be opened via an integrated system. Subsequently, the variant was analyzed and further developed, until at a certain point it was realized that its development is more difficult from manufacturing cost point of view [5].

The innovative medicine dispenser has been designed as a box with compartments dedicated to the medication and a LED in each of these, to indicate the medication to be administered, a clock-like screen equipped with a software system and a system for securing the compartments to be not easily opened by children (Fig, 2).

Fig. 2. A 3D model of the innovative medicine dispenser

The considered innovative medicine dispenser product is a complex one, i.e. is expensive to be in detail designed, manufactured and sold.

So, the second research direction has been developed for achievement an assisted system for personalization and programming of medicines.

3.2. Development of an innovative assisted system for personalization and programming of medicines

This system has been created with the aim to storage the medicine in a simple manner, and to distribute medicines to patients through a web application.

So, the medicine storage is in boxes of different sizes with a simple security system and an electronic label showing the patient's name and the dose to be taken (Fig. 3).

Fig. 3. Medicine storage boxes [7]

The interface of a medicine management application includes information that the user - medical professional or the patient - will enter into the system: patient's name or/and designation of the medicinal product and the frequency of hourly administration (Fig. 4).

Fig. 4. Entering data into the system

The user updates each administration, and this will keep a record of the administrations (Fig. 5).

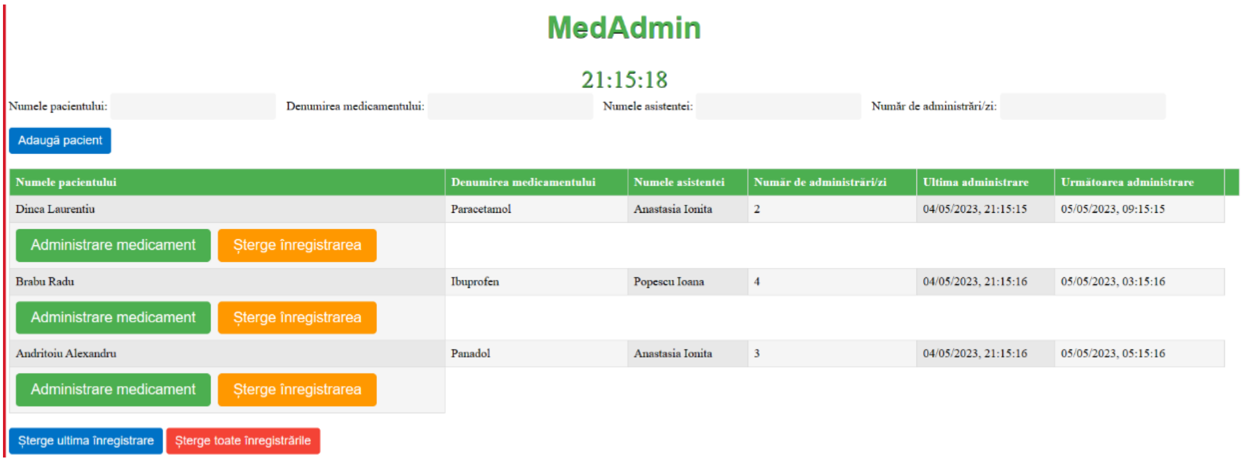

Fig. 5. Last administration

The development of the application permits as each user to have an unique account, and alerts when it is the time to take the medication.

4. Conclusions

A medicine dispenser and an assisted system for personalization and programming of medicines have been developed, as innovative supports for people who need medicines according to a preestablished schedule.

The innovative medicine dispenser has been overall characterized as being of a complex structure, with impact on manufacturing cost.

The innovative assisted system for personalization and programming of medicines has been developed so that to includes a simple medicine storage and the distribution of medicine through a web-based application, and is considered a safe system for further development.

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MODULAR ELECTROCHEMICAL POLISHING EQUIPMENT

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ABSTRACT:This paper deals with the state of the art of electrochemical polishing. The main details of the polishing process are the dimensioning of the electrode-shell, the choice of the type of counter-pressure chamber, the choice of the type of flow of the electrolytic liquid, the type of surface to be polished and the establishment of a type of process that will improve the quality of future polished surfaces. The aim is to rebuild a modular electrochemical polishing equipment in order to obtain the highest quality surfaces with the lowest roughness in the shortest time. Thus, the present work will provide information about the process and the existing equipment on the market with the help of patents, to be developed in the dissertation. Finally a concept proposal for the future equipment will be presented.

KEYWORDS: electrochemical polishing, anode, cathode, electrolytic liquid, modular equipment, ECM.

1. Introduction

Electrochemical polishing, also known as anodic polishing or electrolytic polishing (especially in metallography), is an electrochemical process that removes material from a metal part, reducing surface roughness by smoothing out micro-peaks and valleys, improving the surface finish. This process takes the place of electroplating. It is used for polishing, passivating and deburring metal parts. It can be used instead of fine abrasive polishing for microstructural surface preparation [1].

2. Current status

Electrochemical polishing involves an anode, consisting of the workpiece to be machined, and a cathode represented by the tool being placed in an electrolyte bath, where solutions of basic, acidic or neutral character are present. The anode is connected to the positive (+) source of the current source and the cathode to the negative (-) source. The current passes from the anode, where the surface metal is oxidised and dissolved in the electrolyte, and then the oxidation products pass to the cathode. A reduction reaction takes place at the cathode, producing hydrogen. [3] This achieves the reduction of the roughness of the machining surface according to the scheme in Figure 2.1, underlying the anodic dissolution, which occurs in the electrolyte bath, and as a result an electric field is created between the tool and the

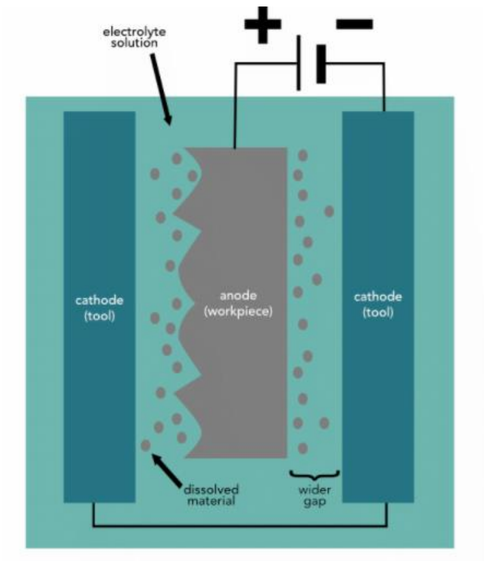


Fig. 1. Schematic of the electrochemical polishing process [4]

workpiece. And on the surface of the blank a passivated layer is formed in the region of the micro-warpage, where the current intensity is higher, so the electrical resistance is lower in these areas. [4].

3. Strategic product marketing

Identifying market opportunities

In order to identify market opportunities, first, the needs of future customers must be found. Needs that will be met by the product of choice.

Thus, 5 needs were identified:

- The need to create surfaces with high corrosion resistance and to increase the service life of parts;
- The need to increase processing productivity;
- The need to create surfaces with minimal risk of contamination (sterile);
- The need to remove radioactivity from certain surfaces;
- The need to create low roughness surfaces.

Data collected from potential customers:

The questionnaire will be used to identify customer requirements. The questionnaire guide used in the collection of raw data aims to obtain answers that answer questions such as:

1. What is your field of activity?
6. Would electrochemical polishing equipment be useful in your work?
7. Which of the following advantages do you consider the most important?

The results of these questions are as follows:

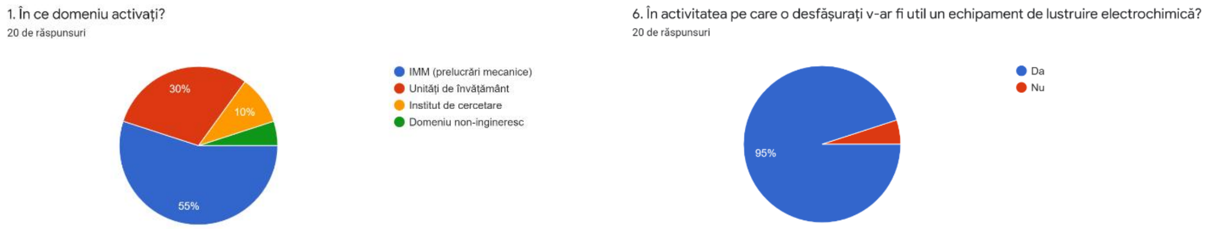


Fig. 2 Question 1 and 6

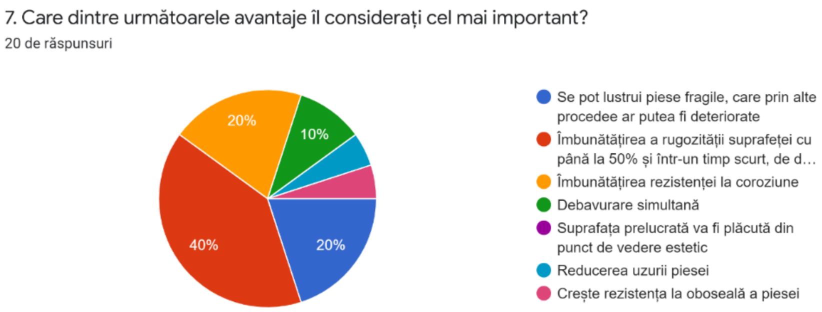


Fig. 3 Question 7

From the responses we received we can say that there is a great interest in the product. Electrochemical polishing is preferred over mechanical finishing, with respondents considering that electrochemical polishing equipment would be useful to them.

4. Modeling of electrolyte fluid flow

- Choice of calculation mode: Choose *2D Axisymmetric* dimensional space (for a part of revolution that has symmetry about a central axis), then the Physics mode used: Fluid Flow-Laminar Flow, then steady state. This assumes that the electrolyte flow is laminar (constant velocity in the machining gap).

In the figure below you can see the parameterization of the model:

Name	Expression	Value	Description
W1	10[mm]	0.01 m	rază piesă
H1	0.4[mm]	4E-4 m	interstițiu de prelucrare
W2	5[mm]	0.005 m	rază sculă
H2	1.5[mm]	0.0015 m	înălțime canal electrolit
a	0.0001[m]	1E-4 m	pas
b	0.000016[m]	1.6E-5 m	Rz
sigma	7.95[S/m]	7.95 S/m	conductivitate el NaCl
Eeq_K	-0.85[V]	-0.85 V	potential de ech catod
Eeq_A	-1.55[V]	-1.55 V	potential de ech anod
i0_K	0.3[A/m^2]	0.3 A/m²	densitate de curent de sc...
i0_A	1[A/m^2]	1 A/m²	densitate de curent de sc...
b_K	-220[mV]	-0.22 V	curba Tafel, catod
b_A	55[mV]	0.055 V	curba Tafel, anod

Fig. 4. Modelling parameters in Global Definitions

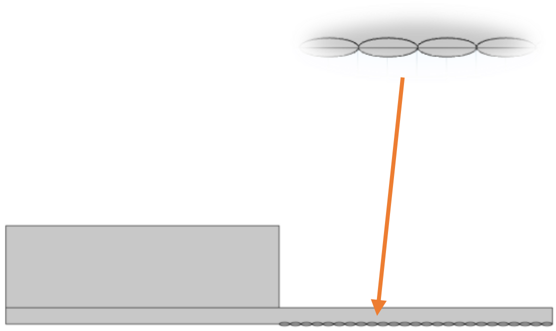


Fig. 5. Creating geometry in the work area

- The creation of the geometry is exemplified in figure 3.: Use the drawing tools integrated in the Geometry node of the Model Builder (*Rectangle*, *Ellipse*, *Boolene operations: Difference*, *Union*).
- The microgeometry of the modelled part is modelled with ellipses, starting from the parameter Ra=0.8 µm which is correlated with Rz=height of the ellipse.
- The material allocation is shown in Figure 8.: It is assimilated with water, the electrolyte liquid, its proportion in solution being over 90%. Search for the liquid in the COMSOL material library and allocate it to the geometry:

	Property	Variable	Value	Unit	Property group
☑	Density	rho	rho_liqu...	kg/m³	Basic
☑	Dynamic viscosity	mu	eta_liqui...	Pa·s	Basic
	Thermal conductivity	k_iso ;...	k_liquid...	W/(m·...	Basic
	Coefficient of thermal expansi...	alpha_...	(alpha_li...	1/K	Basic
	Heat capacity at constant pres...	Cp	C_liquid...	J/(kg·K)	Basic
	Local property HC	HC	HC_liqu...	J/(mol...	Local properties

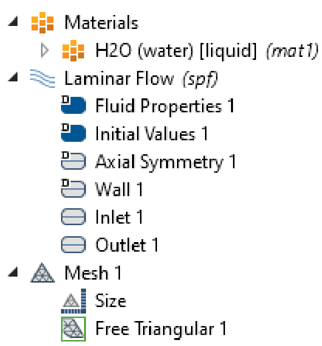


Fig. 6. Material allocation

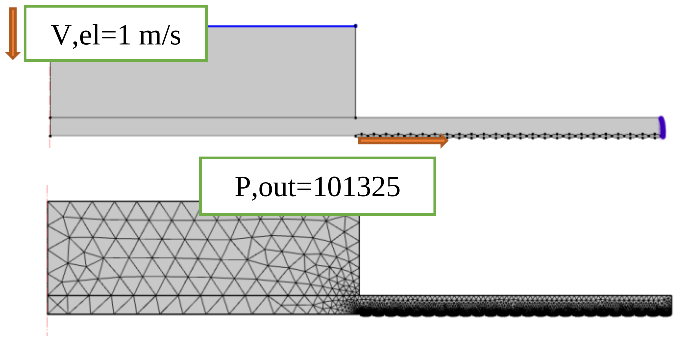


Fig. 7. Boundary conditions and discretization of the electrolyte fluid flow circuit

- The boundary conditions are shown in Fig. 7. as an inlet and an outlet at atmospheric pressure, Electrolyte inlet velocity, Vel - [m/s]; Outlet pressure - Pout [Pa];
- Discretization, shown in Fig. 7. with triangular elements of *finer* size. A division of the geometry into 16345 free triangular elements is observed.
- Run the model in steady state and visualize the results, watching the variation of flow velocity and pressure, as in Figure 9:

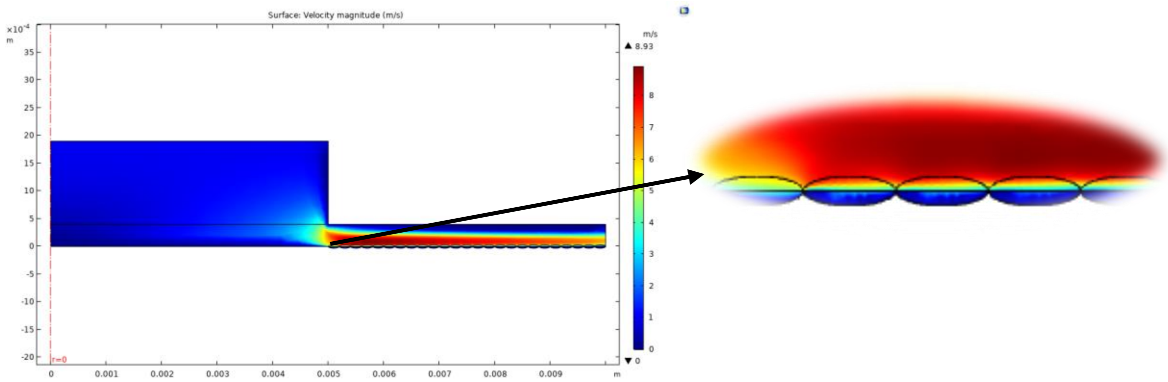


Fig. 8. Variation of electrolyte flow velocities and pressures at a processing gap sf=0.4 mm, initial Ra roughness of 0.8 µm and electrolyte inlet velocity 1m/s

5. Detailed design

The designed device is installed on the machine tool table
The following steps are taken to process the PSF:

1. The PSF is clamped in the device as follows:Clamping and orientation of the PSF is done by means of 4 guide and fixing wedges POI, a CII type plate, 4 locking and fixing elements, and then clamping is done by means of 4 hexagon socket screws DIN 912 M5
2. Assemble the Plexiglas front panel using 4 corners;
3. Fasten with 12 hexagon socket screws DIN 912 M4;
4. Lower the electrode tool for machining;
5. The electrolytic fluid is allowed to enter with tap 1;
6. Open tap 2 for the flow of electrolyte fluid from the device;
7. Process PSF;
8. After machining the electrode tool is withdrawn;

9. Turn off tap 1 to stop the electrolyte entering the device;
10. Remove the 4 three-dimensional corners and the hexagonal socket screws to remove the Plexiglas front panel;
11. Remove the Plexiglas front panel;
12. Loosen the 4 hexagon socket screws together with the locking and fastening elements;
13. Remove the PSF from the device;
14. The cycle begins again.

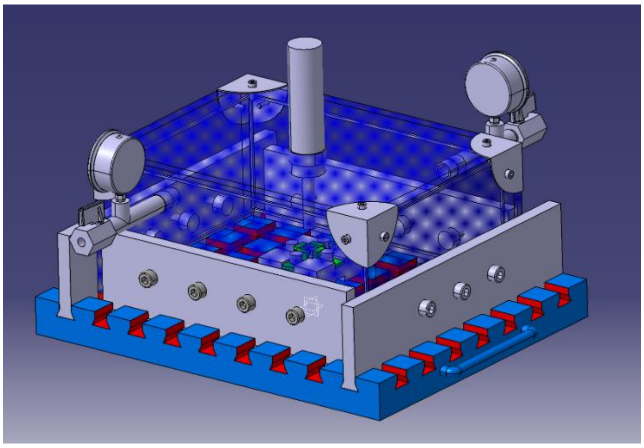
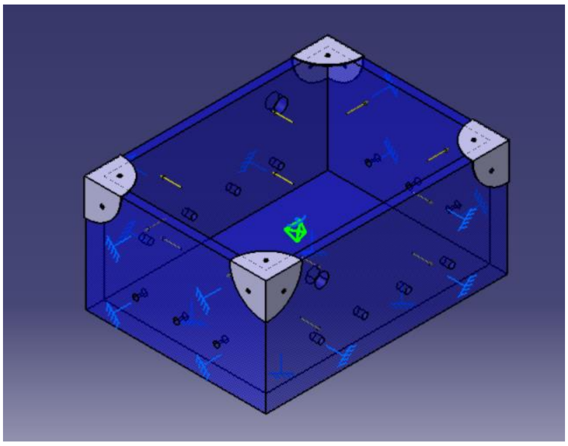


Fig 9. Partial concept

6. Manufacturing - product prototype testing

FEA check of side walls. In this part of the work it will be checked whether the deformations and unit stresses of the side walls have appropriate values within the required limits. During processing, the sidewalls will be subjected to a pressure of 20 atm (2 MPa), exerted by the electrolytic liquid.



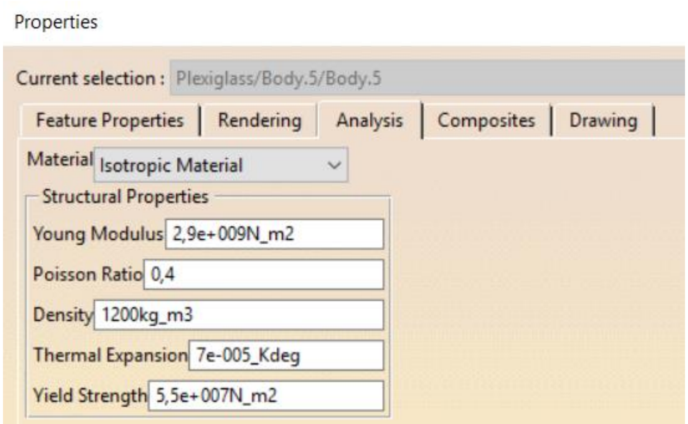


Fig.10 Defining the bearings and forces

Fig.11 Material properties

The foundations and forces have been defined as shown in the figure and the material properties of the side walls (Plexiglas) are shown in the figure. **Definition of the forces exerted**

by the electrolyte fluid and the amount of charges applied.

The wall widths are 30062 mm^2 and 21889 mm^2 . Thus the forces exerted on them are:

For walls 1 and 3:

P=F/S [Mpa]

P=2 MPa

S=30062 mm^2

$\rightarrow$F = 60124 N

And **for walls 2 and 4**, following the same formula resulted F=43778 N

Using this input data, FEA analysis was performed for the device walls. From the whole report of interest are the unit stresses (Von MisesStress) and the deformations (Displacement).

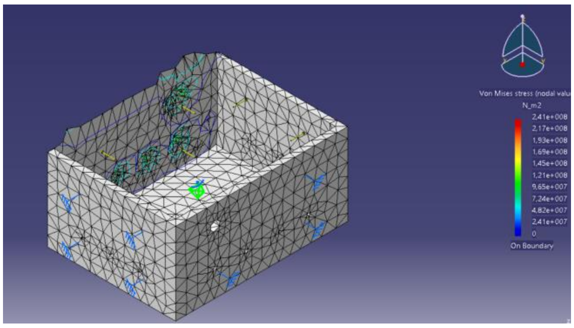


Fig.12 Unit efforts

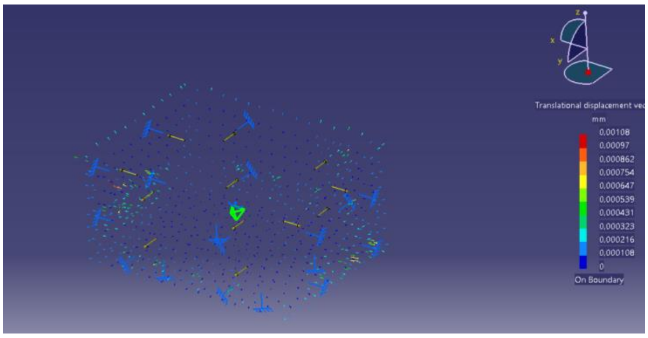


Fig.13 Deformations

The maximum breaking stresses occur in the upper area of the device and has values within the limits - 2.41e+08, and the deformations are 0.0011 mm .

7. Economic analysis of the product

What do we mean by economic analysis of a product?

Economic analysis is an extremely important step when it comes to the development and physical realisation of a product. This analysis can determine from the outset what the potential profitability is and what the potential costs will be.

By definition, analysis is a general method of researching a product and the phenomena that go to make it up, based on breaking them down into their component parts and studying each of them. It contributes to raising the level of knowledge from the particular to the general, from the concrete to the abstract [14].

Economic analysis involves a composition of phenomena that relate to production, distribution, goods and services. Thus, we can speak here of satisfying needs either through the consumption of goods and services from outside (for example, using the resources of other companies, persons or institutions in the form of purchases) or through the consumption of own goods and services. Own goods and services also include the time allocated by each team member, intellectual property, and the location or environment in which the work is carried out.

A product goes through a continuous process called the product life cycle. Thus, from the moment of conception to the moment of disposal, the product goes through a series of stages called launch, development, maturity and decline (Figure 14).

Fig. 14. Life cycle phases of a product

In engineering, when we talk about cost, it can be divided into several categories, being ultimately made from a division of several elements, such as the cost of raw material, materials to be used, the cost of semi-manufacturing, machining and finishing, the cost of each branch working on the production of a product (sections, departments), also known as the cost of labour, the cost of employees (CAS, taxes, salaries, bonuses, leave, compensation, etc.).) or unforeseen costs (defective items, production errors, accidents)[15].

In the framework of the project, we carried out an economic analysis based, initially, on direct costs. thus, we analysed the components that will take part in the realisation of the proposed concept, and later on, a more detailed economic analysis will be carried out, which will also include costs related to personnel, auxiliary materials, semi-manufacturing or labour.

Thus, in the table below we can find a list of products and items to be purchased for the realisation of the product under development.

Table 1.Table of initial estimated costs

Crt.	Name	Quantity	Technical features	Date of purchase	Estimated cost
1	Mass of the device	1	Dimensions : 300x200x100 Material: Steel	14.04.2023	1800 RON
2	Device table clamp	2	Dimensions : 50x25x35 Material: Steel		88 RON
3	Hexagon socket screws	38	Diameter: M8x10 Group: 8.8, 10.9 Material: steel, stainless steel Coating: Burnished, Galvanized, White		54 RON
4	Plexiglas panel	5	Dimensions : (L x W)(mm) 100x67x5 cm		1245 RON
5	Pressure gauge	2	Measuring range: 0.5-7.5 bar Length x width x height : 100x30x160 mm		44 RON
6	Tap	2	Inlet diameter : 0.75 inch Output diameter: 0.5 inch Maximum working pressure : 10 bar		166 RON
7	Guide wedge	4	Dimensions : 10x20x10 Material: Steel		160 RON
8	Forks	4	Dimensions : height 47mm, length x width : 47mm Colour: white		50 RON
9	Gasket	1	Length: 1000,00mm Net width: 6,50mm Height: 10,00mm Net mass: 0.07kg		50 RON
10	Part fixing plate	1	Dimensions: 50x50x5 Material: steel		360 RON

11	Blocking element	4	Dimensions: 20x20x20 Material: steel		240 RON
12	Cock	1	Ө20x80		400 RON
13	Electrolyte liquid	1	Composition UNI805: Phosphoric Acid + Additives DOES NOT CONTAIN: toxic substances such as Hydrofluoric Acid and Azotic Acid Container: 1 litre		211 RON
	TOTAL				4868 RON

8. Conclusions

This paper deals with the state of the art of electrochemical polishing. The main details of the polishing process are the dimensioning of the electrode-shell, the choice of the type of counter-pressure chamber, the choice of the type of flow of the electrolytic liquid, the type of surface to be polished and the establishment of a type of process that will improve the quality of future polished surfaces. The aim is to rebuild a modular electrochemical polishing equipment in order to obtain the highest quality surfaces with the lowest roughness in the shortest time. Thus, the present work will provide information about the process and the existing equipment on the market with the help of patents, to be developed in the dissertation. Finally a concept proposal for the future equipment will be presented.

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RESEARCH REGARDING THE DESIGN AND DEVELOPMENT OF A LINE FOLLOWER ROBOT IN THE MEDICAL INDUSTY

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ABSTRACT: The aim of this paper is to research the possibility of designing and developing an automated method for the transportation tasks performed inside a hospital. The proposed solution is a line follower robot that can track a black line drawn on a white surface. This paper is composed of two main parts. The initial section of the paper describes the advancements achieved concerning the product's mechanical component, detailing the design process of these parts and the utilization of 3D printing technology for their production. The second part of the paper delves into the creation and evaluation of an experimental model for the electrical aspect of the circuit. It elucidates the assembly procedure for the electrical components and delineates the operational principle of the robot.

KEY WORDS: line follower robot, medical industry, transportation

1. Introduction

This paper focuses on the impact that the evolution of robotics had on the medical field because of the high importance that medicine has in our lives. Although there are complex robots that are already used by medics and surgeons, the current paper analyzes the possibility to implement a cheaper technology to help especially the nurses in the hospital: a solution for the transportation tasks performed inside a hospital (such as transporting food and medicine). Considering this as the main objective, the proposed solution entails the design and development of a line follower robot.

A line follower robot is an automated guided vehicle, a programmable mobile vehicle that can follow a line drawn on a surface. It can be a black line on a white surface or a white line on a black surface – the main idea is to be a high contrast. This type of robot can also use an invisible magnetic line [1]. The robot follows the pre-defined lane by using a feedback mechanism [2].

This type of robot is useful for transportation tasks, especially for transporting heavy weights from one certain point to another. The line follower robot has multiple applications, in areas such as industry – replacing conveyer belts, automobile – the robot can be used as an automatic car, domestic – for example floor cleaning or guidance – in public places such as museums or malls [3].

By using this type of robot for transportation tasks, the medical personnel can better focus on the urgent needs of the patients and on providing better healthcare for them. Also, due to the pandemic situation, the medical department faced a lot of changes and difficulties. By using robots, human interactions will be limited, so there will be less chance of spreading the virus from an infected patient to a member of the hospital staff.

Keeping this in mind, the next part of this paper will be centered on describing the progress that was made regarding designing and developing the solution proposed.

2. Current stage

Other studies have considered introducing line follower robots in the medical sector. For example, one research [4] analyzed the possibility of transferring the patients from the ambulance to the hospital room by using a line follower robot. This concept represents a solution for the need to limit the human interactions in the pandemic scenario and to properly manage the high number of incoming patients considering the reduced number of medical personnel. The prototype uses an Arduino board, DK Electronics, a Bluetooth chip and IR sensors and Arduino language was used to write the code. One of the problems of the prototype was that it didn't stop if there were obstacles on the path. The authors decided to program the robot in a way that allows them to stop its automatic movement and move it manually if there is any obstacle on the path.

Another study [5] states that there are a high number of patients who die because of the low number of trained medical personnel. That's why the authors suggest designing and manufacturing a line follower robot for a better health care management system. This robot has the following components: a LDR sensor for sensing the path, an IR proximity sensor to stop the robot in case any obstacles appear on the path, a comparator, a motor driver, actuator, and a microcontroller. The main advantages offered by this solution are lower medical costs for the patients, less work for the reduced number of nurses and better monitoring of the patients.

3. Development of the prototype

3.1. The mechanical component

The hardware part of the product has two main functions, first to be able to sustain and transport the supplies and second to support the electrical components of the assembly. To create the mechanical subassembly, the components presented in Table 1 were designed. These will be manufactured by using additive manufacturing technologies.

Table 1. Components of the assembly

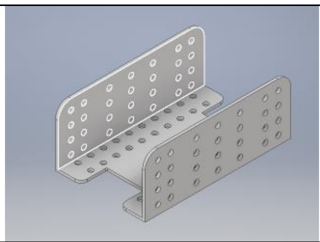
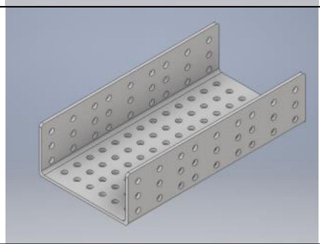
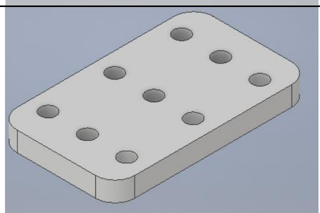
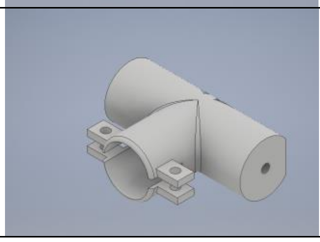
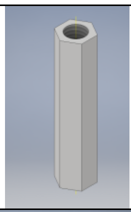
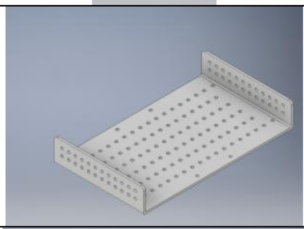
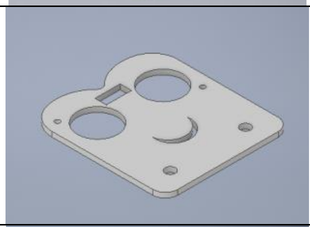
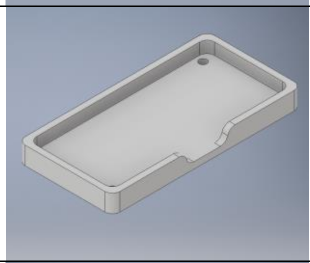
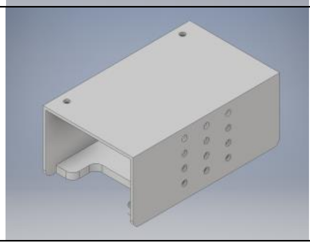
Number	Name of the component	Image of the component	Quantity in the assembly	Material
1	Case 1		1	Z-hips material
2	Case 2		1	Z-hips material
3	Spacer		2	Z-hips material
4	Motor support		2	Z-hips material

Table 1. Components of the assembly (continuation)

Number	Name of the component	Image of the component	Quantity in the assembly	Material
5	Pin		8	Z-hips material
6	Upper part		1	Z-hips material
7	Distance sensor support - front		1	Z-hips material
8	Distance sensor support – back		1	Z-hips material
9	Wheel support		1	Z-hips material

The final 3D design is presented in fig. 1.

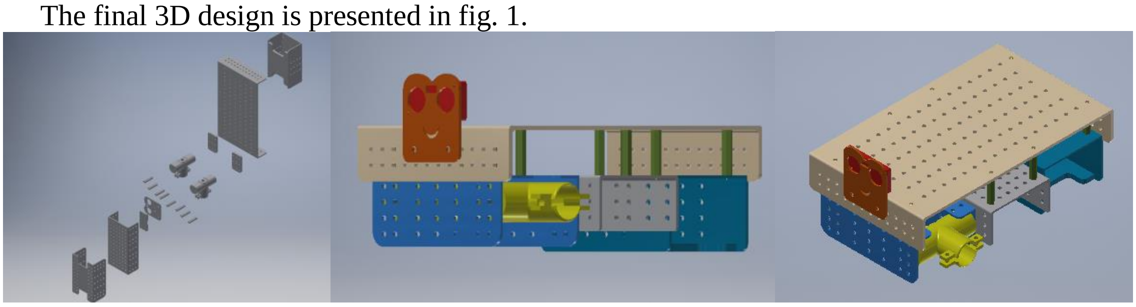


Fig. 1. Mechanical components of the robot

At this stage, the assembly contains only the parts that will be manufactured by 3D printing. To fix the parts, screws and nuts (M4) will be used. Those were not included in this stage of the 3D design.

To manufacture the parts Fused Deposition Modelling (FDM) technology was used. The machine used is Zortrax M300+ [10]. Some of the components required support structures to be printed correctly while others could be printed without those structures. Considering this, the parts were grouped into two printers and the parameters were set accordingly (fig. 2 A, fig.2 B.).

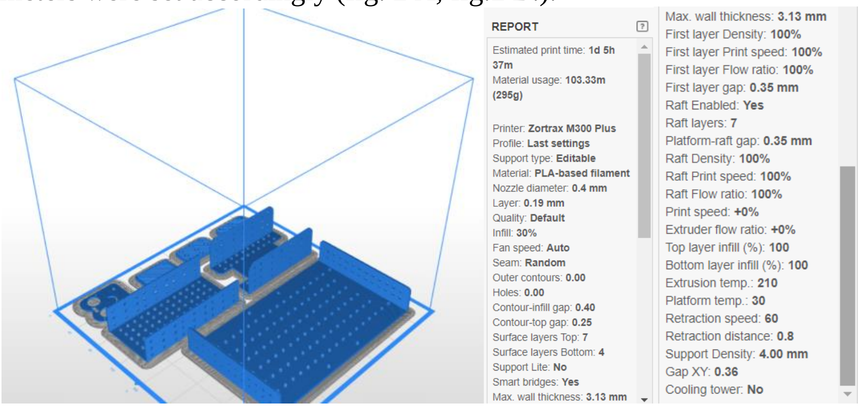


Fig. 2. A. First printer – without support structures

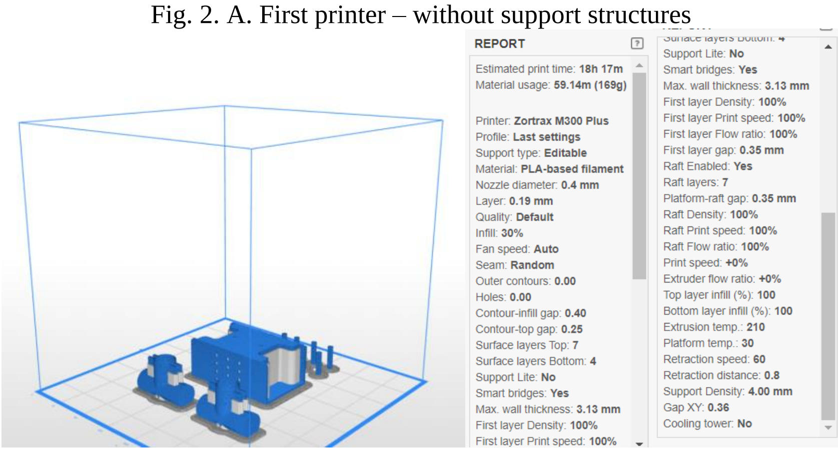


Fig. 2. B. Second printer – with support structures

The results of the printing simulation regarding the printing time, the material used, and the cost of the material are presented in Table 2.

Table 2. Results of the printing simulation

	First printer	Second printer
Estimated print time	29 hours 37 minutes	18 hours 17 minutes
Material usage	295 g / 37 m	169 g / 59.14 m
Material cost	21 euro (105 lei)	12 euro (60 lei)

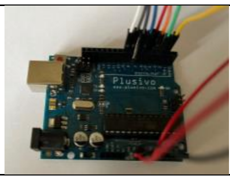
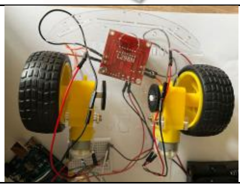
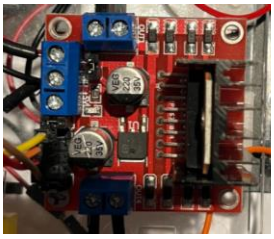
The 3D printed parts are presented in Figure 3.


Fig. 3. 3D printed components

3.2. The electrical component

The list of the components used to manufacture the experimental model described in Table 3.

Table 3. Description of the electrical components

Index	Name of the component	Image of the component	Number of components used in the circuit	Description of the components and its connections
1	Arduino board		1	This is a microcontroller board [7]. The rest of the components will be connected to its digital/ analogic pins.
2	Breadboard		1	A breadboard was used so that all the connections could be made. A mini version was chosen so that all the components can fit on the chassis.
3	DC motor		2	Each DC motor has two pins that will be connected to the motor driver's outputs [11].
4	Motor driver L298N		1	This motor driver has 4 outputs, to which the two motors will be connected. Also, it has 4 input pins that will be connected to digital pins of the Arduino board. Besides that, to control the speed of the motors, the two enable pins were connected to PMW pins of the Arduino board. Additionally, the motor driver needs to be connected to GND and to power supply [11].
5	Ultrasonic sensor HC-SR04		1	The ultrasonic sensor has four pins – one pin that must be connected to 5V, one trig pin, one echo pin and one pin that must be connected to GND. The trig and echo pins are connected to digital pins of the Arduino board [7].
6	Infra-Red (IR) sensor		2	The IR sensor has 3 pins – one is connected to GND, one is connected to 5V, and the third one is connected to a digital pin of the Arduino board [12].
7	Battery		4	Four batteries of 1.5V each were used to ensure the power supply for the two motors. The battery support is connected to the motor driver.

After establishing all the components that must be used, a connection diagram was created (Figure 4).

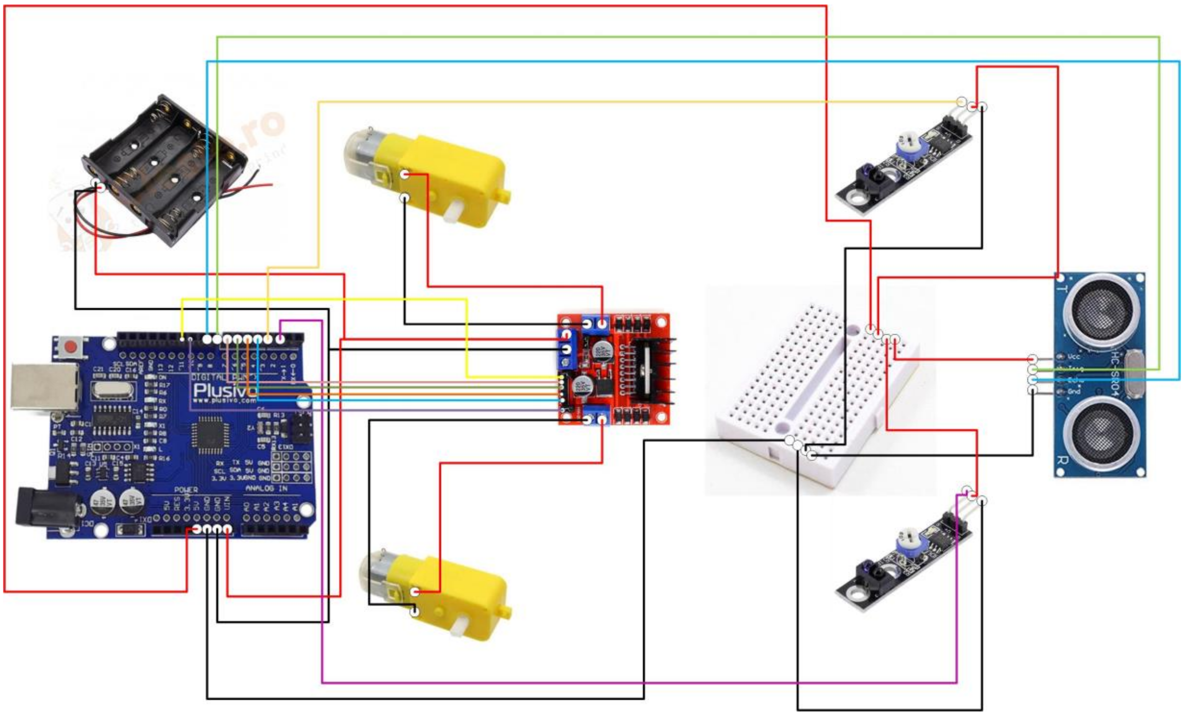


Fig. 4. Connection diagram of the electrical components

The robot will work by the following working principle: the IR sensors are assembled on the chassis so that they can detect the black line. Depending on the values received from the IR sensors, the motors rotate or stop. The ultrasonic sensor is used to detect the possible obstacles that might appear on the line. If there is any obstacle closer than 20 cm, the line follower will stop.

To test the code, the experimental model presented in figure 5 was developed.

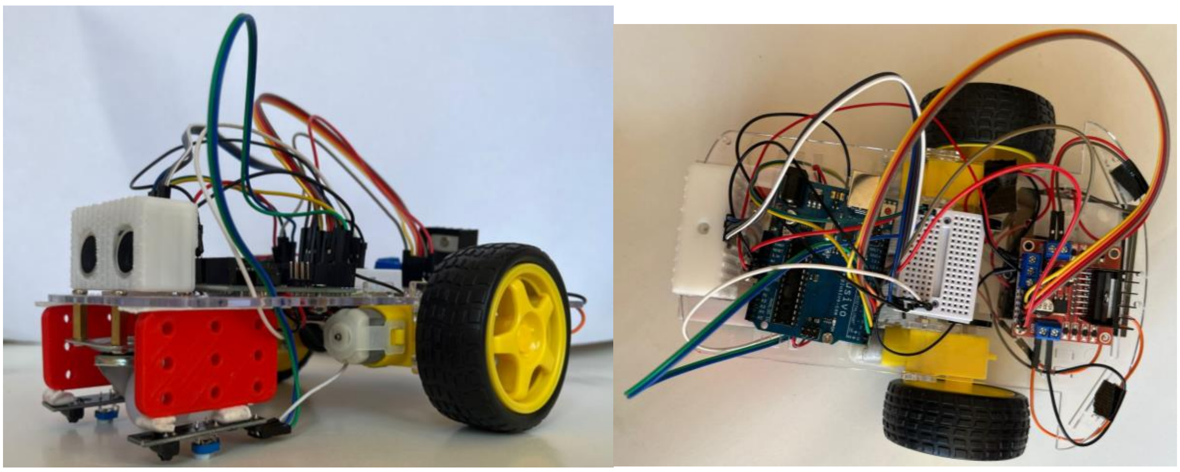


Fig. 5. Experimental model

This is an experimental model designed just for testing the prototype. This setup helped in better understanding the working mode and the correct placement of each component on the chassis. This might generate some design modifications on the mechanical component of the product.

The code used for the robot is composed of three main parts [9]:

1 – in this part of the code all the connection of all the components to the board's pins were declared. The connection diagram presented in Figure 4 was respected. The IR sensors are connected to digital pins 2 and 3. The trig pin of the ultrasonic sensor is connected to pin 8 while the echo pin is connected to pin 9. The two motors are connected to the motor driver, that is connected to the Arduino board. For the left motor, pins 4 and 5 were used and for the right motor pins 6 and 7 were used. The enablers of the motor driver are connected to pins 10 and 11. Besides that, two constants were also declared: “duration” and “distance”, used to store values received from the ultrasonic sensor.

2 – in this part of the code the data type of each component was declared. The IR sensors and the echo pin of the ultrasonic sensor are inputs, while the motors and the trig pin of the ultrasonic sensor are outputs. The input components read information and send it to the controlling board. It processes it and, depending on the information received, it sends certain “instructions” to the output components.

3 – first, the ultrasonic sensor was initialized. Its echo pin is an emitter. It sends an ultrasonic pulse and if there is any obstacle it reflects to the sensor, to the receiver trig pin. The travel time must be calculated to determine the distance to the obstacle. After that, the value read by each IR sensor must be known. To do that, the “digitalRead” function was used [9]. The speed of the motors was set by using “analogWrite” function [9]. The two enable pins of the H bridge were connected to PMW (Pulse Width Modulation) pins of the Arduino board. Those type of pins allow us to adjust the average value of the voltage that is reaching the motors. In the next part of this section, the “if” function was used to control the DC motors depending on the information received from the IR and ultrasonic sensors. The working conditions are summarized in Figure 6.

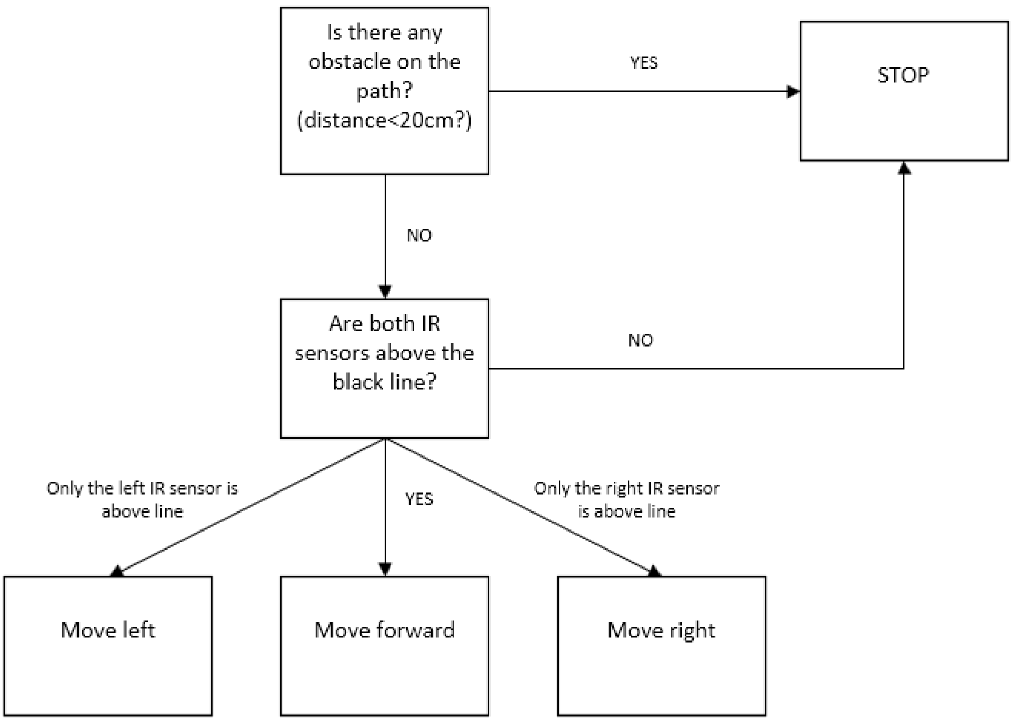


Fig. 6. The working conditions of the robot

To control the spinning directions of the motors the HIGH or LOW logic was applied, according to the information received from the IR sensors.

This logic is presented in Table 4.

Table 4. HIGH/LOW logic used to control spinning direction

Input 1	Input 2	Spinning Direction
Low	Low	Motor OFF (stop)
High	Low	Move forward
Low	High	Move backward
High	High	Motor OFF (stop)

4. Conclusion and future research directions

In conclusion, this research represents a first step in developing the solution proposed. The most notable improvements made are:

- Designing and manufacturing a first concept of the mechanical component of the product.
- Choosing the electrical components and creating a connection diagram and a working principle.
- Connecting all the components according to the connection diagram and writing the code according to the working principle of the robot.
- Testing the experimental model.

However, there are still aspects that need to be improved. Regarding this aspect, the future research directions that will be considered are:

- Adapting the code, so that the robot will be able to come back to the starting point of the path and to avoid the obstacles.
- Optimize the mechanical design of the robot so that all the components can properly fit on the chassis and create a special compartment for the medication that needs to be transported to the patient.

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MINI EDM SYSTEM WITH CONTACT BRAKING

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SUMMARY: The paper deals with the research, realization, and modeling of a portable EDM equipment with contact breaking that is used in the processing of materials using unconventional technologies. The stages of making the equipment are presented as well as all the components used, detailed in an execution drawing and 3D modeled. Comsol Multiphysics was used to model the coil and simulate its operation.

Key words: EDM, contact breaking, conceptual and detailed design.

1. Processing using EDM with contact breaks

Electric discharge processes are the most widespread nonconventional processes in the world. Contact-breaking electrical processing is a process widely used for cutting conductive materials using mainly a solid tool-electrodes. We are witnessing a continuous evolution in the use of new types of metallic materials and the growth of new modern technologies in fields such as aeronautics, automotive, car construction, etc., using so-called unconventional technologies in which materials processing is done by using and directing energy in various forms. [1], [2], [3]. Through this research, it is desired to transmit a special approach regarding the modeling of the technological parameters for the processing with electric discharges with contact brackets, using a transfer object formed by a copper electrode, using an installation formed by an electromagnetic coil, a capacitor that stores electricity and a direct current generator.

2. State of the art

The purpose of EDM is to cut the metal into small sparks. Its advantages are that it will drill holes in metals that cannot be machined by common tools. Cutting of hard steel alloys by electric discharge machining with contact break with electrode tools - metal strip - is one of the modern technological procedures for conventional processing of certain categories of steel alloys (hard and extra hard), in economic conditions of optimum efficiency . [4], [5], [6], [7]. We can highlight the existence of different values of the working parameters, determined by the workpiece. The tool, usually made of copper or graphite, and the workpiece are connected to the poles of a power source. The material of the part is removed by the action of vaporization of the electric discharges in the form of sparks that take place between the tool electrode and the part electrode. The tool usually has the shape of the negative cavity that needs to be processed into the piece, and this can take many very complex shapes. The mechanical part, the head, is simple and portable, but precise, made of copper. The very high current is concentrated in a small point on the workpiece and the metal melts. The molten metal in the workpiece immediately solidifies into the dielectric fluid. Fresh dielectric fluid is continuously pumped to remove metal particles that are separated there by a filter that allows the dielectric to be recycled.

Materials to process:

• Any material that conducts electric current, regardless of its hardness, can be machined by EDM.

• Used mainly for alloy and high-alloy steels, especially for machining die cavities.

• The melting temperature of the processed material and the latent heat of melting are important properties that determine the material removal rate (MRR), which gives the productivity of the process. [8], [9]

3. Identifying Market Opportunities

N1: Customer needs portfolio
N2: The need to process materials by unconventional processes
N3: The need to remove broken tools
N4: The need for small, portable and inexpensive equipment
N5: The need to process materials that have a high hardness.

3.1 Opportunities/ Products / Clients

a) Market opportunities:
For N1:
Need to be a small and portable equipment
For N2,N4:
Processing of materials with high hardness
For N3:
Low cost of processing materials

b) Customers for the sale of products:
-Research institutions;
-Micro-enterprises;
-Small and medium enterprises;
-Large enterprises.
-Individuals
-Repair workshops

3.2 Competitive products

There are already competing products on the market at very affordable prices and with an average accuracy, but our product will tend to be one of very high accuracy, being able to be directed electronically and with multiple working heads, which competing products do not offer. working electrodes in several variants.

Fig 1 Competitor product

4. Conceptual design

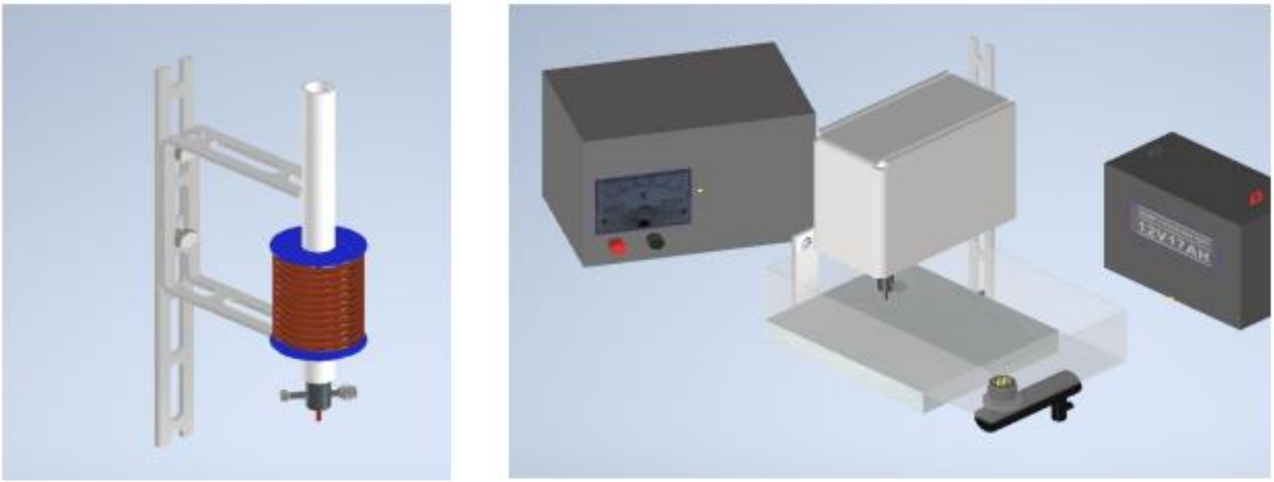


Fig. 2. 3D Modeling of working head and assembly with current generator and supplying battery 12V

The model of the work head and the support was made in Autodesk INVENTOR according to the real dimensions and the calculated data. In fig. 3 the execution drawing of the work head is made with the afferent dimensions and the notation of the components.

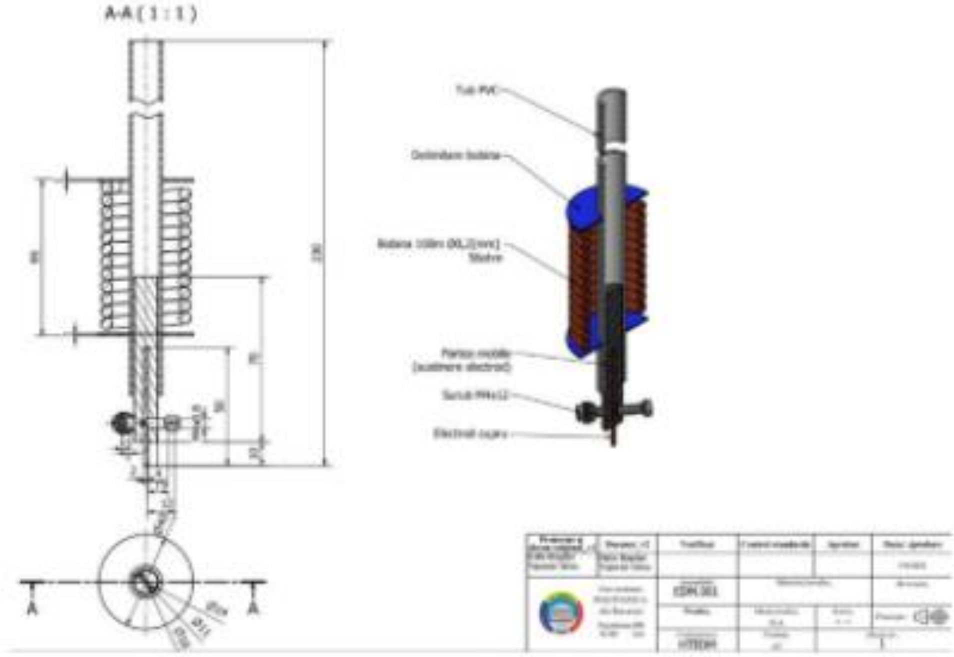


Fig 3 Design of the working head

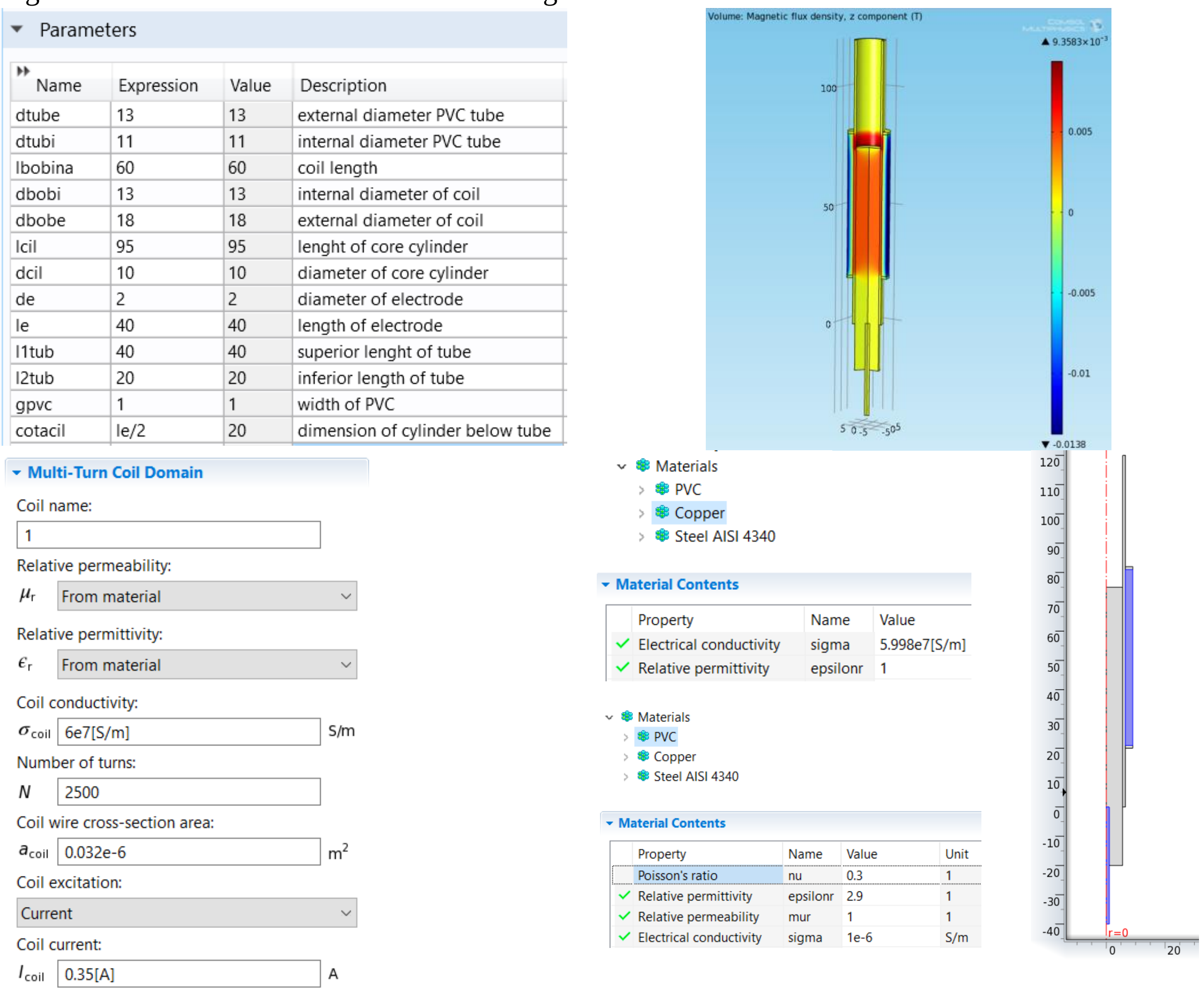
The project consists of several work heads that will be attached:

- circular shape of different diameters
- square shape of different sizes
- other shapes such as triangle, rhombus, ellipse

Fig. 4 Shapes of tool-electrode

5. Working head

Before making the coil, a numerical calculation was performed in the COMSOL Multiphysics program to determine the coil characteristics. fig. 5.



Parameters

Name	Expression	Value	Description
dtube	13	13	external diameter PVC tube
dtubi	11	11	internal diameter PVC tube
lbobina	60	60	coil length
dbobi	13	13	internal diameter of coil
dbobe	18	18	external diameter of coil
lcil	95	95	lenght of core cylinder
dcil	10	10	diameter of core cylinder
de	2	2	diameter of electrode
le	40	40	length of electrode
l1tub	40	40	superior lenght of tube
l2tub	20	20	inferior length of tube
gpvc	1	1	width of PVC
cotacil	le/2	20	dimension of cylinder below tube

Fig. 5 Characteristics of the working head

In Fig. 5 the parameters of the coil, of the PVC shaft, the details about the electrode and the copper wire from which the coil is made were introduced. Fig. 5 represents the force of the coil on the metal rod in which the copper electrode is attached, we can see the red surface where the highest magnetic force takes place. Respectively in Fig. 4 we have the conductivity of the wire, the number of windings, the cross-sectional area of the wire and the current passing through the coil: 0.35A. FIG. 5 represents the electrical characteristics of the coil.

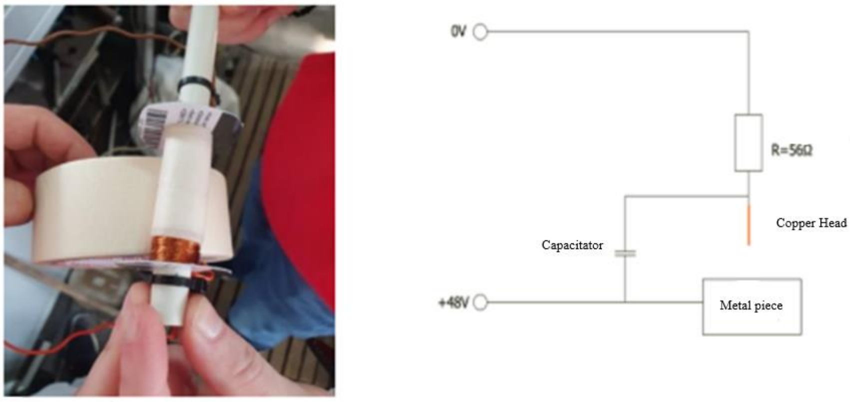


Fig. 5 Wiring diagram

Winding calculations were performed which led to the realization of the coil using the following formulas:

$$R = \rho \frac{l}{s} \quad [1]$$

- l= length of winding wire [m] l=100 m
- ρ= wire resistivity $[\Omega \frac{mm^2}{m}]$ $\rho(cooper) = 1{,}68 * 10{-}8\ [\Omega m] = 0{,}0168[\Omega\ mm2\ m]$ [2]
- S= Cross-sectinal area mm^2 S=0.03 mm^2
- Winding wire diameter: Db=0,02[mm]
-Length of winding wire: L=60[mm]

Coil resistance calculation:

$$R = 0{,}0168 \frac{100}{0.03} = 56[\Omega] \quad [3]$$

The wiring diagram contains a coil, a copper electrode, capacitor and circuit power supply. The circuit has a 48V supply, the negative pole enters through the coil, then passes through the capacitor, which is in the circuit with the electrode Following that the positive pole is connected to the workpiece and to the other end of the capacitor, thus storing electricity.

6. Market research and improvements

The purpose of market prospecting is clear and precise: to obtain information by which to identify the advantages that propel you into the niche in which you are going to introduce a new brand. Thus, through specific market research tools, methods are identified to improve your product's performance, increase sales and generate greater profit. Analyzing the competition, we made improvements to the equipment.

We found out that the weak points of our equipment are the plastic container in which the workpiece is located.

Fig. 6 Plastic container

For this aspect, a vessel of larger dimensions and made of thicker plastic was chosen. The main advantages being that we can process larger pieces. Another problem with the equipment could be overheating of the coil, which could lead to its burning. To prevent this problem, we could choose a pneumatic work head. Burning the coil would mean a repair cost of the equipment, which cannot be done by a simple user without improved knowledge.

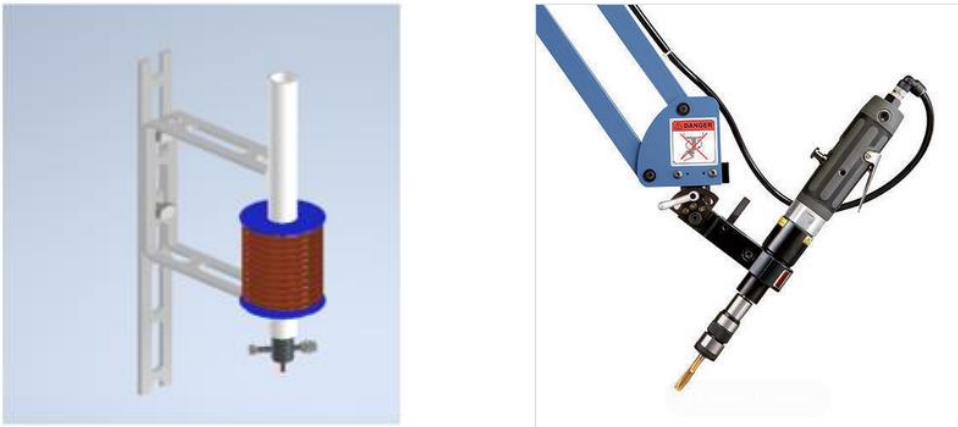


Fig. 7 Working heads

Analyzing the competition, we discovered an improvement in the body of the working head.

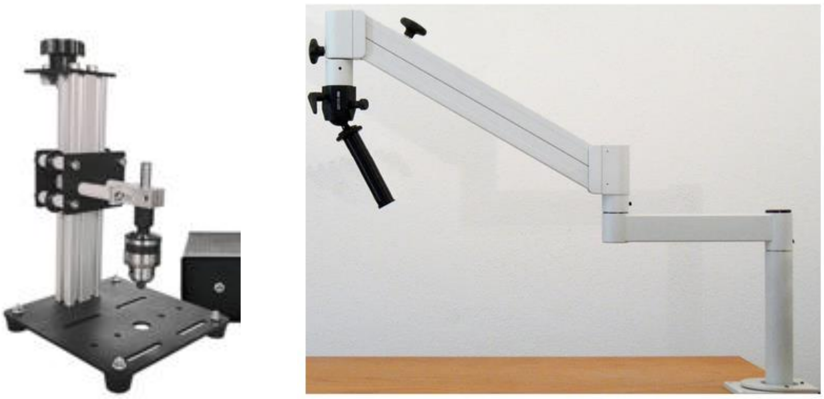


Fig. 8 The body of the working head

Disadvantages of the body :

- limited size
- poor quality materials
- Cannot mount the body
- No swivel range to rotate

The advantages of this body:

- Adjustable to the weight
- Easy disassembly
- Easy to transport
- The holder is mounted directly on table(screwed), optionally a table clamp is available
- Secure heigh lock in any position
- Swivel range: 360 grades

- Hinging arm lift: +/- 200mm
- Premium materials
- High standards of stability and flexibility

However, the new articulated arm leads to an increase in the manufacturing cost of the product.

7. The performance of competing products

The analysis of competing products is necessary first of all to be able to establish the minimum specifications of the product developed in this way, but also to see on which side the new product can excel. Secondly, the competing products represent an important reference for determining the evolution of the products and adapting some improvements to the old models. The objective specifications of the future product must be as close as possible to those of the competition. The comparison also serves to determine specification limits and establish a price that is attractive to both customers and the manufacturer. For electro-erosion processing devices assisted by ultrasounds, their spectrum of use and degree of interchangeability will be determined in this way.

From the market study, several types of EDM machines with different configurations could be identified:

The most distinctive aspect is that of the type of electrode used, namely
-EDM with filiform electrode
-EDM with non-profiled massive electrode
-EDM with massive profiled electrode

The degrees of universality determined are:
- Universal EDM
- Specialized EDM
-Specific EDM

Depending on the order type, they can be configured in the following ways:
- EDM with manual control
- EDM with numerical control
-EDM with adaptive control

From the perspectives of work axes
-EDM with machining on one axis
- EDM with processing on two axes
-EDM with three-axis machining

Electrode positioning allows:
-EDM for horizontal processing
-EDM for vertical processing
-EDM for machining in any position in space

8. Conclusion

The results of finite element modeling in the dedicated Comsol Multiphysics software allowed the sizing of the work head. Subsequent research will address the realization of a working head with an electromagnetic coil that allows to widen the range of regimes by increasing the current, corresponding to some roughing and semi-finishing processing as well as using different shapes of tool-electrodes.

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SHREDDER FOR PLASTIC WASTE RECYCLING PROCESS

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ABSTRACT: The idea of this paper was inspired by the Precious Plastic project developed within UPB. following documentation from several sources, I noticed what is the current state of recycling, both nationally and internationally, and the need to involve everyone in the recycling process. thus, we decided to focus on the development of a plastic shredder that can be integrated into a semi-industrial technological line with the aim of achieving several objectives, such as: eliminating the costs of transporting plastic waste, protecting the environment, broadening the area of knowledge for the people who will be involved in the recycling process, the development of new products needed by the faculty. the chopper assembly is composed of several sub-assemblies, and the ones made at the moment are: the chopping mechanism sub-assembly, the bearing-support sub-assembly, the welded frame sub-assembly, the gearing mechanism sub-assembly. the physical realization of the shredder is supported by the company Technobit Automatizări.

KEY WORDS: waste, shredder, recycling, plastic, new products.

1. Introduction

The mechanical recycling flow of the plastic shredder designed by us is a semi-industrial part and it brings to our attention the need for recycling at any level.

The purpose of manufacturing the equipment is to use it and to integrated in the recycling process, within the UPB - FIIR, according to the Precious Plastic project idea.

The technological flow developed within the mentioned project will cover all stages of recycling, from the collection of waste by category to their transformation into other products. The collection of waste within the university institution aims to change it into products needed by the faculty, such as: containers for storage, switches, filaments for 3D printers, test tubes for the Precious Plastic testing lab mechanics, advertising or decorative objects, etc. The design of the plastic shredder was made in 2 variants because we still do not have the entire technological line, which led us to redesign the shredder in a variant that can also be used alone (e.g), while ensuring the safety of the user.

Fig 1.1 PP

The collage from figure 1.2 shows variant 1, the plastic shredder integrated into a technological line composed of 3 equipment, the last one being assigned to the change, respectively the combination with two other process variants.

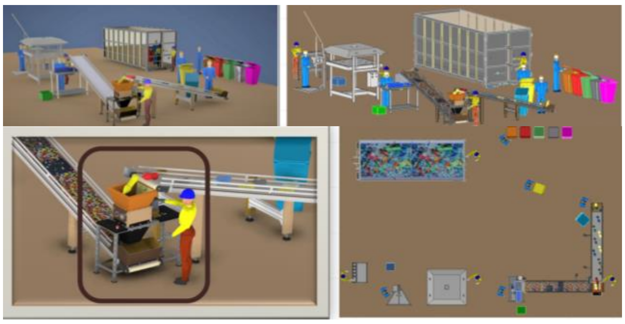

Fig. 1.2. Plastic shredder integrated into a technological line

The equipment used individually, according to the chosen function is in Fig. 1.3.

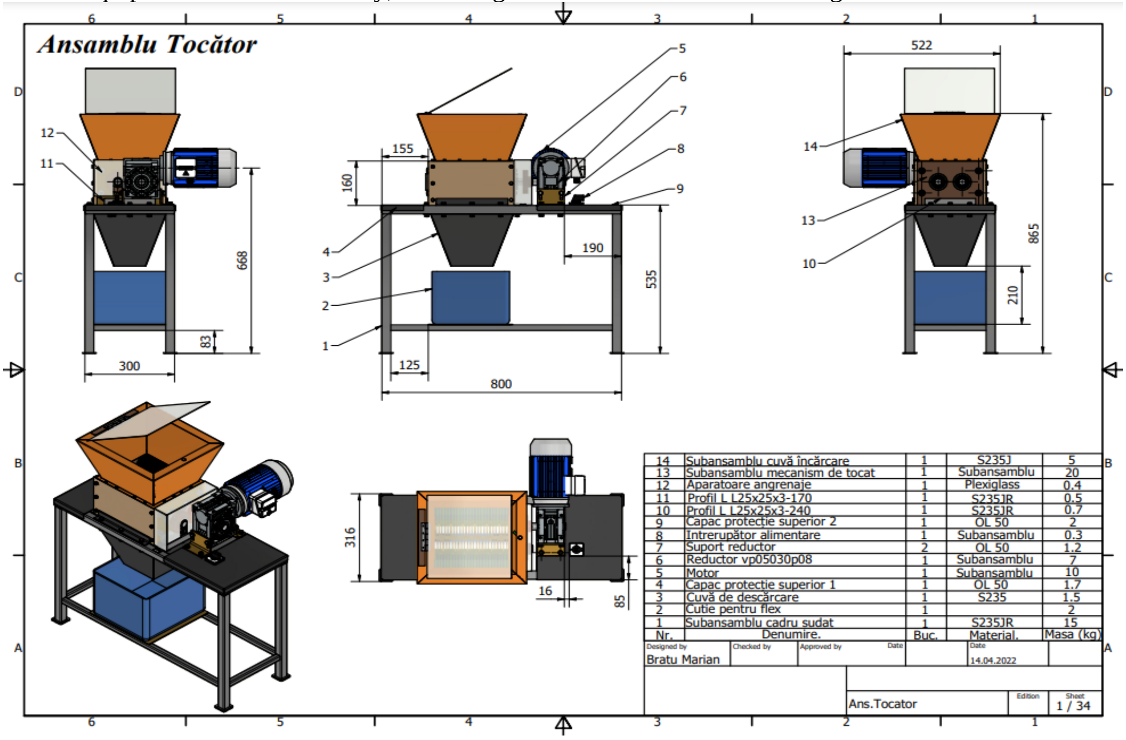

Fig. 1.3. Plastic shredder is used individually

The differences between the 2 plastic shredder models:

1. The tub positioned above the cutting mechanism will have a protective cover attached to protect the user. When the upper protective cover is raised, the sensor will stop the operation of the equipment, thus avoiding the possibility of inserting hands or sleeves.

2. A collection box will be placed in place of the flex conveyor belt. It has an integrated level sensor with a filling level monitoring function. If the filling level exceeds the minimum mark, the belt speed will be reduced and if it exceeds the maximum mark, the machine will stop.

2. State of the art

Shredding plastic waste is an essential aspect of recycling, and using a shredder that has this primary function is inevitable to ensure that the impact of plastic on the environment is minimized. The process of shredding plastic waste has several advantages, including reducing the size of the waste, improving the efficiency of the recycling process, reducing the amount of waste and creating a uniform material for recycling.

Shredders are available in different sizes and types depending on the amount and type of plastic waste to be processed. The equipment designed by our team has the ability to shred different types and sizes of plastic waste, taking into account the dimensions of the loading bin. Adapted accordingly according to the method of use and the purpose for which the currently developed product was designed, the necessary documentation for the production of the equipment was drawn up.

Thus, we determined exactly what the purpose of the project is, we identified the market opportunities and analyzed in detail the competing products, the potential customers and the current state of the chosen theme, thus managing to establish the final specifications and characteristics that the product will have. So, we managed to develop the conceptual design stage, carrying out external research to identify new constructive solutions, but also internal research, carrying out a systematic exploration, establishing the component functions and finally building the architecture of the finished product.

We are currently in the process of detailed design of the complete assembly. We completed the establishment of the component elements and their related manufacturing technologies, the establishment of the materials and treatments used in the manufacturing process, the definition of the elements related to the design of the product and its ergonomic conditions.

We have started the actual manufacturing of the product and we are going to finalize the established technologies for all the specific elements and then carry out the testing of the equipment. Next comes installation, commissioning and product documentation. This will contain how to use, safety measures and maintenance required for the shredder and will be made available to the customer at the time of purchase.

In the end, we will design the homologation technology, respectively that of use and sale of the assembly, this being already sketched, we will come back with small additions extracted after the complete realization and assembly. In addition, we will also perform a new, final economic analysis, performing a financial reassessment of the entire project and establishing exactly what the final costs were and what will be the price and profit obtained from the sale of the equipment. These steps being essential to the sales process.

3. The specific elements components and manufacturing technologies.

It is composed of several subassemblies, and the ones made at the moment are the following:

- *The chopping mechanism subassembly (Fig. 1.4.):*

Being a double-shaft chopper, two shafts were used, main and secondary, on which the knives are mounted progressively.

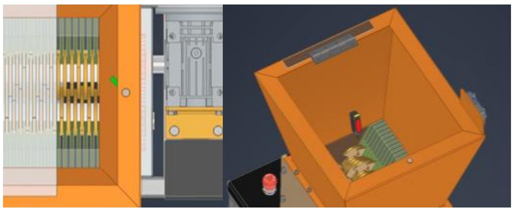

Fig. 1.4. The chopping mechanism – 3D model

The blank (Fig. 1.5. – right) used for the two shafts (Fig. 1.5. – left) is a 32 mm hexagonal bar, made of C45 material. The manufacturing technology used to make them is as follows:

a) The hexagonal bar is cut to the required length with a band saw, for metals, then it is turned at the ends, to the diameter D=25 mm, and the wedge channels are made by milling and the channels for the safety rings, on the diameter from outer end;

b) The turning of the ends was done on a parallel lathe, with a longitudinal turning knife;

c) The channels for the safety rings were made on a parallel lathe, with a cutting knife;

d) Milling of wedge channels was done on a FUS22 milling machine, with a D=8 mm finger mill.

Knives (Fig 1.6.) in 100 pieces, 50 positioned on the secondary shaft and 50 on the main one. They are made of S355 steel and are 5mm thick. The manufacturing technology being:

a) Laser cutting of the outer and inner contour;

b) Turning on both sides, 0.2 mm machining allowance (required for use of spacers).

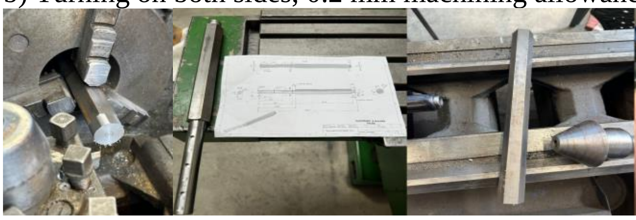

Fig. 1.5. Shaft for knives

Fig. 1.6. Knives

Fig. 1.7. The machining process of the shafts used for the radial arrangement of the blades

In Fig 1.9 you can find the threaded rods (4 pieces) made of steel. They have the role of gripping the front and side walls and maintaining their fixed position, without the risk of misalignment over time, especially in the context of the existence of vibrations and fairly significant movements such as the level. They are assembled two by two, on each wall, in the corners of the loading tub to give extra balance.In Fig 1.9 you can find the threaded rods (4 pieces) made of steel. They have the role of gripping the front and side walls and maintaining their fixed position, without the risk of misalignment over time, especially in the context of the existence of vibrations and fairly significant movements such as the level. They are assembled two by two, on each wall, in the corners of the loading tub to give extra balance.

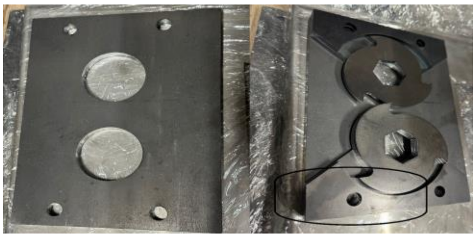

Fig. 1.8. Side and front walls

Fig. 1.9. Threaded rods

Fig. 1.10. Regulation-support

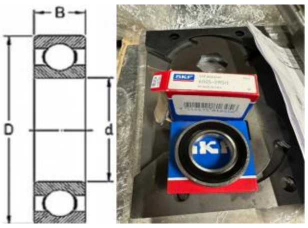

Fig. 1.11. Regulation

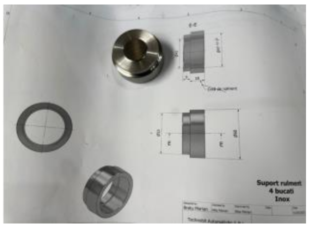

Fig. 1.12. Support

- The bearing-support subassembly (Fig. 1.10.) consists of 4 bearings, model SKF 6005-2Z, shown in Fig. 1.11. They are of the radial type with single row balls and have metal protection on both sides of the bearing. The supports used for the bearings (4 pieces), found in Fig. 1.12, are made on a parallel lathe, using a front turning knife. The material used for this landmark is stainless

Fig. 1.13. Trial assembly of the chopping mechanism subassembly

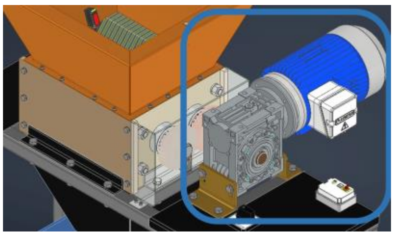

Fig. 1.14. Gearmotor 3D model

- *Motor-reducer subassembly (Fig. 1.14.):* The technical data of this subassembly, found in Fig. 1.15, the physical version is as follows: Motor-reducer size 50, transmission rate, i=30, tubular output shaft and motor: 220 V, 50 Hz, 1.1 Kw, 1500 rpm, small flange.

Fig. 1.15. Motor-reducer

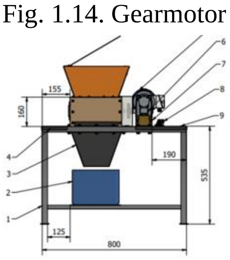

Fig. 1.16. Welded frame

- *The welded frame sub-assembly (Fig. 1.16.):* This has the dimensions indicated in the figure, namely: 535 x 800 mm. At the current stage, its component elements have been cut according to the instructions and are to be welded in the position indicated in the overall drawing. The semi-finished product is of the rectangular pipe type (Fig. 1.17.).

Fig. 1.17. Rectangular pipes

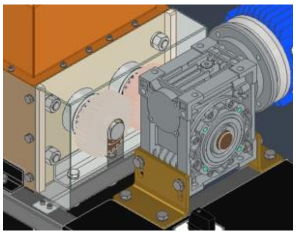

Fig. 1.18. Gearing

- *Sub-assembly of the gearing mechanism: (Fig. 1.18.)* positioned behind the Plexiglas guard and made up of two gears (Fig. 1.19.), cylindrical, with straight teeth, with a wedge channel inside (made on the mortising machine) from material C45 with the following relevant characteristics: m=2.5 mm and z=32 teeth.

Fig. 1.19. Gear

4. The operating mode of the developed product

To start the process of shredding plastic waste it is necessary to integrate it into a complete recycling process. Thus, when the waste reaches the loading tank of the shredder, it is initially collected separately according to the type of waste and sorted according to the identification code of the plastic (the 7 categories). Afterwards, it is necessary to prepare the waste, which consists of cleaning, drying, separation into elements if they are made of different materials (in most cases the label). Once the waste is in the vat, the shredding process can begin. Radial arrangement of blades on 6-sided milled shafts to provide continuous, simultaneous movement through repositioning frequency. This mounting method streamlines the time the waste is trapped between the blades.

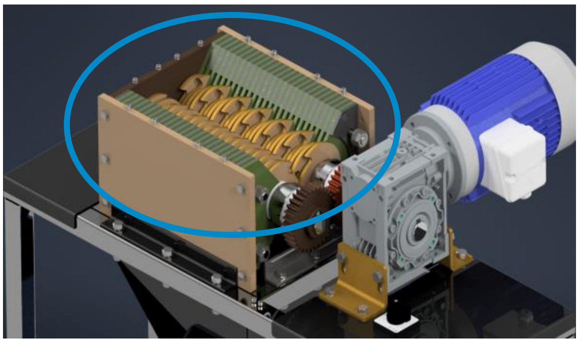

Fig. 1.20 the blades of the cutting mechanism

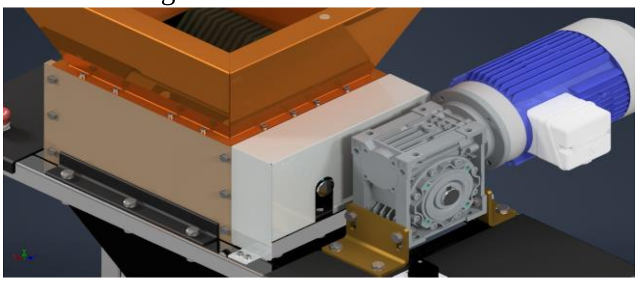

Fig. 1.21. Gear mechanism protective cover

For the safety of users, multiple precautions have been taken to avoid possible ways of injury. Thus, in order to avoid the introduction of hands or clothes when the gearing mechanism is working, but also to prevent premature wear of the gears, the use of a protective cover, made of Plexiglas, was implemented, as can be seen in Fig. 1.21..

Also, for emergency protection, a mushroom-type safety button (Fig.1.22.) is used, with an immediate stop function in case of necessity. It is placed within easy reach of the user, on the work table.

In addition, there are multiple sensors that we are considering for introduction within the chopping assembly, such as the one for disconnecting the electric current, positioned on the loading tank, with the role of stopping the operation of the equipment, to prevent the introduction of hands or clothes into the chopping mechanism, but also the use of level sensors, with the function of determining the degree of filling.

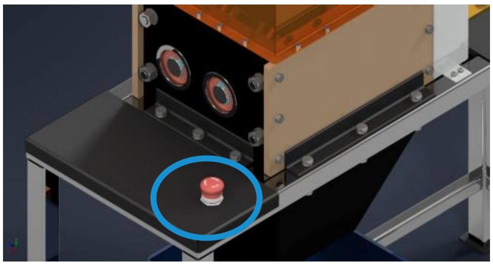

Fig. 1.22. Safety button

The on/off button contributes effectively to reducing time and energy consumption. It is also positioned on the work table, for easy operation, being in the immediate vicinity of the user operating the function at the time. This is a switch type button, being very intuitive and easy to handle.

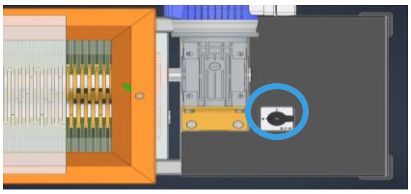

Fig.1.23. Buton pornire/oprire

The following usage scenario (mode of operation) for the equipment was drawn up.

a) As a first step in the recycling process within the project, containers are placed (fig. 1.24. and 1.25.) in which students/teachers/other people involved can throw different types of waste separately. Anyone can be an integral part of the process, even if they participate to a minimal extent. This fact can convey to others who are around that person that there is an opportunity to contribute effectively.

Fig.1.24. Selective containers [1]

Fig.1.25. Containers located in the recycling section

b) Following is a sorting of the plastic categories carried out by the parties directly involved in the Precious Plastic project. Fig. 1.26 and 1.27. presents the categories of plastic but also some examples of products made from each category. Their purpose is to make it easier to select plastic by category.

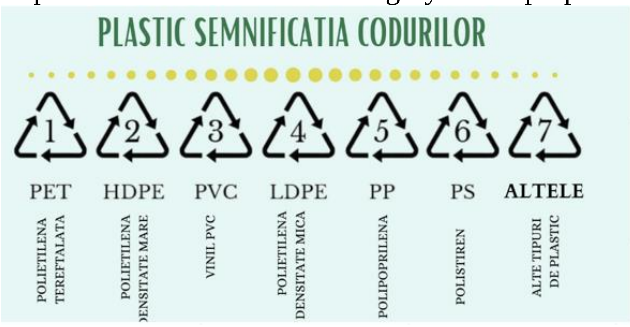

Fig. 1.26 Plastic categories and associated codes [2]

Fig.1.27 Examples produced - different types of plastic [2]

c) The sorted plastic will be taken to the place where recycling is carried out. The first equipment will be mechanically loaded with the prepared plastic. This equipment will wash and dry the waste.

The initial preparation process, which consists of sorting, washing, drying and separation (for waste consisting of several types of plastic, e.g. label, cap, etc.), can be done entirely by hand or as a combined process (so as shown in Fig. 1.28 – 2 views), both manual and automated, depending on the available resources that are cost-effective to allocate to the process.

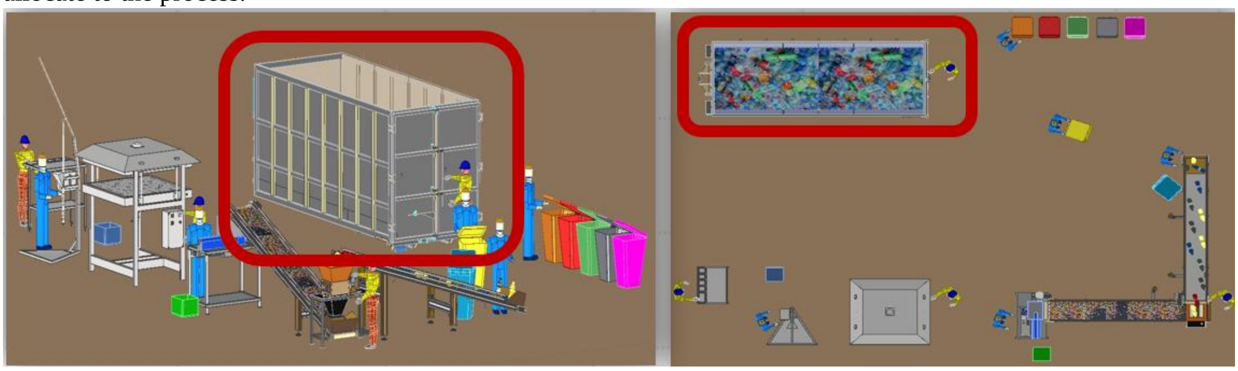

Fig. 1.28 Waste washing and drying equipment

d) The second equipment, is the one developed by our team, namely the chopper.

e) The sheet press (models of sheet presses are shown in fig. 1.29) works by introducing the flex, which will be pressed between two plates, at a high temperature. The result obtained are rectangular plastic sheets, the size of plates. The press can take any type of flakes (small, medium, large), but it is recommended to use the large ones, because the time for shredding is reduced.

Fig. 1.29 Sheet press [3]

f) The injection machine (examples of injection machines in Fig. 1.30) has fast and high-precision production, but it takes a little more effort at the beginning to design and make a mold. The medium shredded plastic enters the hopper and is heated and pressed through a long shaft into the mold

Fig. 1.30 Injection machine [3]

g) Extrusion is carried out with the help of an extruding machine (examples of extruding machines can be found in fig. 1.31) and is a continuous process in which the finely chopped plastic enters a hopper, heated and pressed with a screw through a long shaft, and the result obtained are pieces of plastic, cylindrical in shape. With this machine, filament can be created, the obtained material being wound on a spool.

Fig. 1.31 Extruding machine [3]

5. Conclusions

Considering both the sub-assemblies made up to now (the chopping mechanism sub-assembly, the bearing-support sub-assembly, the welded frame sub-assembly, the gearing mechanism sub-assembly) and those that are to be physically made we can say that the chopping machine we are developing it represents a complex piece of equipment, the manufacturing process being a detailed one.

We can also state that the aforementioned plastic shredder differs from other products on the market in several ways:

- It is a semi-industrial equipment that allows the recycling process to be carried out within companies, faculties, hospitals or other institutions that do not have recycling as their main field of work, but want to actively participate in this process;
- It eliminates the costs of transporting plastic waste to institutions specialized in the recycling process, it gives an advantage to the companies that opt for the purchase;
- Improves the area of knowledge for the people who will be involved in the recycling process, helping to raise a better awareness of the need for recycling and the negative effects that its lack brings, and implicitly it can become a powerful influential act, easily spread;
- Participates in the process of creating new products needed by each institution where recycling will be carried out, eliminating the costs necessary to purchase these products.

In conclusion, we can say that the shredder developed by our team is an indispensable machine for the recycling technological line, which participates in keeping a cleaner and less polluted environment, as we all want, and according to our research it can be a real success on market.

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7. Notations

The following symbols are used throughout the paper:

Fig. = the figure
UPB = Polytechnic University of Bucharest
FIIR = Faculty of Industrial Engineering and Robotics
mm = millimeters
d = diameter
i = transmission rate
v = volts
hz = hertz
kw = kilowatts
rot/min = revolutions/minute
m = module
z = number of teeth

ELECTRICAL DISCHARGE DEPOSITION EQUIPMENT

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SUMMARY: The electric discharge deposition process (EDD) is a new machining process for metal fabrication. In this process, the high level of wear of the tool electrode is used to obtain the deposition of the metallic material. The equipment was modeled in Autodesk Inventor Professional 2022, and the simulation process was simulated in Comsol Multiphysics 5.5. In this paper, the coil was modeled to simulate the variation of the magnetic flux and how it affects the trajectory by changing the intensity.

KEY WORDS: deposition, electrical discharge, equipment, simalation, trajectory

1. Introduction

The demand for micro-scale parts production has been increasing day by day. The deposition of thin layers on metals and semiconductors finds a great application in these fields. Electric discharge deposition (EDD) is one of the most important deposition techniques in the research community. The following are reported from the literature currently available.

The µ-EDD process is performed in normal atmosphere, and the tool electrode is connected to the positive terminal, where ions are emitted from its surface and have a path directed by the magnetic field to the surface of the part. Because the ion pulse is higher, they lead to the deposition of the tool's material on the surface of the workpiece [1].

During the discharge process, a voltage is applied between two electrodes (the tool and the workpiece). When the electrodes are very close to each other, under the action of Joule heating and the force of the electric field, the surface of the cathode will emit a mass of electrons. Under the force of the electric field, the electrons are accelerated, going to the anode. High-speed electrons collide with the average electrical particles bringing a large portion of electropositive particles. This collision occurs continuously during the discharge process, so the electrical particles will grow, forming a plasma channel [2].

Fig. 1 shows the electrical discharge deposition equipment designed in Catia software for the conceptual design chapter.

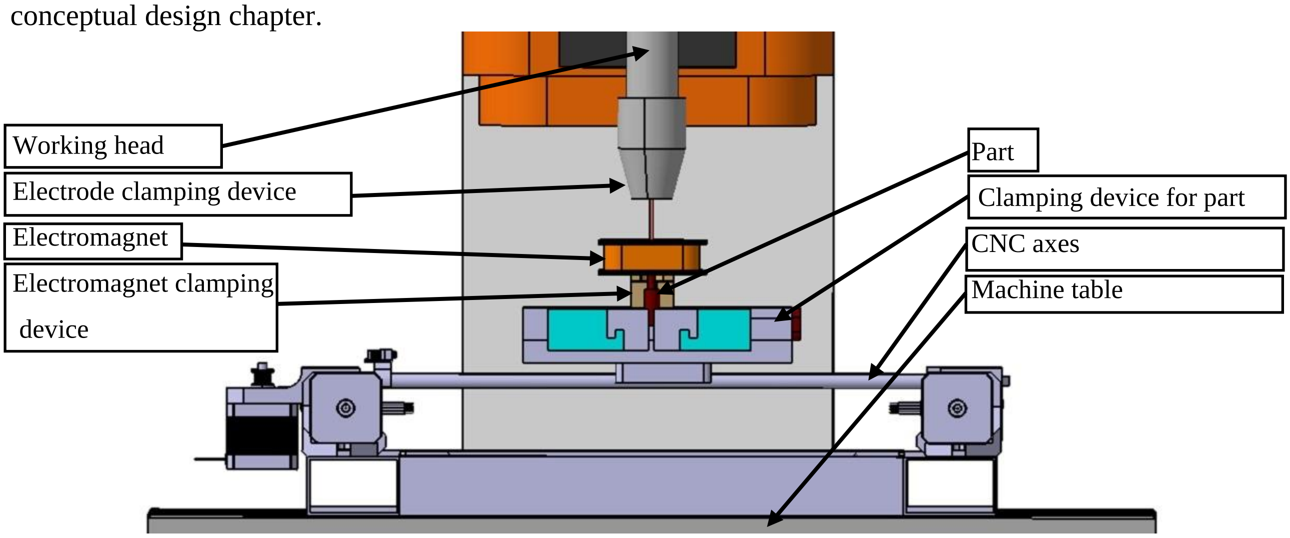

Fig. 1. Block diagram of electrical discharge deposition equipment

2. Conceptual design

2.1 General function and component functions

The general function of the EDD equipment, which is the subject of this paper, is to deposit material by electric discharge in the magnetic field.

The general function is subjected to an analysis process which will result in first the main functions and then the secondary ones. The main functions are properties of the product that determine the general function. Secondary functions result from the interaction between the main functions and are called internal interactions, and the interactions between the main functions and the environment are external interactions.

The functions of the EDD equipment are listed in Table 1.

Table 1. Functions of the EDD equipment

FG	***Layer deposition***
No.	*EDD Functions*
1	Attaching the tool electrode Secondary functions: chuck opening; electrode insertion; screwing in the chuck key to tighten the electrode.
2	Workpiece holding Secondary functions: vise opening; the introduction of the piece; screwing in the chuck key to tighten the electrode
3	Providing an electromagnetic field: Secondary functions: power supply start; Supply of the subassembly of electromagnets with electricity from the source;
4	Ensuring the generation of magnetic flux; Secondary functions: pressing the buttons on the control panel, adjusting the voltage and current, in the drives, adjusting the current density on the surface; ensuring a direction of propagation.

Among the main functions established above, a list of critical functions has been compiled (Table 2), which determines the commercial success of the product. These critical functions correspond to the sizes and requirements with the maximum relative importance.

Table 2. List of critical functions

Function number	***The critical function of the product***
1	Ensuring ion flow generation
2	Providing an electromagnetic field
3	Attaching the tool electrode
4	Workpiece holding

2.2. Result concept

Diagrams of ideas and solutions were made, and four concepts were developed from them. An evaluation matrix was necessary to adopt the optimal concept, which is represented in figure 2.

Electric spark deposition machine that has a mechanical clamping device for the part, numerically controlled and the provision of an electromagnetic field actuated by a button, the adjustment of the tool to the height is done by preliminary test passes.

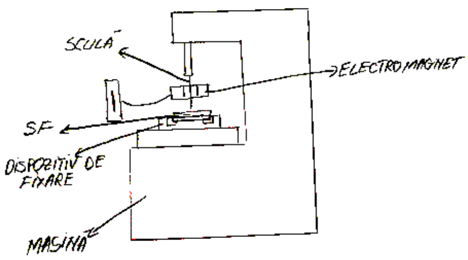

Fig. 2. Optimal solution

3. Prototype manufacturing

For the clamping of the tool electrode an elastic bushing is used, which is attached to the working head of the ELER electroerosion machine of the Unconventional Technologies Laboratory of the Faculty of Industrial Engineering and Robotics, Polytechnic University of Bucharest.

The figures below show the subassemblies of the developed EDD equipment:

Fig. 5. Framework

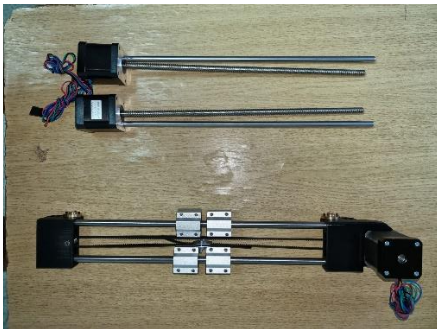

Fig.6. Axes, guide columns and stepper motors

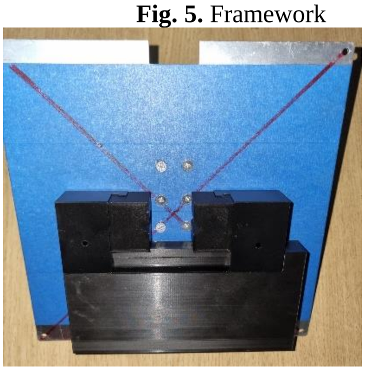

Fig.7. Part holding device

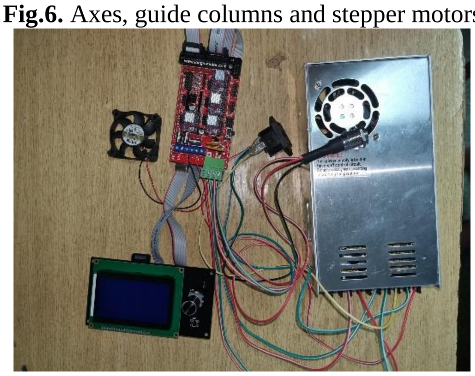

Fig.8. Electronic components

Fig.9. Coil

The product is clamped using a device (as shown in Fig. 10) placed on the machine table which can move on 2 numerically controlled axes with an accuracy of 0.1mm using the axes of a modified 3D printer, representative of Figure 11.

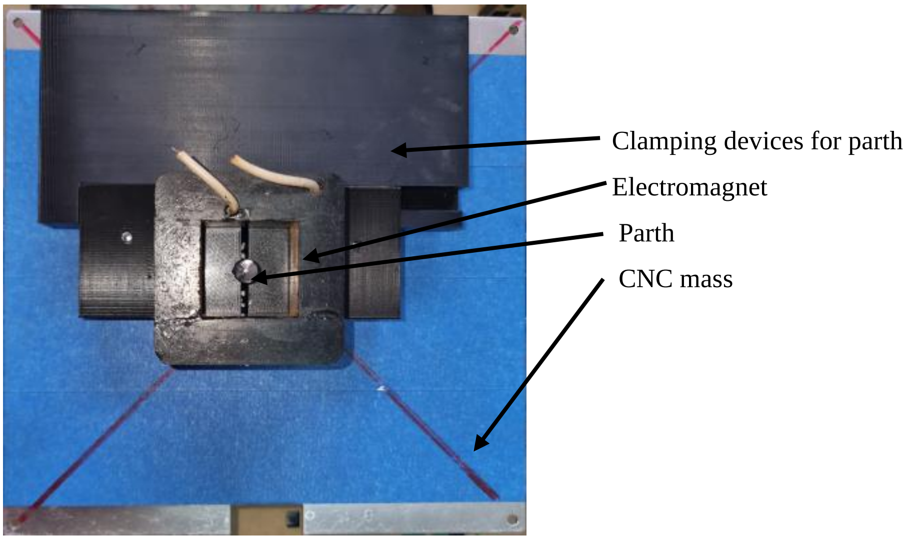

Fig. 10. Clamping devices for parth

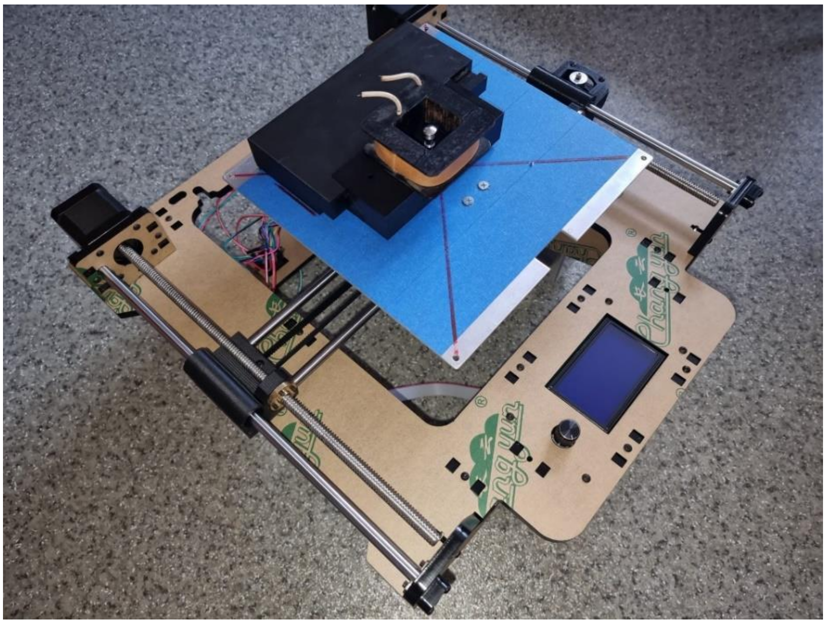

Fig. 11. CNC device

4. Modelling and simulation of the electrical discharge deposition process

Using the program Comsol Multiphysics 5.5, the magnetic flux created by the electromagnet and the particle path from the electrode were modeled and simulated, the results of these simulations are shown in Figs. 12, 13, and 14.

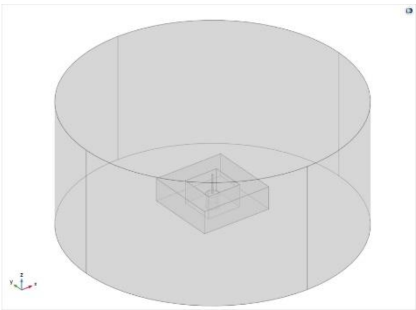

Fig. 12. Geometry of the working space

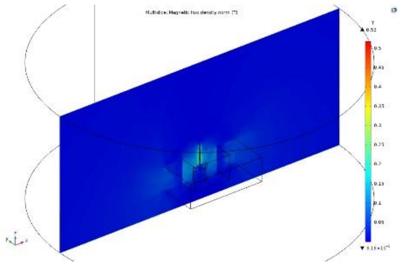

Fig. 13. Magnetic field simulation

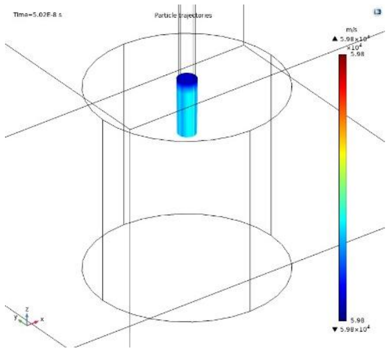

Fig. 14. Simulation of ion trajectories

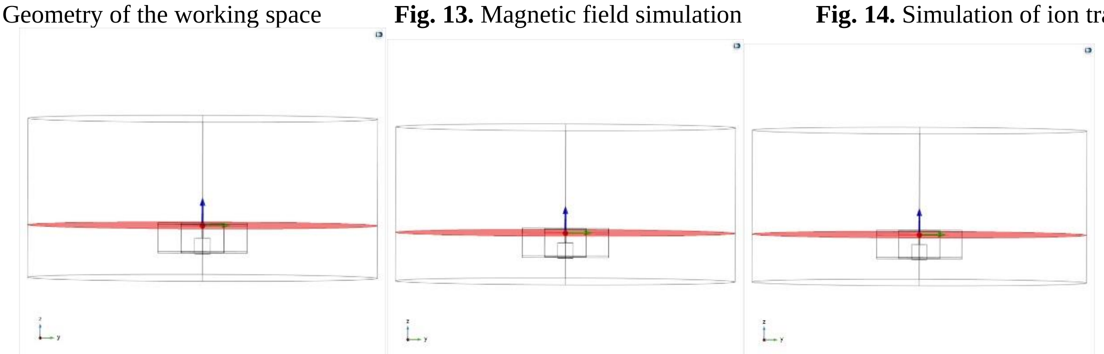

Fig. 15. Cutting planes at Z=3 mm; Z=2 mm; Z=0 mm;

In order to see the deviation of the beam trajectory, the planes in Figure 15 were used to highlight the beam position in red, black and blue respectively in the Poincaré graph, and the graph represents the trajectory of the ions from the electrode-shell above the electromagnetic coil, which is an unrealistic model because deposition by electrical discharge cannot be achieved.

Three simulations were analysed for three different materials, namely Wolfram, Aluminium and Nickel, and the difference in the visualisation of the particles in the three section planes can be seen in Fig. 16-18.

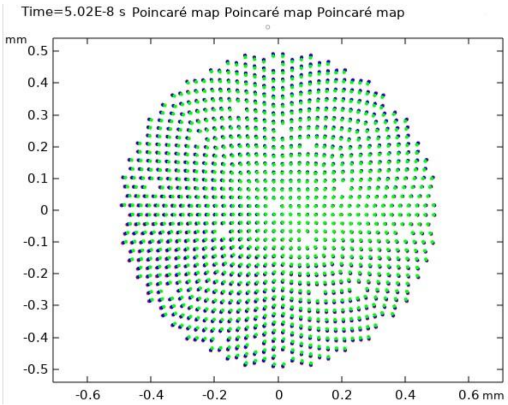

Fig. 16. Aluminium Poincaré Graph

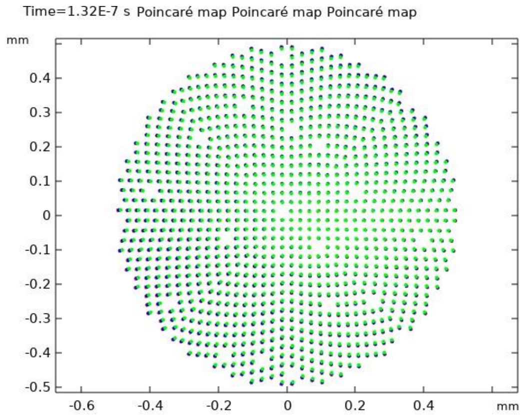

Fig. 17. Wolfram Poincaré Graph

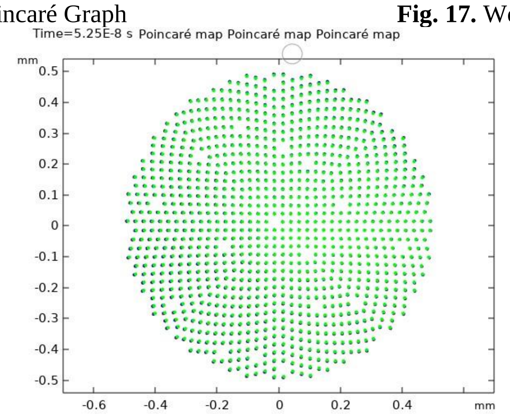

Fig. 18. Nickel Poincaré Chart

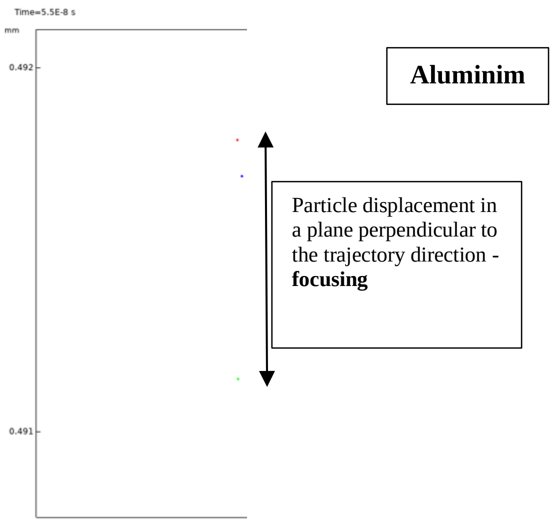

Fig. 19. Distribution in detail - focusing / defocusing of Al ions

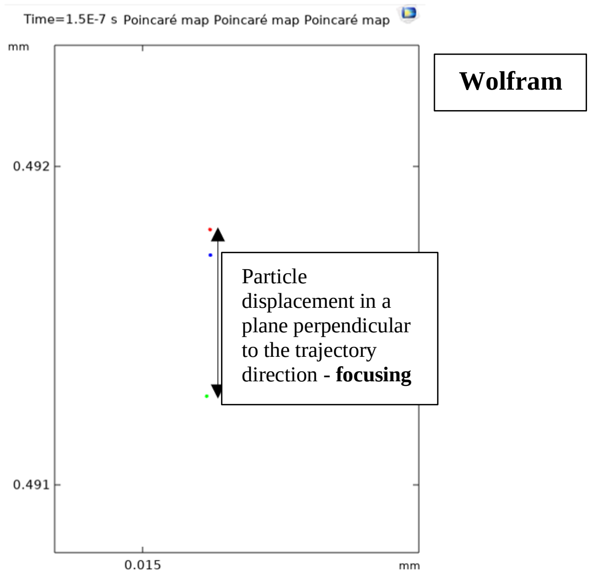

Fig. 20. Distribution in detail - focus/defocus of W ions

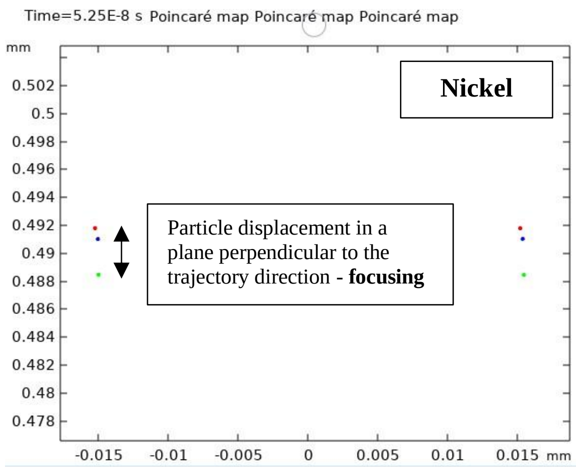

Fig. 21. Distribution in detail - focusing/defocusing of Ni ions

In Figures 19-21, it can be seen that for aluminium, tungsten and nickel ions the magnetic field focus is about 0.001 mm, the distance between the red and green points.

5. Conclusions

- The key factors influencing this electrical discharge machining process are current, duty cycle (deposition time) and pulse on time (pulse time).
- The multi-layer deposition process also shows the same trend as that followed by the single-layer deposition process.
- The deposition dimensions of the material are framed in a point (on a surface) with dimensions between 0.2 and 0.3mm.
- The deposition precision on a given trajectory is given by the precision with which the two axes can move, so the precision achieved by the equipment is 0.1mm.

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MODELING, SIMULATION AND REALIZATION OF A COLLABORATIVE ROBOT

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ABSTRACT: In this work we consider the creation of a collaborative arm capable of repeating series of movements continuously. The field of the robot is an industrial one,being designed to increase productivity and reduce the risk of operator injury. In the first stage, the optimal component elements of a Slave robot arm were designed, modeled and identified. In the second stage, the components were 3D printed and assembled, and then the robot was programmed to repeat the movements. In the last stage, economic studies were carried out to identify the optimal constructive variant to be sold, and endurance and functionality tests were carried out.

KEYWORDS: robot arm, learning, modeling, command.

1. Product description

The proposed objective is to create a collaborative robot commanded by a controller, capable of reproducing movements in continuous flow. To achieve the objective, in the first stage the kinematic elements were designed, 3D modeled and the resistance of the entire robot was checked. After the first attempt, the decision was made to take over a similar, but more resistant, model from the online environment. Successively, 3D printing and assembly of all components was carried out, and then we moved on to the electronics and programming part. After certain endurance tests, the optimal necessary components for the realization of the robot and the controller for an efficient commercialization were analyzed from an economic point of view.

In the first stage, the decision was made to make a controller and a robot arm. The controller will have the role of commanding the robot arm.

The stages of design and installation of the controller were the following:

1.The dimensions of the potentiometers were analyzed to identify the optimal shape and dimensions for the realization of the controller and a 3D model was made to establish the position of the components.

Fig. 1 3D modeled potentiometer

2. In the end, a simple, light, and maximally intuitive to command form was chosen. It was decided to incorporate the potentiometers that control the movement of the Slave arm into the

controller housing. An LCD display and a button have been installed inside the case, helping in counting and in identifying the robot's current operating mode. The button was installed to be able to reset the current counter.

Fig. 2 Controller

The stages of designing and modeling the robot arm were as follows:

a) a) Different engine models were analyzed to identify the optimal variant. After a detailed analysis, MG995 servomotors were chosen due to the following advantages:
- The angle of rotation of the motor is proportional to the number of pulses;
- Maximum torque is available when the engine is off;
- Excellent response when starting and stopping, and vice versa;
- The absence of a brush, the duration of operation depending on the duration of use of the bearings;
- The speed is proportional to the pulse frequency.

Fig. 3 MG995 Servomotor

b) The various components of the Slave arm were modeled, and after a functional analysis it was decided to take over a model from an online library due to its stability.

Fig. 4 3D rendered assembly of the Slave arm

c) The next stage was the 3D printing and assembly of the Slave arm components.

Fig. 5 Printed elements

Fig. 6-7 Assembly of the main elements

Fig. 8 Final assembly of the 3D components

c) The last stage is represented by connecting the cables, mounting the servomotors and connecting to the controller.

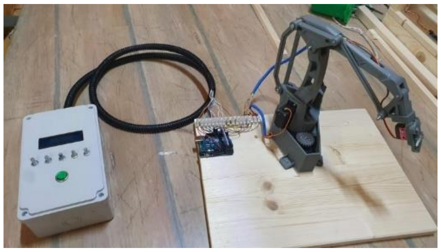


Fig. 9 Complete assembly

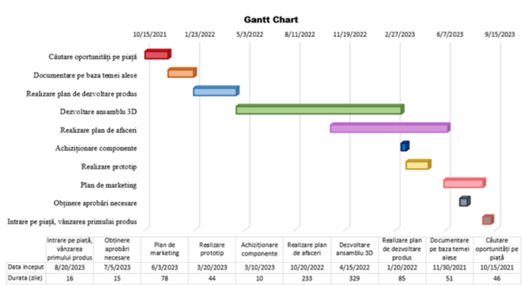
2. Market analysis, S.W.O.T

In order to achieve effective management and to develop a successful project, we prepared the SWOT analysis for the proposed product: collaborative robotic arm. This analysis will allow obtaining an overview of the positioning and the factors that influence the company's activities.

Table no. 1: SWOT Analysis for Collaborative Robotic Arm

"S"trengths:	**"O"pportunities**
1) The robot fulfills its role of easing the work of the staff 2) Made of durable materials at affordable prices 3) Easy to use device	1) Increased demand for collaborative robots in industry 2) Special robotics classes organized at schools/high schools/universities 3) Collaborations with educational institutions 4) Small companies at the beginning of the journey or in the development stage
"W"eaknesses	"T"hreats
1) Existence of similar products on the market 2) Lack of experience in the industrial robot market	1) Increase in the prices of the materials used in the construction of the product 2) Loss of jobs by personnel whose work has been replaced by robots

3. Presentation of the general strategy



With the help of the Gantt chart, the main activities carried out in order to realize the project over 3 years until the sale of the first product on the market were drawn. The Gantt chart is often used in project management because it clearly illustrates their status, graphically highlighting the order and time allocated to tasks.

Fig. 10 Gantt chart for organizing activities

The company will start with a legal form of limited liability company (romanian: societate cu răspundere limitată – SRL), carrying out our activity in accordance with Romanian laws and its statute.

Table no. 5 shows the estimated costs for the milestones used to create an early version of the proposed product that can be dedicated to manufacturers and traders in the industrial area of small products such as: buttons, plugs/caps, make-up shades, nail polish , etc.

Table no. 5: Financial analysis of early product

No. crt.	Components	No. pieces	Price/piece/kg/m (cu Tax)	Total price (cu Tax)
1	Arduino UNO	1	59 ron	59 ron
2	Jumper wires Slave-Master Master-Master	set	2.5 ron	2.5 ron
3	LCD Display	1	14 ron	14 ron
4	I2C serial module	1	8.5ron	8.5 ron
5	SG90 Servomotors	1	13.6 ron	13.6 ron
6	MG955 Servomotors	3	31.5 ron	94.5 ron
7	Connection box with pre-setup	1	29 ron	29 ron
8	Potentiometers	5	1.4 ron	7 ron
9	IR obstacle sensor	1	2.2 ron	2.2 ron
10	Connection strip 14x2	1	30 ron	30 ron
11	Connection strip 3x2	1	15 ron	15 ron
12	Recall button	1	5 ron	5 ron
13	Hardware elements for robot assembly	set	15 ron	15 ron
14	Spiral cable protections	0.5 m	1.5 ron	1.5 ron
15	PLA	0.63 kg	53 ron	53 ron
Pret per produs final				350 ron

Production will start in an industrial hall, manufacturing around 40 collaborative robots monthly (about 2 collaborative robots per day) for the first 6 months. Production times will be slower due to the global shortage of electronics stocks, the reduced number of staff and the amount of money the company is starting with. In the 2nd part of the year, however, a doubling of production is foreseen.

Starting from this point, following the accumulated experience, the entry into the market and the profit obtained by marketing this product, it will be possible to develop a further improved version of it. In 2 years we can approximate the launch of a new product from the same market segment with the same uses, but of different sizes and shapes, superior quality that allows the handling of objects of larger size and dimensions or that have special requirements to be handled.

4. Conclusions

Following what was described in the first chapter, it emerges that the robot we propose for sale allows further improvements in terms of hardware and software with the experience accumulated over time and the continuous technological evolution.

Considering that the industrial robots' market in Romania is still developing, and the main suppliers of such products are foreign companies that collaborate directly with factories in the country, or other company that play the role of distributors on the Romanian market, we believe that the idea of founding a companies producing collaborative robots in the country is a business idea that will be successful in the long term.

There are many chances to enter the industrial robot market in the country through partnerships with educational institutions that can present the product to classes in robotics, technology, computer science, etc., small companies at the beginning of the journey that cannot afford to spend a substantial amount for most existing products on the market that perform the same tasks but at a noticeably higher price, part-time student internships which can represent experience for them and a possible employee for our company, and so on.

Taking into account all the above, we are confident that our product will be viewed with interest in the country's market, and that in about 3 years we will be able to expand our company offering a wider range of products and services.

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INNOVATIVE METHODS OF MANUFACTURING HYDROELECTRIC TURBINE BLADES FROM POLYMER COMPOSITE MATERIALS

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SUMMARY: Hydrodynamic energy systems produce renewable electricity by harnessing the kinetic energy of a body of water, energy resulting from their movement. Among the objectives of this scientific research are the realization of a preliminary model of a hydroelectric turbine as well as the realization and testing of cellular biomimetic structures that will be used, after optimization, in the manufacture of the turbine blade, increasing efficiency and reducing it`s weight.

KEY WORDS: turbine, energy, water, composite materials, additive manufacturing

1. Introduction

The planet is becoming increasingly polluted and new sources of cleaner energy are being sought. To minimise pollution, the most sought-after methods are in nature, using water, wind and sun. Looking at the three broad categories, two of them are limited: the sun can be used when it is in the sky and the wind can be used at a certain speed, with the possibility of it being non-existent for some time. In contrast, (flowing) water has no limitations, at best it can increase its flow at times when rainfall has taken its place, resulting in much better efficiency.

The hydrographic area is very large and worth exploiting, so the research direction of this work is to develop a small hydroelectric turbine that could be placed in river and stream beds. In order to develop something different from what is available on the market, the research focuses on optimising the structure of the turbine blade, i.e. avoiding its total filling with biomimetic-inspired sandwich cell structures.

2. Current status

Renewable energy is one of the biggest challenges facing the planet, which is why engineers around the world are studying new technologies to replace polluting energy production.

In this project, an easy solution has been developed to provide reliable, predictable energy at low cost. This technology is a hydroelectric turbine made of polymer and composite material for direct use in rivers, irrigation canals or tailraces that channel water from existing dams. It is made up of several sub-components, as shown in Figure 2.1.

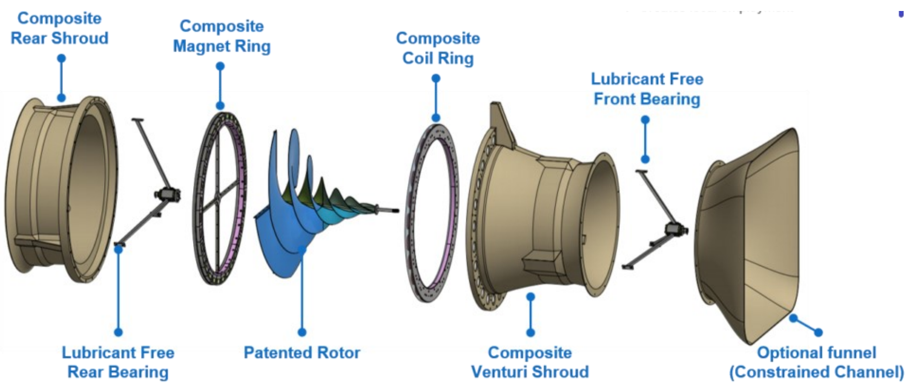

Fig. 2.1. General components of a hydroelectric turbine [7]

The most important component is, of course, the rotor and in figure 2.2 shows the 3D model made in CATIA software.

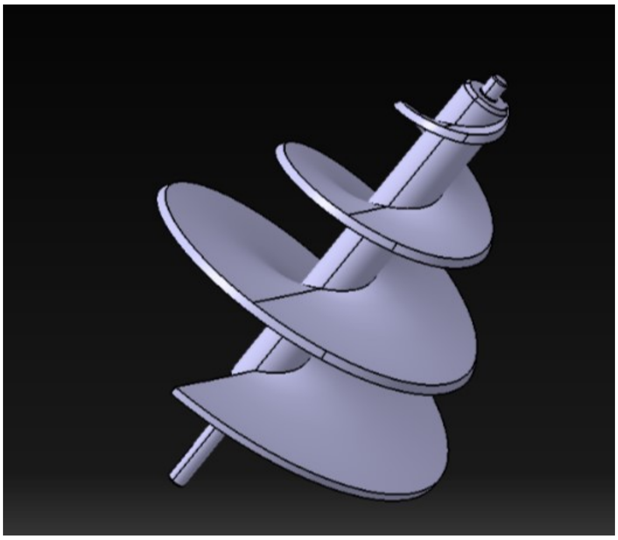

Fig. 2.2. Hydroelectric turbine rotor

Most hydroelectric turbines include propeller or fan blades arranged radially around the central axis and activate another mechanism to generate electricity inside the turbine when it is rotated by water, which is channelled down the turbine. These turbines work best in high head water systems, where the water falls a considerable distance along with the intake velocity and water pressure to produce a greater amount of power. In figure 2.3 shows the preliminary hydroelectric turbine using the rotor from figure 2.2.

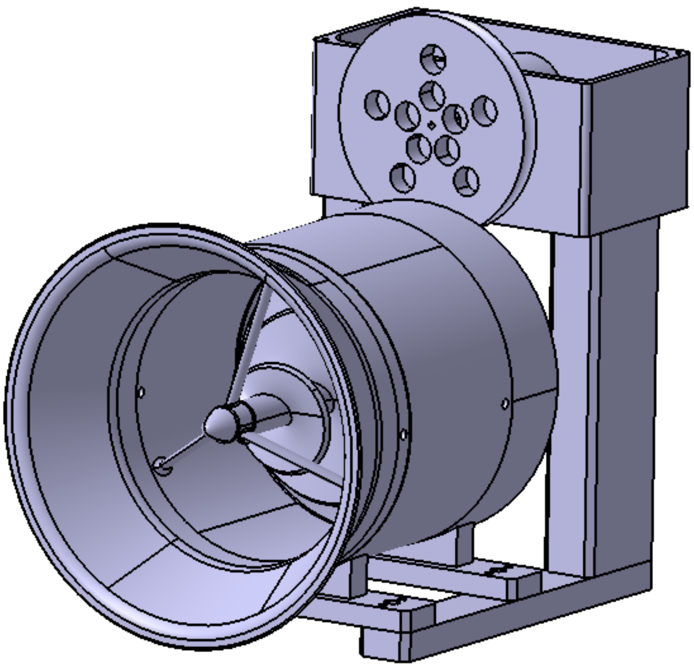

Fig. 2.3. Preliminary hydroelectric turbine

3. Manufacturing equipment

The MARKFORGED X7 printer works on the principle of FDM (Fused Deposition Modeling) 3D printing, the construction of the mark is achieved by layer upon layer of extruded material. The roll of thermoplastic filament is loaded into the printer and once the extrusion nozzle reaches the set temperature, the filament melts and the construction of the first layer of the landmark begins on the machine table through the printer's extrusion head. The extrusion head is attached to a system of three axes that move in the x, y and z directions, allowing movement to build the next layers [1].

The plastics used by this printer are: Onyx, Onyx FR, Onyx ESD and Nylon White, all of which can also have glass fibre, carbon fibre and Kevlar fibre reinforcements [2].

Fig. 3.1. Printer 3D MARKFORGED X7 [3]

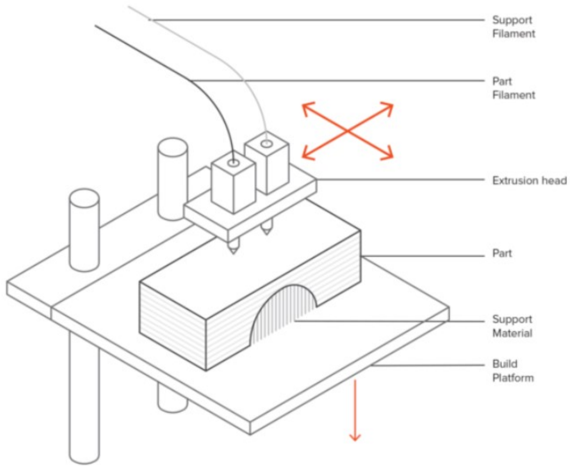

Fig. 3.2. Principle of operation FDM [8]

4. Used materials

Onyx is an ideal material for one-of-a-kind parts, based on a very tough nylon that provides parts with equal or greater stiffness than any pure thermoplastic material available for professional 3D printers. This material can be used in its pure state or can be additionally reinforced with different types of fibre: continuous carbon, Kevlar or glass fibre [4, 5]. The properties of the Onyx material can be seen in Table 4.1. Onyx has a degree of thermal deformation at a temperature of 145°C.

Table 4.1. Material properties [6]

Properties	**Onyx**
Density[g/cm^3]	1,2
Viscosity [cPs]	-
Flexural strength [MPa]	81
Tensile modulus [MPa]	1400
Flexural modulus [MPa]	2900
Ultimate tensile strength [MPa]	36
Impact strength [J/m]	330

5. Prototyping

The 3D concept of the prototype was created using Catia V5 design software and the elements that make up the prototype are highlighted in figure 5.1.

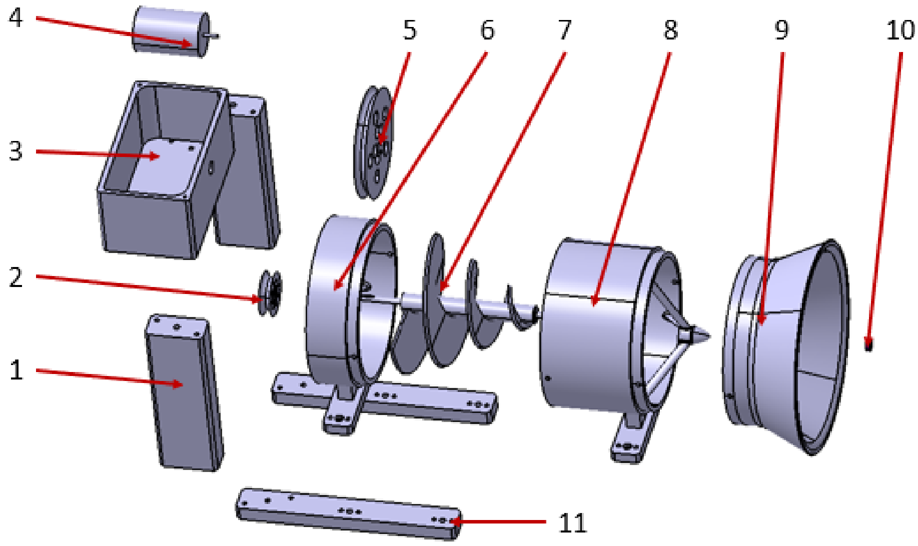

Fig. 5.1. Component elements

The detail of the component parts is as listed:

1 - housing support leg;
2 - small wheel;
3 - dynamic housing;
4 - dynam;
5 - large wheel;
6 - lower casing;
7 - rotor;
8 - upper casing;
9 - funnel housing;
10 - bearing;
11 - support sole.

As previously mentioned, the manufacturing of the components will be done using 3D printing and their assembly will be modular but also with standard connecting elements such as screws, pins and 2 special bearings chosen for use in water.

6. Testing

Given the recommendations and the suitable qualities of the chosen material, it was possible to carry out controlled tests on it. By controlled tests we mean testing specimens to different stresses: tensile stress and bending stress. In figure 6.1 shows a picture of the specimen during the bending test on the INSTRON DX equipment.

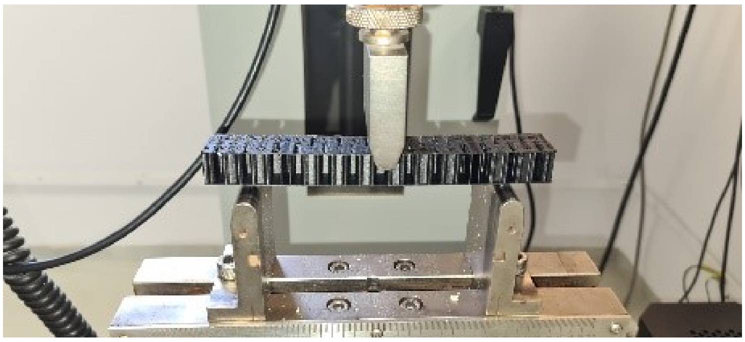

Fig. 6.1. Bending test

Different types of cellular structures were tried for the inner shape of the specimens, for some of them the 3D model was interfered with because it was concluded that their initial design was not adequate, e.g. in the case of bone-type structures, their connecting bridge was the first to fail, requiring thickening.

The first steps in the integration of the sandwich structures investigated in this work were taken and they were introduced in the NACA XXXX series airfoils. The first integrated structures were bone and snowflake structures, which can be found in figure 6.2 and 6.3.

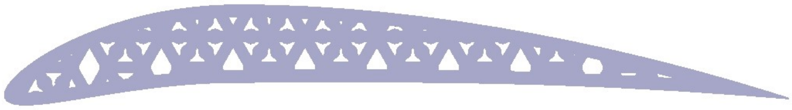

Fig. 6.2. Integration of snowflake cells into the structure

Fig. 6.3. Integration of bone cells into the structure

The airfoils were additively manufactured using MARGKFORCED technology and tested for 3-point bending. These tests are necessary at this early stage of integration in order to bring optimizations to the sandwich structures, resulting in the best mechanical performance relative to the limitations of additive manufacturing technology.

The test results show a bending strength for the snowflake structure of up to 3000 N and for the bone structure 500 N.

7. Conclusions

The initial steps were to design and develop a hydroelectric turbine capable of providing the user with a free source of electricity, provided by nature when the user is in remote areas without other public sources.

Of course, this concept was developed following needs, such as:

- the need to communicate with the outside world (charging a mobile phone);
- the need for light (the ability to turn on a light bulb);
- the need for warmth (the ability to heat an element to light a fire).

These are small but necessary needs if the user is isolated, hiking or simply running out of electricity, but is nevertheless near running water.

The development of the turbine's design, material and size also remains an open topic, as research can develop an improved version that can be cheaper, lighter, smaller in size and produce more electricity.

This new concept can be seen as a plus and a great benefit to adventure enthusiasts and to people who cannot afford the benefits of a popular medium that offers an advantage such as electricity.

8. Development directions

Biomimetic cells can be used as sandwich structures in the composition of reinforced polymer composite parts such as turbine blades or other components of the structure.

In addition to the high strength offered by these structures, the aim is to reduce the mass of the whole assembly by implementing them in the other components supporting the electrical part and the tubing.

Coating of certain surfaces can be done in such a way that the water flow is smooth and uniform, but at the same time provides additional protection of the material.

At the same time, the aim is to simulate with the help of dedicated test software different types of stresses on the turbine auger in order to develop an ergonomic design that meets the requirements for which it was developed.

After assembling the prototype, it is intended to test it on a water pump where the flow rate is determined in order to calculate all the forces occurring during use, but also in mountainous areas, on a spring where the water flow rate is fluctuating in order to observe its behaviour.

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CNC SYSTEM FOR LASER ENGRAVING AND MICROTEXTURING

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ABSTRACT: In the research paper we chose to make a CNC laser engraving and microtexturing, used for wooden objects, polypropylene, which has a power of 10W. The points reached by the paper being the strategic marketing of the product, the project management, the establishment of specifications, the conceptual design, the manufacture and testing of the product prototype and last but not least the economic analysis.

KEY WORDS: CNC, engraving, microtexturing, laser.

1. Introduction

Laser CNCs are modern equipment used in many industries. They are mainly found in laboratory environments, production units and various workshops. Laser engraving and cutting machines are used to engrave a variety of surfaces. The machine ensures precise cuts even at very high resolutions.

2. Stadiul actual

The laser offers the fastest cutting method on the market for a wide range of materials, offers competitive and high-quality products, incomparable to those made by traditional cutting techniques.

Engraving is a genre of visual arts whose techniques consist of digging, incising, perforating or obturating by various physical or chemical processes a usually flat surface, either in order to print and subsequently multiply the image, or to obtain a self-artistic object. stagnant. [2]

Laser engraving can be done on a wide range of products: wood, plastic, leather, metal, glass, etc. This procedure allows the inscription and personalization of different products with a high precision of the finest details. The market consists of signboards, keychains, decor accessories, personalized gifts, ornaments, souvenirs, etc. [3]

3. Planning the dissertation project

• Program Management Plan: establishes the processes, procedures, and documentation for planning, developing, managing, executing, and controlling project plans.
• Establishing a process for all project activities that represents the identification and documentation of specific actions that must be taken to achieve project objectives.
• Allocating resources for identified activities represents the process of estimating the type and quantity of resources, labor, equipment, or ongoing work to perform project activities.
• Estimating activity duration is the process of estimating the time required to complete each activity with the estimated allocated resources.

The planning of the project activities was done with the help of the Primavera P6 program.

NecM Proiect		494	494	0%	12-Oct-22	$13,124.34	05-Jan-23	914
NecM.Etapa 1 Cercetare de piata		45	45	0%	12-Oct-22	$913.43	19-Oct-22	914
A1000	A1.1 Identificarea oportunitatilor de piata	6	6	0%	12-Oct-22	$121.79	12-Oct-22	914
A1010	A1.2 Stadiul actual	4	4	0%	12-Oct-22	$81.19	13-Oct-22	914
A1020	A1.3 Formularea misiunii	3	3	0%	13-Oct-22	$60.90	13-Oct-22	914
A1040	A1.4 Selectarea potentialilor clienti	8	8	0%	13-Oct-22	$162.39	14-Oct-22	914
A1050	A1.5 Date culese de la potentiali clienti	8	8	0%	14-Oct-22	$162.39	17-Oct-22	914
A1060	A1.6 Date despre produse concurente	16	16	0%	17-Oct-22	$324.77	19-Oct-22	914
NecM.Etapa 2 Managementul proiectului		47	47	0%	19-Oct-22	$954.02	27-Oct-22	914
A1140	A2.1 Structuri de dezagregare a proiectului	8	8	0%	19-Oct-22	$162.39	20-Oct-22	914
A1150	A2.2 Managementul operativ al proiectului	12	12	0%	20-Oct-22	$243.58	24-Oct-22	914
A1160	A2.3 Structura de dezagregare a costurilor	7	7	0%	24-Oct-22	$142.09	24-Oct-22	914
A1170	A2.4 Analiza financiara estimativa	20	20	0%	25-Oct-22	$405.97	27-Oct-22	914
NecM.Etapa 3 Stabilire specificatii		32	32	0%	27-Oct-22	$649.55	02-Nov-22	914
A1030	A3.1 Cerinte caracteristici	6	6	0%	27-Oct-22	$121.79	28-Oct-22	914
A1070	A3.2 Performante ale produselor concurente	18	18	0%	28-Oct-22	$365.37	01-Nov-22	914
A1080	A3.3 Valorile obiectiv si limita I acceptabile	8	8	0%	01-Nov-22	$162.39	02-Nov-22	914
NecM.Etapa 4 Proiectare conceptua		116	116	0%	02-Nov-22	$2,354.61	22-Nov-22	914
A1090	A4.1 Functia generala si functiile componente	9	9	0%	02-Nov-22	$182.69	03-Nov-22	914
A1100	A4.2 Cercetarea externa pentru identificarea de sol. constructive	30	30	0%	03-Nov-22	$608.95	09-Nov-22	914
A1110	A4.3 Cercetarea interna pentru solutii constructive noi	35	35	0%	09-Nov-22	$710.44	15-Nov-22	914
A1120	A4.4 Explorarea sistematica	26	26	0%	15-Nov-22	$527.76	18-Nov-22	914
A1130	A4.5 Arhitectura produsului	16	16	0%	21-Nov-22	$324.77	22-Nov-22	914
NecM.Etapa 5 Proiectare detaliata		188	188	0%	23-Nov-22	$3,502.92	26-Dec-22	914
A1180	A5.1 Proportionare, forme, dimensiuni si tolerante	40	40	0%	23-Nov-22	$811.93	29-Nov-22	914
A1190	A5.2 Determinarea conditiilor ergonomice	40	40	0%	30-Nov-22	$811.93	06-Dec-22	914
A1200	A5.3 Definire elemente de design	36	36	0%	07-Dec-22	$730.74	13-Dec-22	914
A1210	A5.4 Stabilire materiale si tratamente	17	17	0%	13-Dec-22	$271.13	15-Dec-22	914
A1220	A5.5 Descriere si calcul solicitari principale ale produsului	25	25	0%	15-Dec-22	$398.72	20-Dec-22	914
A1230	A5.6 Elaborare desene de ansamblu si de executie	30	30	0%	20-Dec-22	$478.46	26-Dec-22	914
NecM.Etapa 6 Fabricarea - testarea prototipului produs		16	16	0%	26-Dec-22	$3,734.90	28-Dec-22	914
A1240	A6.1 Tehnologia de fabricare/testare prototip	16	16	0%	26-Dec-22	$3,734.90	28-Dec-22	914
NecM.Etapa 7 Omologarea, utilizarea, comercializarea s		16	16	0%	28-Dec-22	$324.77	30-Dec-22	914
A1250	A7.1 Tehnologia de omologare-utilizare-comercializare-reciclare a	16	16	0%	28-Dec-22	$324.77	30-Dec-22	914
NecM.Etapa 8 Analiza economica		24	24	0%	30-Dec-22	$487.16	04-Jan-23	914
A1260	A8.1 Costul cercetarii dezvoltarii. Reevaluarea financiara a proiec	24	24	0%	30-Dec-22	$487.16	04-Jan-23	914
NecM.Etapa 9 Elaborarea cartii produsului		10	10	0%	04-Jan-23	$202.98	05-Jan-23	914
A1270	A9.1 Descrierea; Instalarea si punerea în functiune; utilizarea; ma	10	10	0%	04-Jan-23	$202.98	05-Jan-23	914

Fig. 1 Allocation of activities necessary to complete the project

Financial management and risk management

For the financial evaluation of the project, the cash flow discounting method presented in the table below was used.

Table 1

N	I0	V		Ch		CF	i
0						-15133	
1	15133	V1	27500	Ch1	15000	12500	0.09
2		V2	36000	Ch2	18000	18000	
3		V3	51000	Ch3	21000	30000	

VAN	25669.82	
RIR	58%	
Cfmed	8556.605	
TR	1.768575	
IP	1.696281	
	TRUE	IP> 1!

Terms of delivery

The sales process is initiated by sending an Offer by the Seller-Buyer. The offer includes: the products, the quantity, the price, the terms and methods of payment, the delivery term and is accompanied by the present general conditions.

Methods and conditions of payment

The contractor will issue the invoice for the delivered product.
VAT is added to the prices indicated above according to the regulations in force on the invoicing date. Payment will be made within a maximum of 15 days from the invoice date.

The protocol of qualitative reception will accompany the invoice and is the necessary element for making the payment, together with the other supporting documents such as:

- the quality and guarantee certificate;
- declaration of conformity;
- the shipping notice of the product;
- the reception report;

4. Evaluation of concepts

Since the number of concepts is not very large, it is not necessary to sort them, so we will make a matrix of their evaluation, table 3.

For this we choose a reference concept, in our case concept 3 because this concept is an obvious solution to the design problem. It is a simple solution, which involves relatively low costs.

The evaluation scale of the concepts was established in relation to the reference concept (concept 3), the proposed evaluation scale being from 1 to 5, where 3 is the same as the reference concept and 5 is much better than the reference concept.

Evaluation criteria were established and for each the associated sub-criteria were established, taking into account the requirements of the clients and the objective specifications. In addition, I set a weight for each one, according to what is shown in table 2.

Table 2 Selection criteria and weight of criteria

Nr. Criteriu	**Criteriul de selectie**	**Pondere [%]**
1	**Simplitatea operarii**	**15**
1.1	Se introduce cablu USB de la un PC	7
1.2	Se apasa butonul on/off	5
1.3	Verificarea statusului prin indicator LED	3
2	**Usurinta folosirii**	**10**
2.1	Usurinta punerii in functiune	3
2.2	Usurinta manevrarii	3
2.3	Usurinta curatarii dupa utilizare	2
2.4	Siguranta in functionare	2
3	**Fiabilitatea**	**15**
3.1	Componente fiabile	5
3.2	Interschimbabilitatea pieselor	5
3.3	Rezistenta si durabilitatea subansamblurilor	5
4	**Design si ergonomie**	**10**
4.1	Aspect vizual placut	3
4.2	Proportionalitatea formelor	1
4.3	Dimensiuni de gabarit reduse	3
4.4	Fixare/eliberare	1
4.5	Stabilitate in functionare	2
5	**Universalitatea**	**5**
5.1	Diverse industrii	2.5
5.2	Diferite proiecte	2.5
6	**Usurinta fabricarii**	**15**
6.1	Tipul materiilor prime si materialelor	10
6.2	Prelucrabilitatea materialelor	5
7	**Cost**	**30**
7.1	Costul fabricarii	20
7.2	Costul intretinerii	7
7.3	Costul scoaterii din uz	3

Table 3 "Concept Evaluation Matrix"

Criteriul de selectie	Pondere [%]	Concepte							
		Concept 1		Concept 2		Concept 3 (Referinta)		Concept 4	
		Evaluare	Scor ponderat	Evaluare	Scor ponderat	Evaluare	Scor ponderat	Evaluare	Scor ponderat
Simplitatea operarii	**15**								
Se introduce cablu USB de la un PC	7	4	0.28	4	0.28	3	0.21	4	0.28
Se apasa butonul on/off	5	2	0.1	3	0.15	3	0.15	4	0.2
Verificarea statusului prin indicator LED	3	1	0.03	1	0.03	3	0.09	5	0.15
Usurinta folosirii	**10**								
Usurinta punerii in functiune	3	3	0.09	2	0.06	3	0.09	4	0.12
Usurinta manevrarii	3	3	0.09	2	0.06	3	0.09	5	0.15
Usurinta curatarii dupa utilizare	2	1	0.02	3	0.06	3	0.06	5	0.1
Siguranta in functionare	2	3	0.06	3	0.06	3	0.06	3	0.06
Fiabilitatea	**15**								
Componente fiabile	5	3	0.15	3	0.15	3	0.15	3	0.15
Interschimbabilitatea pieselor	5	2	0.1	2	0.1	3	0.15	4	0.2
Rezistenta si durabilitatea subansamblurilor	5	3	0.15	3	0.15	3	0.15	4	0.2
Design si ergonomie	**10**								
Aspect vizual placut	3	1	0.03	2	0.06	3	0.09	4	0.12
Proportionalitatea formelor	1	2	0.02	2	0.02	3	0.03	3	0.03
Dimensiuni de gabarit reduse	3	3	0.09	3	0.09	3	0.09	3	0.09
Fixare/eliberare	1	4	0.04	1	0.01	3	0.03	3	0.03
Stabilitate in functionare	2	3	0.06	2	0.04	3	0.06	3	0.06
Universalitatea	**5**								
Diverse industrii	2.5	1	0.025	2	0.05	3	0.075	3	0.075
Diferite proiecte	2.5	1	0.025	2	0.05	3	0.075	4	0.1
Usurinta fabricarii	**15**								
Tipul materiilor prime si materialelor	10	4	0.4	3	0.3	3	0.3	4	0.4
Prelucrabilitatea materialelor	5	3	0.15	3	0.15	3	0.15	5	0.25
Cost	**30**								
Costul fabricarii	20	2	0.4	2	0.4	3	0.6	4	0.8
Costul intretinerii	7	1	0.07	2	0.14	3	0.21	3	0.21
Costul scoaterii din uz	3	2	0.06	2	0.06	3	0.09	2	0.06
Scor total			**2.44**		**2.47**		**3.00**		**3.84**
Rangul		***1***		***3***		***2***		***4***	

The concept with the best result is concept number 4. It obtained a better score than the reference concept.

Product architecture

For the chosen concept, an architecture was created in which most of the elements that will constitute the final product are described.

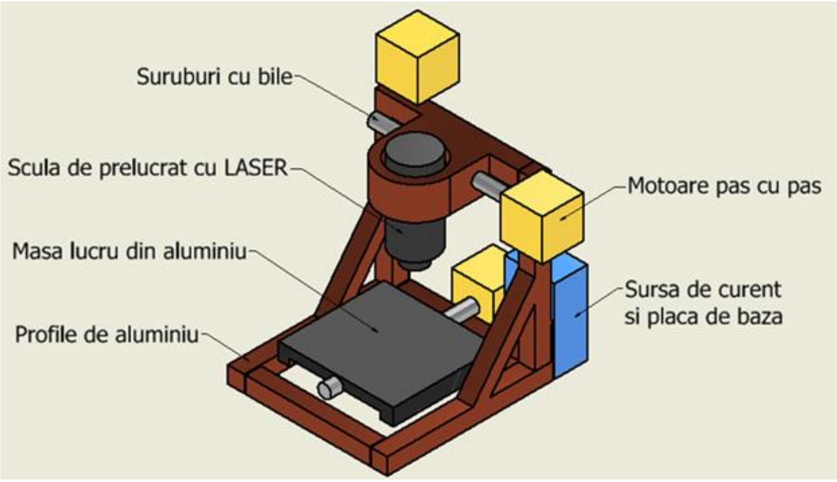

Fig. 2

5. Manufacturing – testing the product prototype

For the realization of this prototype CNC laser engraving and microtexturing I used the following materials:

- Aluminum bar
- Laser for Mini 3-Axis CNC Carving Engraving Machine PVC,PBC,wood,Chigods, 445nm 1600MW TTL PWM
- A4988 STEPPER MOTOR DRIVER
- Stepper motor, NEMA17
- Router Desktop Milling Machine CNC1610 w/ ER11 (1610 Pro)

Way of working:

- The realization of the supports for the laser and motorized module were made by hand, in a mechanical workshop.
- The electrical circuits were tested before connection with a Digital Multimeter to measure the voltage in order not to short-circuit the existing motherboard.
- To program the laser module and the stepper motor, I used 2 software: Arduino IDE and LaserGRBL.

Fig. 3 Support Laser Mode

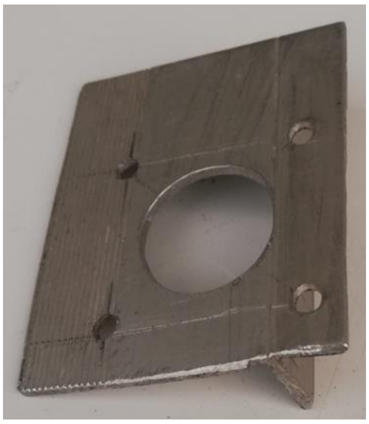

Fig. 4 Engine support

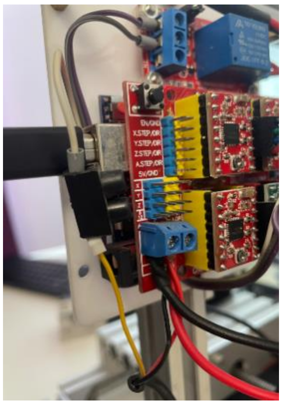

Fig. 5 Connect Laser Mode

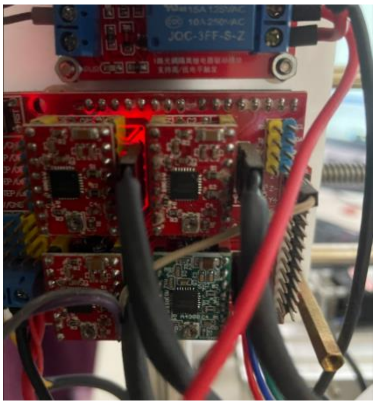

Fig. 6 Engine connection

Fig. 7 Result paper

Fig. 8 Metal result

6. Marketing

Figure 9 shows on the map several legal entities located near the headquarters where the processing procedures are carried out, namely the Polytechnic University, as can be seen the products made by the CNC System are intended in principle for those who want to make or own objects custom or at least non-mass produced items.

Several legal entities located near the headquarters were selected and the distance between the Polytechnic University and each merchant was calculated and an attempt was made to estimate the cost of transporting the product through two courier companies.

• Raimar deals with the customization of watches, it is located in the City of Bucharest, Bulevardul Iuliu Maniu 546-560, the distance from the Politehnica University is 6 km; the transport cost is (15 lei – Fan Courier; 18 lei Cragus);

• Malvensky deals with jewelry customization and is located at a distance of 5.6 km from the Politehnica University in Bucharest, 46 Lascăr Catargiu Boulevard; the transport cost is (12 lei – Fan Courier; 13 lei Cragus);

• Happy Gift deals with the customization of glass, plastic and metal objects and is located in Bucharest at a distance of 8 km from the Politehnica University, Str. Alexandru cel Bun no. 43, the cost of transport is (19 lei – Fan Courier; 20 lei Cragus).

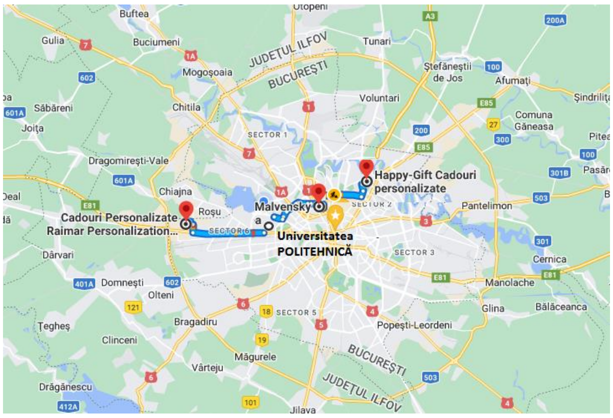

Fig. 9 Representation on the map of possible customers

Therefore, as a possible customer, any person can be considered because we encounter these procedures applied to the products we use at every step.

7. Economic analysis

The calculation presented below helps to determine the number of parts (critical number) from which it becomes profitable to use laser instead of milling.

The parameters Ai and Bi are calculated with the relations presented below:

$$A_i = m_{sf} \cdot c_m + (1+\frac{R_f}{100})\frac{\tau_{buc}}{60} s_{mi} + \frac{\tau_{buc}}{60}\frac{c_{MU}}{F_n} \quad (1)$$

$$A_1 = 7.66*25+ (1+\frac{170\%}{100})* \frac{10}{60} * 5+ \frac{10}{60} * \frac{400}{992} = 192.41 €$$

$$A_2 = 4.25*20+ (1+\frac{150\%}{100})* \frac{5}{60} * 3+ \frac{5}{60} * \frac{500}{1984} = 85.27 €$$

$$B_i = C_{SDV} * \frac{a+j}{100} \ (2)$$

$$B_1 = 500 * \frac{100\%+25\%}{100} = 6.25 €$$

$$B_2 = 600 * \frac{100\%+20\%}{100} = 7.2 €$$

In the case of two variants of carrying out an operation, the relations of manufacturing costs are as follows:

$$C_{xi}= A_i \text{ x} + B_i = C_{x1}= 192.41 * 1 + 6.25 = 198.66 € \ (3)$$

$$C_{xi}= A_i \text{ x} + B_i = C_{x2}= 85.27 * 1 + 7.2 = 92.47 € \ (4)$$

The critical number of parts x_{cr}, from which a variant starts to become more economical than another variant is determined by equalizing the corresponding costs according to the relations:

$$x_{cr} = (B_2 - B_1) / (A_1 - A_2) = (7.2 – 6.25) / (192.41 – 85.27) = 0.00887 \text{ buc } (5)$$

The total workload is the workload required for activity k of the research-development process and is calculated using the following relationship:

$$V_{M\,CD} = 100+ (\sum Ni * ki) *1*1.2*0.35 = 247 \text{ ore } (6)$$

The design labor cost is determined by the formula below:

$$C_{MAN} = V_{M\,CD} \cdot \text{Smh} = 247 \text{ [ore]} * 3.5 \text{ [RON/oră]} = 864.5 \text{ [RON]} \quad (7)$$

The CAS social insurance contribution is represented in relation 8:

$$\text{CAS} = 10 \% * C_{MAN} = 86.45 \text{ [RON] } (8)$$

The calculation of the cost at the level of the design workshop is carried out with the help of relation 9:

$$C_{AP} = C_{MAN} + C_{MAT} + \text{CAS} + C_{GAP} \ (9)$$

$$C_{AP} = 864.5 + 500 + 86.45 + 380.38 = 1831.33 \text{ [RON]}$$

Expenses with indirect remuneration and administrative expenses with design activities can be found in the relationship below :

$$C_{GAP} = R_{AP} \ (C_{MAN} + \text{CAS}) = 0,4 \ (864.5 + 86.45) = 380.38 \text{ RON (10)}$$

The determination of the total design cost will be done using the relationship:

$$C_{cp} = C_{AP} + C_{D} + C_{AT} = 1831.33 + 27.47 + 18.31 \approx = 1877.11 \text{ RON (11)}$$

The expenses for the technical assistance are related 12 :

$$C_{AT} = [\ 0,01 \ldots 0,05\ ]\ C_{AP} = 0,01 * 1831.33 = 18.31 \text{ RON (12)}$$

Selling expenses are represented in the relationship below:

$$C_{D} = [\ 0,01 \ldots 0,03\ ]\ C_{AP} = 0,015 * 1831.33 = 27.47 \text{ RON (13)}$$

Calculation of the partial cost of the technological project:

$$C_{cp} = C'_{T} * C_{cp} = 0,9 * 1877.11 = 1689.4 \text{ RON (14)}$$

The calculation of the cost of the technology project is found in the relationship :

$$C_{T} * = C'_{T} \ + C_{m} \ + C_{ast} = 0.9 + 0.045 + 0.045 = 0.99 \text{ RON (15)}$$

Technical assistance costs:

$$C_{ast} = C_{m} = 0,05\ C'_{T} = 0,05 * 0.9 = 0.045 \text{ RON (16)}$$

The unit price or price proposal is calculated according to the relationship:

$$\text{P} = C_{P} + P_{r} = 2800+280=3080\text{lei (17)}$$

The selling price is calculated with the relationship below:

$$P_{v} = \text{P} + \text{TVA} = 3080+739.2= 3819.2 \text{ lei (18)}$$

The technical time norm is calculated, considering the final preparation time τ_pî=10 min. The other components of the technical time norm are determined according to the basic time (τ_b) and the effective time (τ_{ef}) according to the following formulas valid in this case:

$$\tau_{dt} = 5\ \%\ \tau_{b} = 5\ \% * 120 = 6 \text{ [min/buc] (19)}$$

$$\tau_{do} = 2\ \%\ \tau_{ef} = 2\%(\ \tau_{b} + \tau_{a}\ ) = 2\ \%\ \tau_{ef} = 2\%(\ \tau_{b} + \tau_{a}\ ) = 2\% * 60 = 1.2 \text{ [min/buc] (20)}$$

$$\tau_{on} = 0,5\ \%\ \tau_{ef} = 0,5\ \%\ (\tau_{b} + \tau_{a}\ ) = 0,5\ \%\ \tau_{ef} =$$

$$=0,5\ \%\ (\tau_{b} + \tau_{a}\ ) = 0.5\ \% * 60 = 0.3\text{[min/buc] (21)}$$

The above calculations were performed between a milling machine and an engraving machine. Therefore, the CNC System for engraving and microtexturing is an advantageous product having one of the lowest prices on the market in relation to the quality.

8. Conclusion

In conclusion, following the research on the market of CNC devices, we can say that we have the most cost-effective product quality price that can satisfy the wishes of all users.

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RESEARCH ON DEVELOPMENT OF HYDRAULIC FIXING MODULES OF PARTS IN INDUSTRIAL CNC TECHNOLOGICAL SYSTEMS

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ABSTRACT: For fixing large-sized and complex parts within technological machining systems, it is necessary to determine solutions after analyzing multiple possible variants. There are several significant advantages of using hydraulic clamping modules for parts in industrial CNC technological systems, especially for fixing parts with complex geometries. Additionally, this article presents data and the main results of experimental research regarding fixing parts using these modules within complex machining processes and systems that include milling, drilling, and threading.

KEYWORDS: part, hydraulic clamping, clamping mechanism, technological system

1. Introduction

The way of fixing parts within technological machining systems is influenced by the constructive characteristics of the parts, as general shape, wall thicknesses, possible space dimensions for fixing, etc. The hydraulic clamping system has higher efficiency compared to other clamping systems with lower energy consumption. In computer numerical control (CNC) systems, the hydraulic clamping system is generally used to maintain the part in the desired position. Compared to manual tightening, the use of hydraulic clamping in the system ensures a constant clamping force on the workpiece, makes the tightening process faster, and allows for automatic or robotic loading of workpieces.

2. General considerations

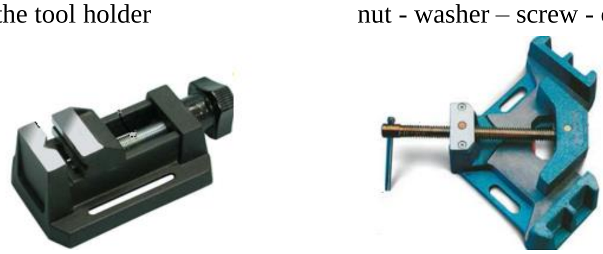
2.1. Types of manual-mechanical technological fixing mechanisms

The clamping mechanisms in the structure of technological machining systems can be pin-type, eccentric, screw-nut, pneumatic motor, hydraulic motor, and clamp (lever), plunger, pressure foot, vacuum, magnetic, etc., while orientation-clamping mechanisms can be with bushings, with elastic bushings, with levers, prisms, etc. [5, 16].

A series of manually-operated clamping mechanisms are shown in Fig. 1.

(a) Clamping with force elements type of screw - threaded hole within lathe tool holder

(b) Clamping with force elements type of nut - washer – screw - clamp at various devices



(c) Clamping with force elements type of screw - fixed nut -jaws, at vises and other devices

Fig. 1. Mechanisms for manual-mechanical clamping (adapted from [6])

2.2. Types of technological fixing mechanisms with magnetic actuation

Magnetic actuation represents a mechanized mode of operation characterized by the fact that the actuation force is generated, for example, by permanent magnets, properly oriented and isolated from each other with the help of non-magnetic isolatorss. Magnetically actuated devices have a number of advantages: low cost; uniform magnetic field distributed over the surface, with fixation without deformations, etc. [13].

Magnetically driven devices are built in the form of magnetic tables/plates. Such a magnetic table used in CNC milling machines is shown in Fig. 2. For holding small and thin parts, the most suitable devices are magnetic fixtures with neodymium magnetic systems [11] (Fig. 3). Neodymium magnets (NdFeB) are smaller and stronger than other permanent magnets.

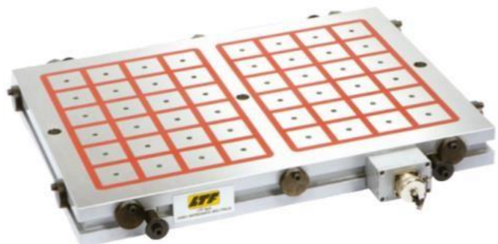


Fig. 2. Electropermanent magnetic table [12]

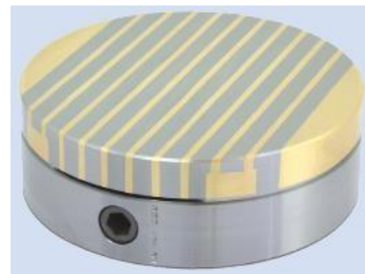


Fig. 3. Permanent magnetic device [11]

2.3. Types of technological fixtures with hydraulic actuation

The hydraulic clamping system has a higher efficiency compared to other clamping systems, with a lower energy consumption, and is driven by a pump that operates at a constant speed. In CNC machines, the hydraulic clamping system is generally used to hold the workpiece in the desired position [3].

Compared to manual clamping, the use of hydraulic clamping systems ensures a constant clamping force on the workpiece, makes the clamping process faster, and allows for automatic or robotic loading of the workpieces [2].

A series of hydraulic clamping mechanisms are shown in Fig. 4.

(a) Rotating clamps

(b) Hydraulic clamp for multiple fixations

(c) Hydraulic cylinders with lever mechanisms

(d) Side clamps

Fig. 4. Hydraulic clamping mechanisms (adapted from [9])

2.4. Clamping System

From a mechanical point of view, the purpose of clamping a workpiece is to keep it in a rigid position so that various actions which can be performed on it. From another point of view, the clamping system is used to overcome the maximum forces that act on the workpiece. A clamping diagram of a hydraulic clamping system in a CNC system is shown in Fig, 5. In the case where a clamp is used to fix a workpiece for machining, the efficiency of the clamp depends on the action type [1]. Some of the main functions that an ideal clamp should fulfill are: reducing the maximum possible stresses acting on the workpiece during machining, eliminating the possibility of deformation due to clamping force, and maintaining adhesion to the workpiece surface during machining despite vibrations caused by cutting tools.

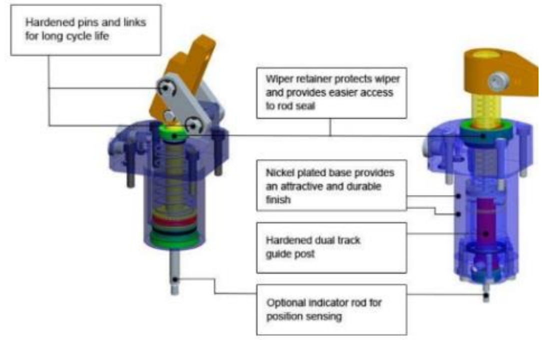


Fig. 5. Hydraulic Clamping System used for CNC machines [1]

2.5. Clamping rules

There are many rules for applying clamp on any work piece, e.g. [1, 5]:

• the clamping force should always be applied toward the locating surface;

• the clamp should be at a safe distance from the tool;

• tlamps should be arranged in such a way that clamping force acts on rigid part of the work. For example, if an I section is to be clamped, the clamp should be adjusted in such a way that clamping force acts on the flanges and not on the web of the I section;

• the design of the clamping device should be done based on the work it has to handle. With the advancement in technology, there are many types of clamping system. Mostly used systems are mechanical clamping systems and hydraulic clamping systems. However, due to greater efficiency and ease of application hydraulic clamping systems. has dominated in the rapidly growing industries.

2.6. Hydraulic clamping systems

The hydraulic clamping system is a fastening system that uses a pressurized liquid such as oil, water, etc. to hold a workpiece in a fixed position during processing. This system is more efficient than other clamping systems due to the reduced friction surfaces. The hydraulic system usually consists of a single or double-acting cylinder and a piston. On the hollow side of the piston, there is a hole for the flow of pressurized liquid. On the opposite side, namely on the rod side, there is a rocker-type, vertical, linked, or other type of clamp that exerts force on the workpiece to achieve the clamping action (Fig. 6).

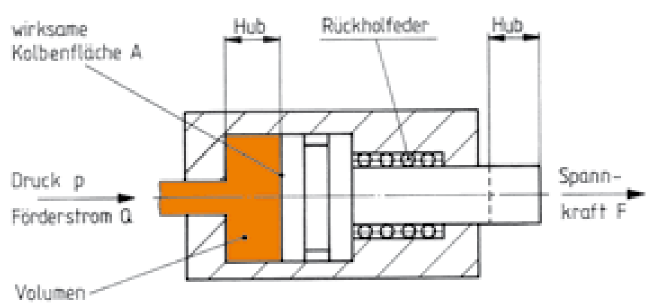


Fig. 6. Illustration of Hydraulic Clamping System [1]

In general, the power source for the hydraulic clamping system is a so-called hydraulic power unit. Its main components include the oil tank, pump, motor, pressure relief valve, pressure gauge, etc. A schematic diagram of such an industrial hydraulic power unit [1] is shown in Fig. 7. An example of such a hydraulic power unit is presented in Fig. 8.

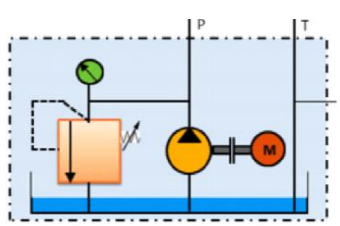


Fig. 7. Hydraulic Power Pack Circuit [1]


Fig. 8. Hydraulic Power Pack Bosch [8]

When high pressure is required, the hydraulic system plays an important role in performing various operations. The necessary pressure in the CNC machine is developed by the hydraulic power pack of several hydraulic components.

The structure of a hydraulic module circuit used in CNC machines is presented in Fig. 9. The most typical applications are shown in Fig. 10.

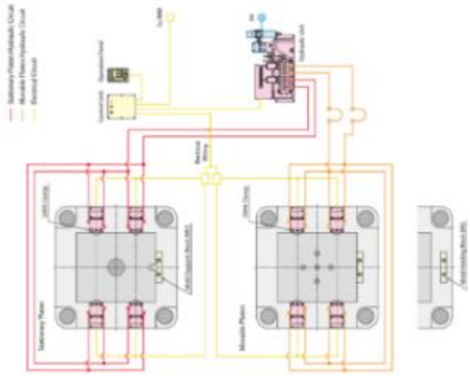
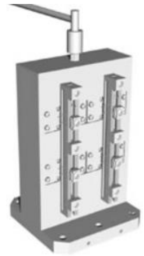


Fig. 9. The structure of a hydraulic module circuit [7]



(a) Continuous hydraulic connection with horizontal machining center

(b) Continuous hydraulic connection with vertical machining center

(c) The hydraulic connection is disconnected after loading (in FMS systems)

Fig. 10. Applications of hydraulic system in CNC centers [2]

2.7. The calculation of hydraulic clamping force

To calculate the necessary clamping force for a workpiece using a hydraulic clamping system, one must take into account the geometry and characteristics of the workpiece as well as the contact surface between the workpiece and the hydraulic module. This calculation is carried out using Eq. (1),

$$F = pA\eta \tag{1}$$

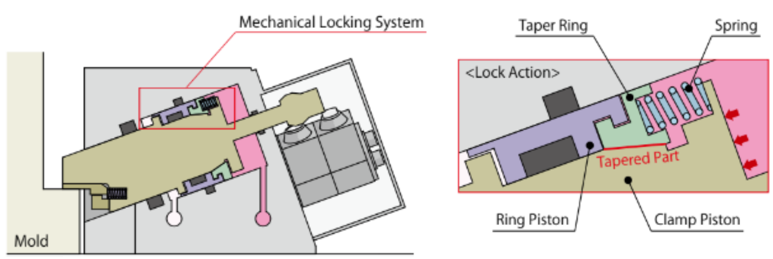
where: p is the hydraulic pressure, A - the active surface area of the piston, η - the transmission efficiency of force.

For example, at a hydraulic module with a diameter of d = 50 mm, hydraulic pressure of p = 65 bar, and transmission efficiency of η = 0.95 [18], the resulting force is F = 1212.5 daN.

3. Modules of parts in industrial CNC technological systems

A hydraulic module [14] used in industrial CNC technological systems for clamping workpieces is shown in Fig. 11.

Fixare hidraulică.mp4



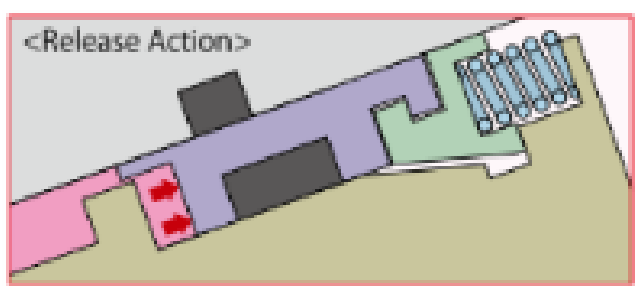


Fig. 11. Hydraulic clamping module [14]

The mechanical locking system prevents the hydraulic device from detaching during the workpiece is fixed and keeps it in the desired position [7].

The part shown in Fig. 12 is a complex model due to its geometric shape. The surfaces to be machined are highlighted in colors. In order to allow machining on all sides, the fixation must be made on surfaces that do not require machining. Therefore, it can be done in two ways, either on the large surfaces in the middle or on the sides. Fixation in the middle of the part can cause significant ovalization due to the lack of material, so the sides are the best option, although their geometry is more complex [10]. Point fixing of the part reduces the contact area (Fig. 13).

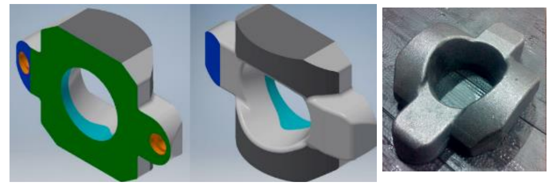


Fig. 12. 3D model of the part and the physical part [10]

Based on previous experiences with hydraulic clamping, several issues have been identified and ways to mitigate or prevent them have been studied. The identified issues and proposed solutions are presented in Table 1.

Fig. 13. Fixing the part with dog point screws for reducing the contact area and the appearance of deformations [10]

Table 1. Analysis of potential issues that may arise [10]

Possible problems detected	Possible solutions/ corrections
Part instability due to irregular clamping area or clamping over parting line	Use of “V” shaped clamps both on top and bottom to compensate for torsion
Excessive vibration during machining	Adding a hydraulic support clamp on the free side of the part increasing support area
Need for calculations during setup increasing human error probability	Adding centring spheres on the tool for the probe to measure and calibrate

4. Case study

The case study refers to the introduction of hydraulic clamping in a complex technological operation, which includes milling, drilling, threading, associated with a complex geometric shape part (Fig. 14).

The elements of the development regarding the application of hydraulic clamping are presented in Fig. 15: (a) an extended sketch of the technological operation; (b) a simplified 3D model of the device.

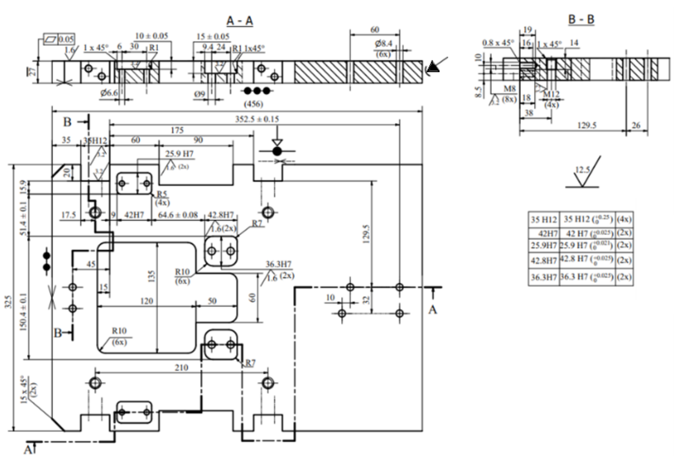
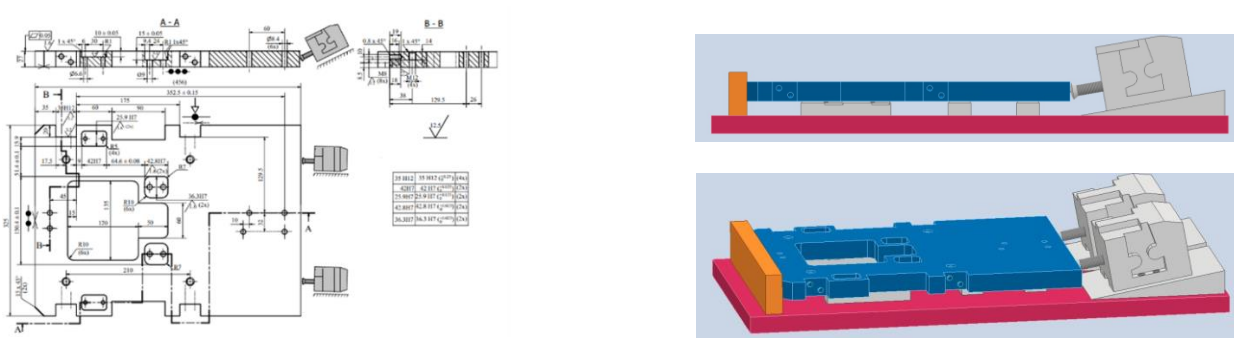


Fig. 14. Technological operation sketch [5]



(a) Extented technological operation sketch

(b) A 3D model of the device in a simplified form

Fig. 15. Elements of development regarding the application of hydraulic clamping

5. Conclusions

In order to fix large-sized parts within machining systems, various fastening schemes and mechanisms need to be analyzed, taking into account specific characteristics of the parts such as the overall shape, wall thickness, etc.

Experimental research on fixing parts with hydraulic modules during complex machining processes shows that technological conditions for using hydraulic devices in CNC machining systems can be determined for complex machining operations.

Developing theoretical and experimental research on hydraulic fixation of parts in machining operations will lead to a reduction in physical effort required for fixing and, correspondingly, to production cost reduction.

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MODELING AND SIMULATION OF THE PRODUCTION PROCESS OF A METAL SLITTING LINE

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ABSTRACT: Modeling and simulating the production process of a metal cutting line consists in creating a virtual representation of the process and analyzing its behavior in scenarios. The objective of this study is to improve the process by identifying inefficient activities and optimizing the involved parameters. To create a model of the production process of a sheet metal cutting line, factors such as workers, specifications of the machines and slitting process parameters (such as cutting length) are considered.
Simulating the production process of a metal cutting line can help identify possible problems such as wear of cutting knives, excessive force on the material, displacement of knives from specified positions, etc. Simulation can be used to adjust process parameters, improve the quality of sheet metal cuts and reduce waste.

KEYWORDS: modelling, simulation, production process, slitting line

1. Introduction

Present paper refers to modeling and simulating the production process of a metal cutting line, with the main purpose of identifying inefficient activities and optimizing the parameters involved by simulating various production scenarios. This study is also based on two internships carried out by the author at *voestalpine Steel Service Center Romania* which is globally leading steel and technology group with a unique combination of materials and processing expertise (500 companies in the group, 50 countries, 5 continents), with an annual production capacity of 130,000 tons (over 2 million tons globally), the lines within this company having a limit of 35 tons per coil, processing material with thicknesses between 0.3 and 6mm, the unrolled rolls having lengths averaging 4000m. For packaging, only 60% of orders use standard euro-pallets, the company having advanced logistics solutions through which pallets are produced for atypical orders so that a variety of products can be manufactured and delivered according to customer specifications.

Fig. 1 Metal slitting line from Fagor Arrasate company [7]

The production process of a metal slitting line is a manufacturing process used to cut large rolls of sheet into narrower strips. The process involves feeding a sheet coil through a slitting machine, which is equipped with circular blades set to the desired width. The blades cut the sheet into strips, which are then wound onto separate rolls. This process requires lines of machines equipped with a coil unwinding machine, a sheet leveling machine, a sheet cutting machine, and a sheet rewinding machine into rolls.

2. Model Definition

The formulated model refers to the activities of the plant where the processes of metal slitting and cut to length are carried out.

Fig. 2 Industrial factory of *voestalpine Steel Service Center* [4]

From an equipment standpoint, two sheet cutting lines are used: one line is for cutting steel rolls into narrower width coils (slitting), while the other is for cutting steel coils into sheet at a specified length. The supplier of these lines is Fagor Arrasate, along with other equipment used in the company, such as packaging systems, the system for handling stored coils, automated quality control tools, etc.

From a shift perspective, the activity is carried out in two shifts, from 6:00 a.m. to 2:00 p.m. and from 2:00 p.m. to 10:00 p.m. In principle, both lines are used at maximum capacity in the first shift, with the steel cut to length line being used the most in the second shift.

From a human operator standpoint, due to the degree of automation in the processes, operators are primarily needed to adjust the machine parameters according to the customer order specifications. The role of the semi-finished products obtained by cutting steel coils into narrower coils and/or sheets is very important because they meet the needs of industries such as automotive, construction, or where cold plastic deformation processes such as stamping and/or deep drawing are used, using such semi-finished products as raw materials.

In order to model a metal cutting line, the following simplifying assumptions have been applied: the materials are uniform, without defects or major deformations, the sheet loading process is automated and does not require human intervention to be executed, cutting is done in a single pass, all measuring and control devices are compliant, and the resting times and needs of human operators are neglected.

To model the sheet cutting process, the following set of variables and parameters will be used: the length of the sheet (L) - variable, the width of the sheet (W) - variable, in accordance with the limits of the line, the thickness of the sheet (T) - variable, in accordance with the limits of the line, the weight of the sheet (G) - variable, depends on the properties of the coil, the sheet loading speed - parameter of the coil-unfolding machine, the cutting speed - parameter of the sheet cutting machine, the speed of retrieving the resulting sheets - parameter of the automatic sheet retrieval and packaging system. The process times are as follows: the time for changing the coil to be cut, the time for unfurling the coil, the cutting time, the time for evacuating the piles of sheets from the material flow zone, the total cycle time. [5]

The model uses the following variables and parameters: the total length of the sheet obtained from the steel coil, the width of the sheet, the thickness of the sheet, the number of cuts, the minimum and maximum cut length, the maximum height of the stack of the resulting sheets, the maximum weight supported per stack of sheets, the material's tensile strength, density, and weight of the sheet.

Based on practical experience from internships, the following simplified model has been developed:

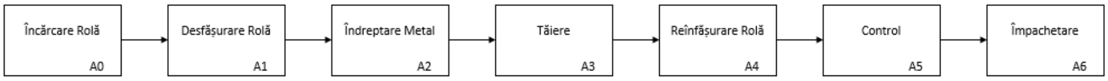

Fig. 3 IDEF diagram of the metal slitting process

Since the coil can be straightened immediately after enough metal has been unwound so that it can be taken over by the straightening machine, and, analogously, the metal can begin to be cut from the moment enough material from the straightening machine of the line has reached the cutting machine (where there are specialized circular knives for cutting the metal), a simplified diagram of the process flow has been created.:

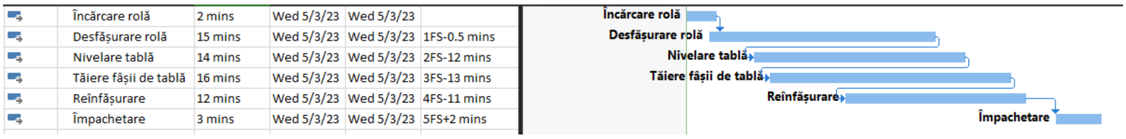

Fig. 4 Diagram of operations in the process of metal slitting.

3. Data Acquisition and Analysis

Based on the author observation and analysis from internships at the company *voestalpine Steel Service Center România*, through direct contact with the production process flow and with information received from the company's experts, information regarding the production cycle have been gathered.

For the slitting line, Table 1 presents the operations and resources required for the relevant metal slitting production process.

Table 1. Metal slitting process

Operation	Machine	Operator
Loading of coil	Coil Entry Machine	Line Entry Operator
Uncoiling of coil	Decoiler Machine	Primary Operator 1 or 2
Straightening of coil	Straightener Machine	Primary Operator 1 or 2
Cutting of coil into narrower coils	Slitter Machine	Primary Operator 1 or 2
Rewinding of sheets back into coils	Recoiler Machine	Primary Operator 1 or 2
Packaging	Automated Packaging System	Packaging Operator

For the steel coil cutting line, Table 2 presents the operations and resources required for the production process of the metal slitting line.

Table 2. Metal cut to length process

Operation	Machine	Operator
Coil loading	Coil entry machine	Line entry operator
Uncoiling	Uncoiling machine	Main operator 1 or 2
Straightening	Straightener machine	Main operator 1 or 2
Sheet cutting	Sheet cutting machine	Main operator 1 or 2
Packaging	Automated packaging system	Packaging operator

4. Simulation Software

In order to simulate the production process of a metal slitting line, the Siemens Tecnomatix Plant Simulation 2201 simulation software tool was chosen. The main features of the production system simulation software tool are: the capabilities to synchronize the simulated process with a real factory (Digital Twin) [6], the capabilities to navigate through well-structured hierarchical 3D models of production facilities using high-performance virtual reality equipment such as SteamVR, Oculus Rift, Windows Mixed Reality, etc., integration into an open system architecture for compatibility with interfaces and integration capabilities, such as ActiveX, C, CAD, COM, JSON, ODBC, Oracle SQL, Socket, XML, etc., free analysis and experimentation through built-in tools and graphical outputs for evaluating the performance of production systems, including automatic obstacle detection, output analysis, machine capabilities, resource utilization, energy consumption, cost analysis, Sankey and Gantt diagrams. Tecnomatix Plant Simulation

2201 uses integrated experiment management tools and neural networks to enable comprehensive experiment development and automatic system optimization through genetic algorithms. [8] The necessary steps for modeling representation are as follows: acquisition of process and resource information, defining machines and their parameters (auxiliary, basic, preparation-conclusion, maintenance times, etc.) and connecting them based on process sequence, defining workstations and required competencies, defining human resources, assigning human resources to machines, updating CAD machine models (current stage). The data resulting from the Tecnomatix Plant Simulation 2201 program has a variety of representations, the most common being the Chart type.

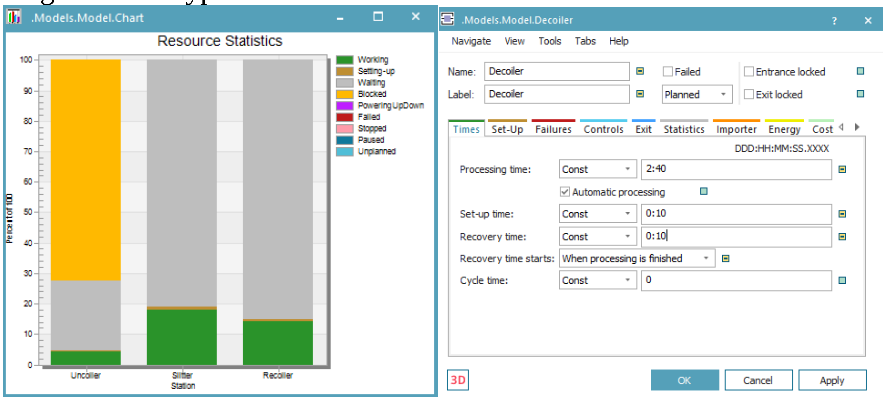

Fig. 5 Representative data for resource usage in simulation and machine parameter editing dialog

The current stage of the simulation does not yet take into account random variables, machine maintenance times, order variations, etc.

The proposed model was chosen based on the practical experience stage at *voestalpine Steel Service Center Romania* and simplified in a form that allows highlighting the stages of the sheet cutting process. The simplified model of the sheet cutting line in Figure 5 consists, in the following order, of a source (representing the system for retrieving coils from the warehouse to the feeding point of the line), the coil unwinding machine, a representation of the accumulated area of the unwound material, the sheet cutting machine, the waste collection machine, the resulting coil rewinding machine, and a Drain object, which replaces the automated packaging area of the production line.

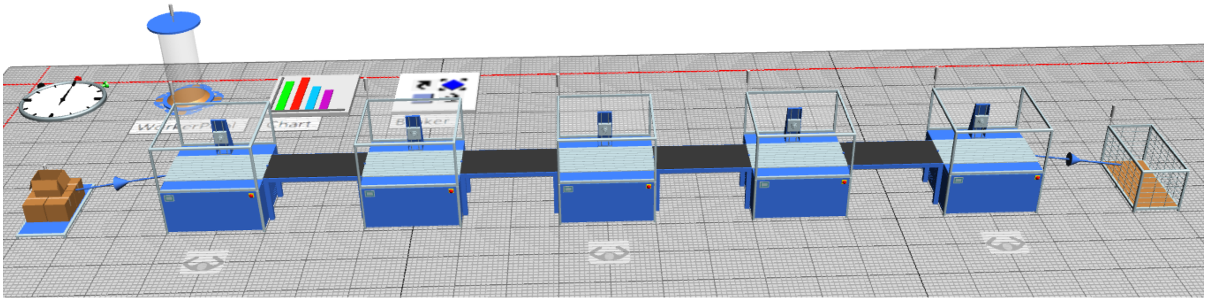

Fig. 6 Simplified model of a metal slitting line.

Based on the simplified model and by using CAD models for the CINSER company's steel slitting line obtained from online sources, relevant initial parameters for the simulation were established. The model was reconfigured so that the placement and parameters of the machines were in accordance with the real model present in the section where the practical stages were carried out. In order to configure the machines with customized graphical representations, the CAD files were imported using the Import Graphics function, and then the graphic model was transformed into a processing station (Make Simulation Object), for which specific machine parameters were established (times, resources, predecessors, etc.).

The machines in Figure 6 are the following: 1 - coil feeding machine, 2 - coil conveyor, 3 - coil unwinding machine, 4 - sheet leveling machine, 5 - coil cutting machine, 6 - automatic packing system for the resulting stacks of sheet coils.

The current research is limited by the fact that simulation programs, despite being a valuable tool for decision-making, is only utilized to a limited extent. This is considered a drawback as these programs have the potential to enable analysis and optimization of all production logistics processes, including interoperation storage and transport, among other possibilities [3].

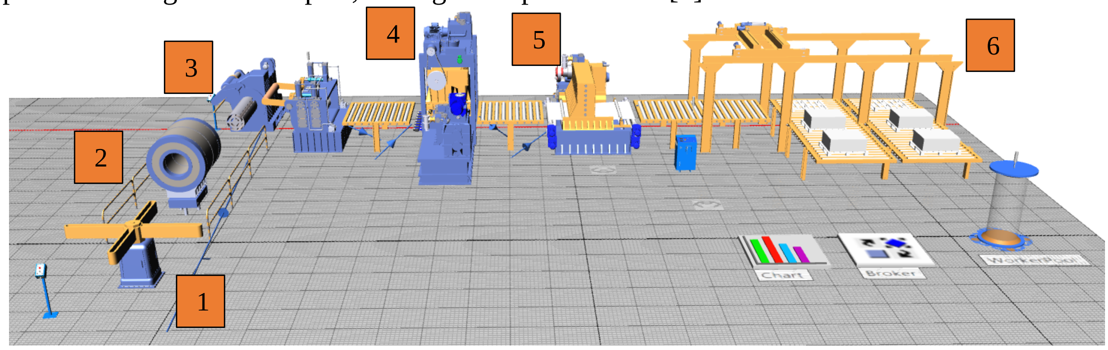

Fig. 7 Model based on CAD files from CINSER's cut to length line

5. Planning and Running the Simulation

The method of choosing the variation intervals for the input variables: based on the information obtained during the internship period along with the formulas used for estimating process times, the following variation intervals were established for a generic order (coil weight: 25t, coil width: 1000mm, sheet thickness: 0.4mm, material: cold-rolled steel, cutting length: 1m):

1. Line feed speed: taking into account that the maximum speed of a cutting line from Fagor Arrasate company is 120 m/min, a speed of 100 m/min will be chosen since the chosen material is considered defect-free and has a thickness of 0.4mm, which facilitates cutting at high speeds.
2. Feed speed (or cutting speed): this must be chosen based on the desired cutting length and the set feed speed, using incompatible settings can lead to waste because the time required for the cutting to be successfully completed must be taken into account. Since the selected cutting length is 1m and the sheet cutting machine can perform a maximum of 180 cuts per minute [7], a cutting speed of 100 cuts per minute will be chosen to synchronize the feed with the cutting and avoid adding idle times.
3. Pressing force: this must be chosen according to the thickness of the material to ensure precise cutting (according to specifications). Since a 0.4mm thick steel coil is used, a pressing force of 10 tons will be chosen.

6. Analysis and Interpretation of Results.

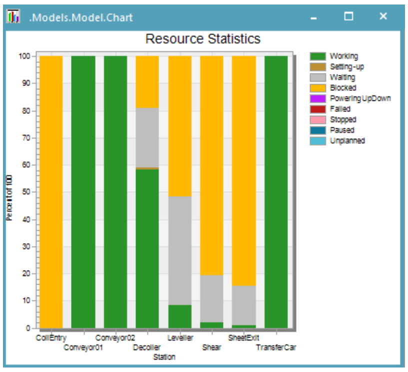

Fig. 8 The resulting data regarding the resource utilization within the simulation

According to the graph in figure 5, the following specifications were concluded regarding the current stage of the simulation model:

1. The Coil Entry object (source object, which simulates the entry of new coils into the system) was 100% blocked throughout the simulation, which is impossible to achieve in practice due

to the variability of orders and waiting times for coils to arrive from the warehouse to the processing line.

2. Conveyor01 and Conveyor02 objects worked at 100%. In reality, they need to rest for a few moments during cutting to ensure the prescribed cutting precision, automatically by the machine's sensors.
3. The Decoiler object, representative of the machine that unwinds the material coil for cutting, worked only 58.33% of the time. In reality, the coil is processed while it is unwound, which suggests that the simulation, at the current stage, does not take this into account.
4. The Leveller object (which simulates the material leveling machine), analogously, was not presented as being in operation throughout the cutting.
5. The Shear object (the cutting machine) was found to have worked only a fraction of the total processing time, which is almost true to reality because cuts are made only once every meter of material.
6. The Sheet Exit object (automatic packaging system) also worked a realistic amount of time, being activated only when the current pallet on which the sheets of metal are sent reaches either the maximum weight of the machine or the maximum weight set by the operator.
7. The Transfer Car object was shown to work constantly during the simulation. In reality, its activation time depends on the distance traveled and the coil loading system's capacity, which is typically four coils.

7. Conclusions

Based on the experience gained during the two internships, the following main stages were identified: the sequence of activities within the processes we observed at voestalpine Steel Service Center Romania was established, the parameters and resources used in the activities of the processes were determined, a simplified model of the process was created based on the real model found in the factory, and the processes carried out in the factory were partially simulated. However, the simulation has the following vulnerabilities: the simulator does not take into account certain real variables, the process needs to be simplified, and the activities cannot be carried out in parallel, the graphical representations are generic. In the near future, the aim is to implement an appropriate graphical representation and accurate simulation of the process. Furthermore, the development of a complete portfolio of useful tools for simulating processes with real materials is desired, so that the Digital Twin functions of the Tecnomatix Plant Simulation 2201 software tool can be used for greater accuracy in simulation, the model can be used within the company, and industry-specific functions of Industry 4.0, such as the Internet of Things (IoT) Engineering, can be implemented.

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RESEARCH CONCERNING THE SUPERFICIAL LAYER AT CLASSIC AND ULTRASONIC AIDED ELECTRICAL DISCHARGE MACHINING

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ASTRACT: The paper deals with a comparative study of superficial layer of CoCr alloys obtained at classic and ultrasonic (US) aided electrical discharge machining (EDM). The machined materials characteristics, the equipment used at laboratory experiments, the working values and the most relevant images of superficial layer provided by scanning electron microscope are presented. Comparative numerical simulation of discharges in case of EDM and EDM+US and their effect on the superficial layer were validated by experimental data.

KEYWORDS: superficial layer, electroerosion, ultrasound, numerical simulation.

1. Introduction

Considering the challenges brought by advanced technologies, electrical discharge machining (EDM) is one of the best alternatives for processing an increasing number of conductive materials with high hardness, non-corrosive and wear-resistant properties [1, 2]. EDM with electrode vibration normal to the processed surface at ultrasonic frequency is characterized by a significant improvement in the main EDM parameters - increased productivity, reduced relative volumetric wear, roughness of the processed surface and the melted and resolidified surface layer [3].

2. The current stage regarding the superficial layer resulting from EDM

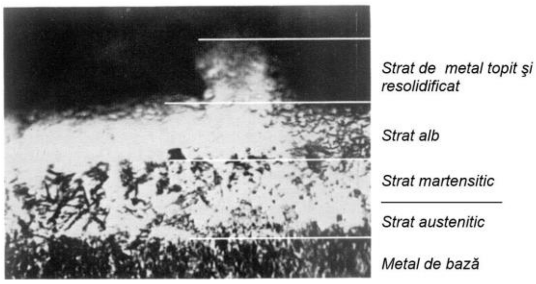


Fig. 1 Surface layer structure, EDM [4]

Surface quality involves both roughness and the structure of the surface layer affected by EDM, namely the thermal influence area. The structure of the surface layer is represented by the austenitic layer, the martensitic layer, the white layer, and the melted and resolidified metal layer - Fig. 1 [4].

Following an electrical discharge, a crater is formed. The material remaining in the craters resolidifies and is called the white layer because it has this color when viewed under a microscope. It is not chemically attacked by usual agents (e.g. nital). [5]. It exhibits numerous micro-cracks as a result of exceeding the rupture strength caused by the thermal shock generated by discharges. Further down, a high surface hardness martensitic layer is encountered (about 1000 HV at a depth of 25 µm) followed by an austenitic layer, typical hardening constituents resulting from the rapid heating and cooling process of EDM. Ultrasonic assistance (US) in EDM finishing (EDM+US) significantly reduces the white layer and hence internal stresses (by about 50%), increasing fatigue resistance (2...6 times) [4].

3. Characteristics of processed CoCr alloys and equipment used

In general, Co-Cr alloys can be described as alloys with high wear and temperature resistance, non-magnetic, with excellent biocompatibility, corrosion resistance, and a high elastic modulus, which also ensures appropriate rigidity [6]. The chemical composition of the two alloys chosen for the study, named System NE and System SOFT, is presented in Table 1, and the mechanical characteristics that influence the layer of solid material removed by US are shown in Table 2.

Table 1 Chemical composition of CoCr alloys [7]

Alloy	Cr [%]	Mo [%]	W [%]	Nb [%]	Si [%]	Mn [%]	Fe [%]	Co [%]
P1, SYSTEM NE	21,0	6,5	6,4	-	0,8	0,65	<0,1	64,4
P2, SYSTEM SOFT	29,5	5,7	-	-	0,95	0,55	0.75	61,8

Table 2. Mechanical characteristics of CoCr alloys [7]

Alloy	Ultimate tensile strength [MPa]	Young modulus [GPa]	Yield strength [MPa]	Break elongation [%]	Rigidity [HV]
P1, SYSTEM NE	850	155	580	3	460
P2, SYSTEM SOFT	447	160	450	15	310

Figure 1 shows the working head of the EDM ELER 01 machine, located in the laboratory of the FIIR faculty, TCM department, UPB, on which an ultrasonic chain was mounted, with a copper disc electrode-tool at the end. The cylindrical-shaped samples of the two alloys were machined at one end using conventional EDM and at the other end using EDM in an ultrasonic field, in order to observe and compare the resulting surface layer obtained using the two methods - see Figure 2.

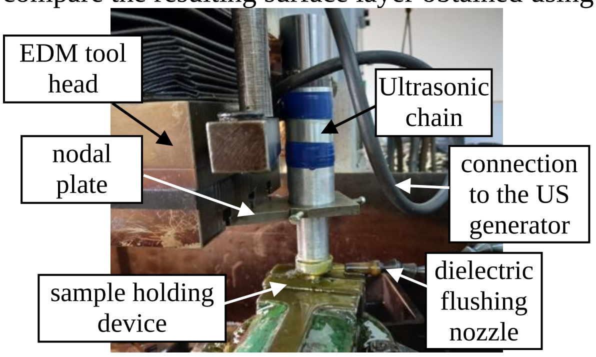


Fig. 2. The tool head of the ELER 01 machine and the US chain mounted on it

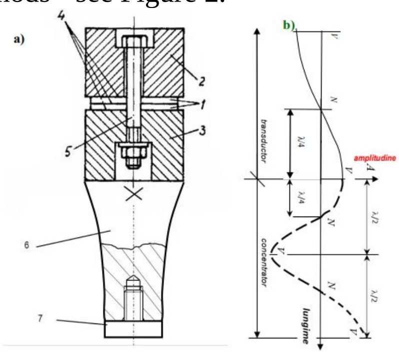


Fig. 3. Ultrasonic chain and standing waves formed within it [3]

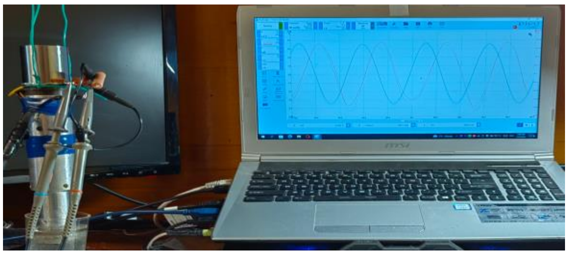


Fig. 4. Determination of the natural frequency (f0=19.21 kHz) of the ultrasonic chain and adjustment of the generator at resonance

The US chain, fig. 3.a, presents a transducer with piezoceramic plates 1 that change their dimensions, connected in a variable electric field given by a US generator, transmitting vibrations, standing waves, fig. 3.b along the US chain. The transducer also includes the reflecting bushing (2), Cu blades (4) for connection to the US generator, the radiating bushing (3) and the screw (5) that assembles the pre-stressed transducer components with 8-10 tf. The amplification of US oscillations is achieved through the horn 6, at the end of which the tool 7 is located (positioned in the antinode). The natural frequency, f_0=19.21 kHz, of the US chain was determined and the US generator was adjusted to the same frequency to obtain resonance - fig. 4.

4. Experimental data regarding the obtained surface layer

The distribution of chemical elements in the surface layer structure of the processed alloys is presented in fig. 5, System NE and fig. 6, System Soft. This was obtained with the EDAX system, generating X-rays from samples processed by scanning with the electron beam of the SEM QUANTA INSPECT F50 - UPB microscope, with a resolution of 1 nm. A reduction in the depth of the C-enriched layer was observed due to the US effect, by collecting a larger amount of melted material by breaking the gas bubble formed around the plasma channel of the discharge at the end of a US oscillation.

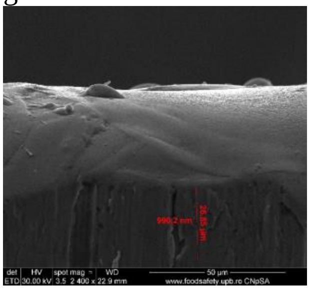
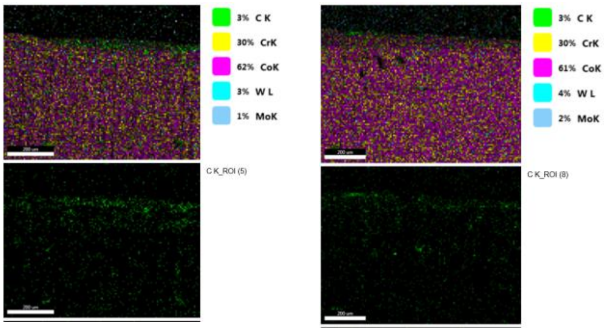


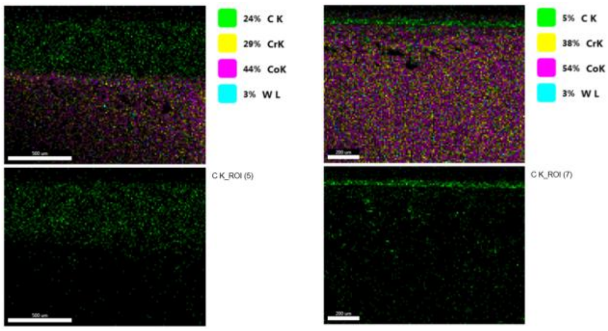
Fig. 5. Microcrack for EDM+US System NE

Thus, for the System NE alloy, the thickness of the layer with significant C content (green color) is approximately 200 µm for classic EDM and approximately 100 µm for EDM+US - see the white reference point, Fig. 6; it was machined with a current I=12 A and pulse time ti=95 µs, while the power of the US generator was Pus=80 W. In the case of the System Soft alloy, the thickness of the layer with high C content is 500 µm for classic EDM and approximately 50 µm for EDM+US - see the white reference point, Fig. 7; it was machined with I=12 A and ti=24 µs, Pus=80 W. This layer with microcracks, produced by the thermal shock of the EDM discharge (Fig. 5) called the white layer, is greatly reduced in the case of EDM+US.



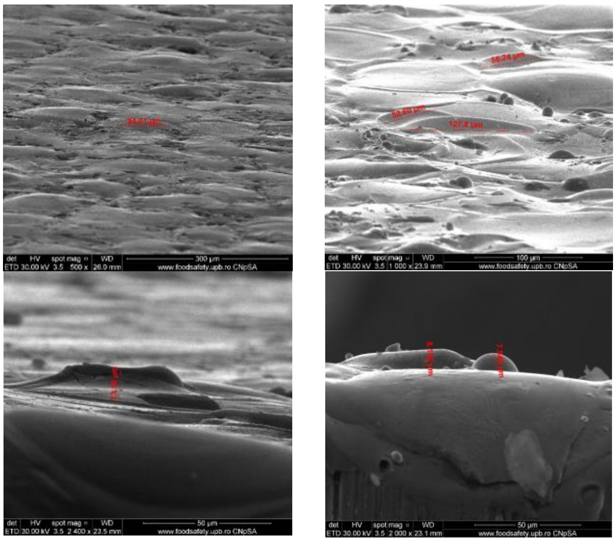
a. System NE - EDM b. System NE - EDM+US

Fig. 6. Repartition of the chemical elements in the composition of System NE in the structure of the superficial layer.



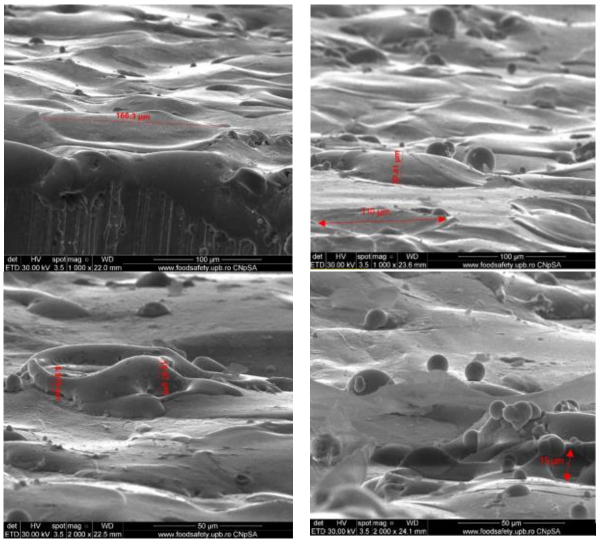
a. System Soft - EDM b. System Soft - EDM+US

Fig. 7. Repartition of the chemical elements in the composition of System SOFT in the structure of the superficial layer.



a. System NE - EDM b. System NE - EDM+US

Fig. 7. Microgeometry of the machined surface at System NE; dimensions of craters (top) and protrusions (bottom)



a. System Soft - EDM b. System Soft - EDM+US

Fig. 8. Microgeometry of the machined surface at System SOFT; dimensions of craters (top) and protrusions (bottom)

The images of the microgeometry of the machined surface obtained with the same SEM microscope at the same processing parameters as before are presented comparatively in Fig. 7, 8. It can be observed that for both materials, at EDM+US compared to EDM, the dimensions of the craters are smaller, and the height of the protrusions is higher for System Soft (lower mechanical resistance to US action) compared to System NE.

5. Numeric simulation of the classic and ultrasonic electrical discharge machining

To study the material removal mechanisms in EDM+US, Comsol Multiphysics was used in 2D axisymmetric space, with the Heat Transfer in Solids module for the EDM component and the Solid Mechanics module for the US component, both time-dependent. The following steps were taken:

(1) Parameterization of the thermal and mechanical models for both materials studied, fig. 9, 10;

Name	Expression	Description
hp	15[mm]	inaltime piesa de proba
rp	4[mm]	raza piesei de proba
I	12	treapta de curent
tif	95e-6	timp de impuls final
acr	47e-6	raza crater initial
bcr	4*Ra	adancime crater initial
rms	0.8e-6	raza material resolidificat
rbg	0.1[mm]	raza bula gaz
Ra	5.5e-6	Ra suprafata prelucrata

Name	Expression	Description
TfCoCr	3000	Temperatura de fierbere [C]
TmCoCr	1330	Temperatura de topire [C]
rcp	1e-6*2.16*I^0.43*(ti*1e6)^0.44	raza canal plasma dependenta de timp
ti	0	timp impuls baleiat
a	1e-6	raza initiala canal plasma
tus	1e-6	timp solicitare US
pus	120[MPa]	presiune ultrasonica
sigmar	850[MPa]	rezistenta la rupere statica NE
tau0	211.2	rezistenta la oboseala forfecare NE

Fig. 9. Model parameters System NE

Name	Expression	Value	Description
hp	15[mm]	0.015 m	inaltime piesa de proba
rp	4[mm]	0.004 m	raza piesei de proba
I	12	12	treapta de curent
tif	24e-6	2.4E-5	timp de impuls final
acr	83e-6	8.3E-5	raza crater initial
bcr	4*Ra	2.2E-5	adancime crater initial
Ra	5.5e-6	5.5E-6	Ra suprafata prelucrata
rms	0.8e-6	8.0E-7	raza material resolidificat
rbg	0.3[mm]	3.0E-4 m	raza bula gaz

Name	Expression	Description
TfCoCr	3000	Temperatura de fierbere [C]
TmCoCr	1330	Temperatura de topire [C]
rcp	1e-6*7*I^0.43*(ti*1e6)^0.44	raza canal plasma dependenta de timp
ti	0	timp impuls baleiat
a	1e-6	raza initiala canal plasma
tus	1e-6	timp solicitare US
pus	120[MPa]	presiune ultrasonica
sigmar	447[MPa]	rezistenta la rupere statica SOFT
tau0	133.8	rezistenta la oboseala SOFT

Fig. 10. Model parameters System SOFT

(2) The geometry (EDM), time-dependent plasma channel radius - fig. 11); (3) Meshing - fig. 12;

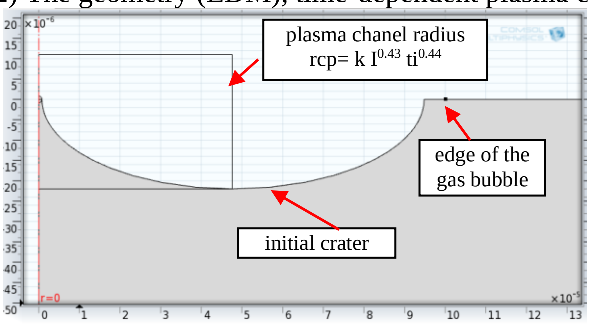


Fig. 11. Geometry of the models in the area of interest

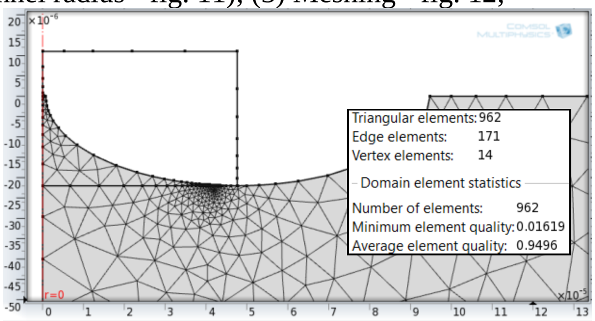


Fig. 12. Discretization, statistics and their quality

(4) Introducing material characteristics for System NE alloy - fig. 13 and System Soft - fig. 14;

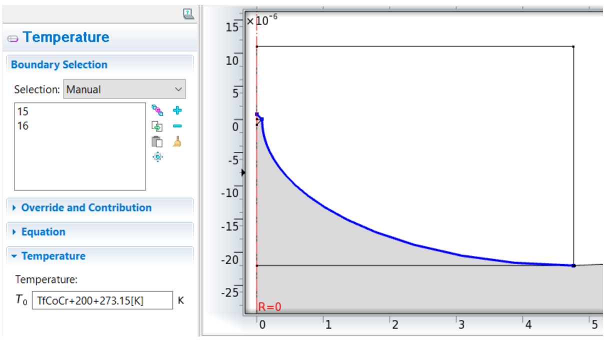
	Property	Name	Value	Unit
✓	Thermal conductivity	k	14.5	W/(m*K)
✓	Density	rho	8400	kg/m^3
✓	Heat capacity at constant pressure	Cp	390	J/(kg*K)
✓	Young's modulus	E	155[GPa]	Pa
✓	Poisson's ratio	nu	0.3	1

Fig. 13. Material characteristics, System NE

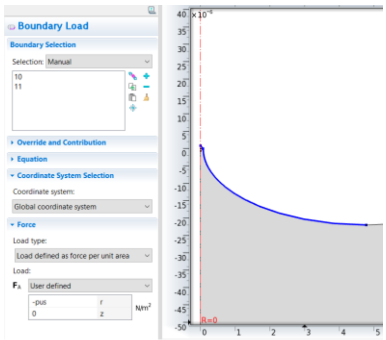
	Property	Name	Value	Unit
✓	Thermal conductivity	k	13.08	W/(m*K)
✓	Density	rho	8250	kg/m^3
✓	Heat capacity at constant pressure	Cp	390	J/(kg*K)
✓	Young's modulus	E	160[GPa]	Pa
✓	Poisson's ratio	nu	0.3	1

Fig. 14. Material characteristics, System SOFT

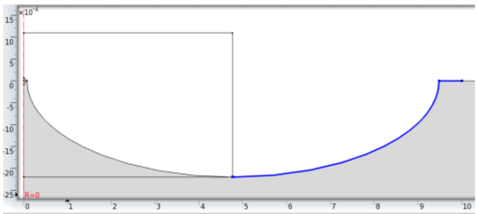
(5) Introducing boundary conditions for the thermal module - fig. 15 and the mechanical module - fig. 16



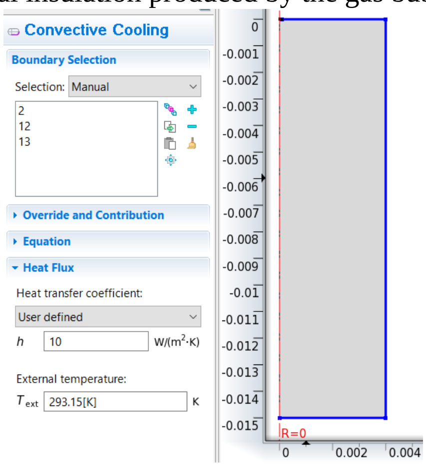
a) temperature at the EDM spot, time-dependent radius



a) cyclic load of the ultrasonic pressure

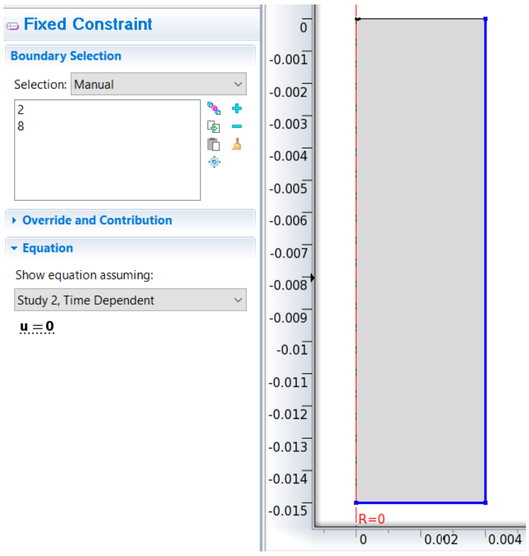


b) thermal insulation produced by the gas bubble



c) convective cooling - workpiece in contact with dielectric

Fig. 15. Boundary conditions - thermal module - EDM



b) fixed surfaces of the workpiece - holding method

Fig. 16. Boundary conditions - mechanical module - US

6. Numerical simulation results

A single discharge was simulated with the thermal module under classical EDM conditions, obtaining the temperature distributions shown in figures 17 and 18. These show the position of the boiling isotherm at the end of the pulse time, which delimits the volume of material removed, according to the overheating model [8]. Values for radius (red arrow) and depth (blue arrow) are validated by real data.

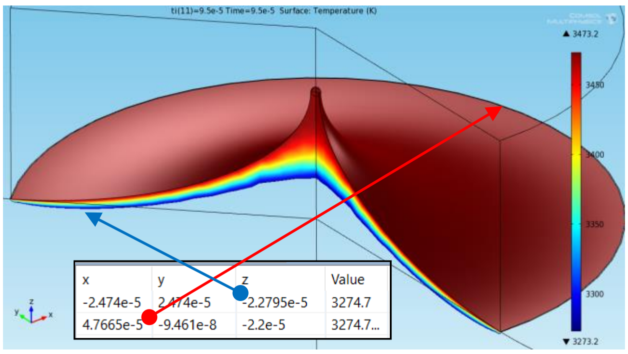


Fig. 17. Boiling isotherm at ti=95 µs, System NE

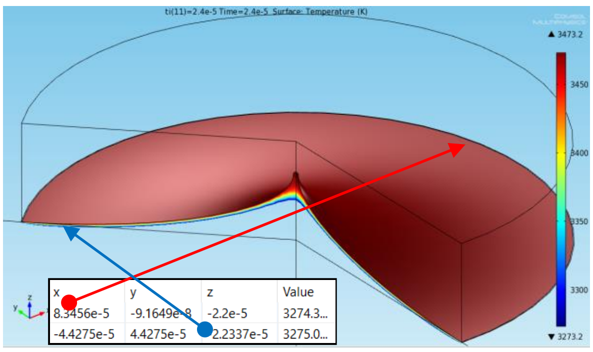


Fig. 18. Boiling isotherm at ti=24 µs, System SOFT

Running the thermal module under EDM+US conditions shows the position of the melting isotherm - fig. 19, 20. The implosion of the gas bubble formed around the plasma channel of the discharge at the end of a US oscillation period allows the dielectric liquid to access the EDM spot area, removing the material delimited by the melting isotherm [8]. Thus, the thickness of the white layer, which comes from the C-enriched melted material of the discharge, becomes much smaller under EDM+US conditions. The probability that the US waves will remove all the melted material is around 30% [8]. For this to happen, the end of the US period (Tus) must overlap with the duration of the discharge. For the remaining craters where removal occurs through boiling (the discharge does not overlap the end of Tus), the mechanical material removal caused by the shock waves of the US cavitation, which generate pressures of the order of 100 MPa, acts - fig. 21, 22.

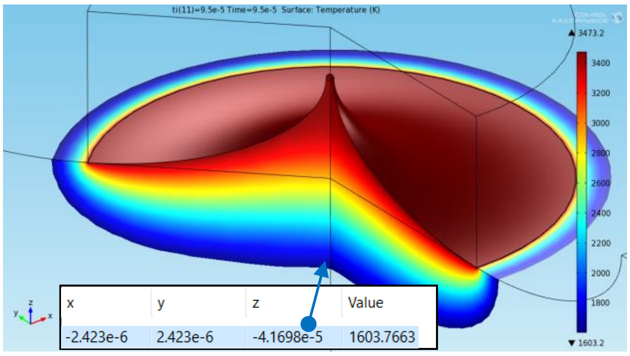


Fig. 19. Melting isotherm at ti=95 µs, System NE

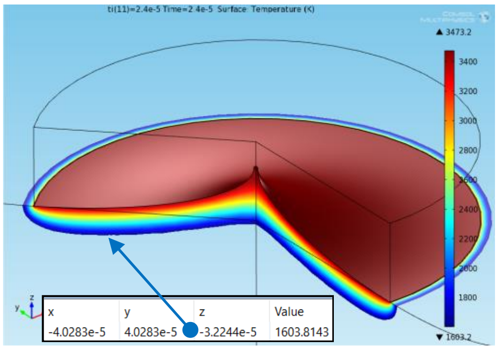


Fig. 20. Melting isotherm at ti=24 µs, System SOFT

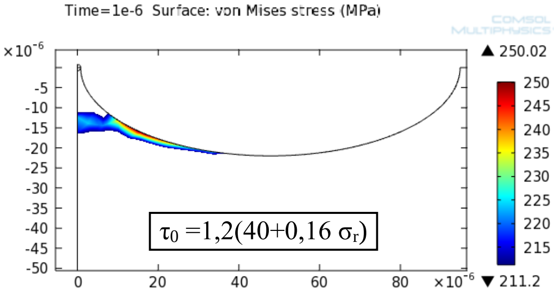


Fig. 21. US removal at System NE, τ_0 = 211.2 MPa

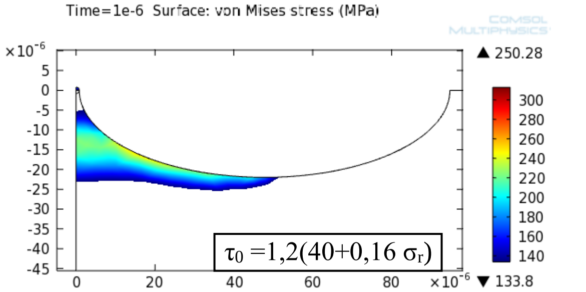


Fig. 22. US removal at System SOFT, τ_0 = 133.8 MPa

7. Conclusions

A numerical simulation of the thermal and mechanical material removal during EDM+US was performed, compared to classical EDM, and validated by experimental data. The ability of US to reduce the superficial white layer containing microcracks is highlighted. The reduction is greater in the case of CoCr alloy System SOFT, compared to System NE, due to lower mechanical resistance to cyclic shear stress produced by the ultrasonic cavitation at the end of Tus period. Future research will focus on minimizing the white layer through EDM+US and determining the processing regime, with the key parameter being the ultrasonic pressure (Pus), which is adjusted by the power from the US generator.

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RESEARCH AND APPLICATIONS ON ORIENTATION AND FIXING OF THIN-WALLED PARTS IN INDUSTRIAL CNC MACHINING SYSTEMS

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ABSTRACT: Precise machining of thin-walled parts such as aircraft components often made of aluminium or composites is critical for achieving the necessary dimensional accuracy and surface quality. However, the inherent vulnerability of thin-walled structures to deformation or damage during machining necessitates the development of orientation and fixing mechanisms to ensure accurate and stable positioning of the components. The paper discusses key elements of fixture design, analyses fixture positioning errors and their implications for manufacturing quality, studies the dynamic characteristics of thin-walled parts, and proposes an orientation and fixing device, with simulated operations for the manufacturing of a thin-walled aero engine component within a CNC machining system. The findings of this study emphasize the importance of fixture design in achieving precise and high-quality machining of thin-walled parts.

KEYWORDS: Thin-walled part, orientation, fixing, fixture design, CNC machining, simulation

1. Introduction

Fixtures are important devices in manufacturing as they hold the workpiece, position it correctly with respect to the machine tool, and support it during machining, directly impacting product quality, productivity, and cost. However, fixturing thin-walled parts is a challenging task, as these parts are susceptible to deformation or damage. Therefore, proper fixture design is necessary to hold the parts securely in place during machining or assembly operations without compromising their integrity. This is done through an extensive technical-economic analysis of interacting factors.

2. General considerations

2.1. Key elements of fixture design

Typically, fixture design involves the identification of locators, support points, and clamps, and the selection of the corresponding fixture elements for their respective functions. There are four main stages within a fixture design process: setup planning, fixture planning, fixture unit design and verification, as Fig. 1 illustrates [1].

A setup represents the combination of processes that can be performed on a workpiece without having to alter the position or orientation of the workpiece manually. During setup planning, workpiece and machining information are analysed to determine the number of setups required to perform all necessary machining operations and the appropriate locating datums for each setup [2].

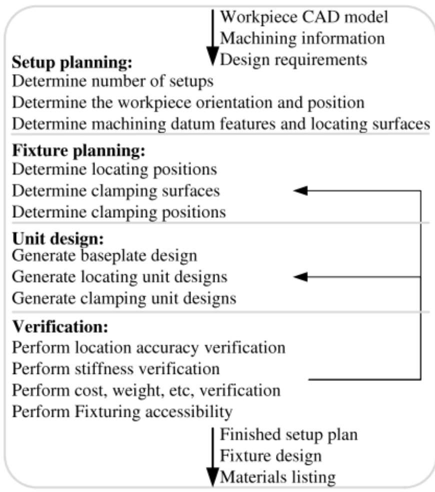


Fig. 1. The basic elements of the fixture design process [1]

During fixture planning, the surfaces, upon which the locators and clamps must act, as well as the actual positions of the locating and clamping points on the workpiece, are identified [1]. The number and position of locating points must be such that a workpiece's six degrees of freedom (Fig. 2) are adequately constrained during machining [2].

In the third stage of fixture design, suitable units, i.e., the locating and clamping units, together with the base plate, are generated. During the verification stage, the design is tested to ensure that all manufacturing requirements of the workpiece can be satisfied. The design also has to be verified to ensure that it meets other design considerations that may include fixture cost, fixture weight, assembly time, and loading/ unloading time of both the workpiece and fixture units [1].

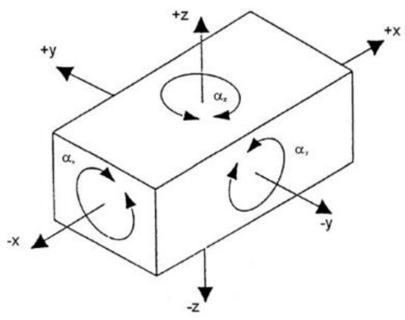


Fig. 2. The six degrees of freedom [2]

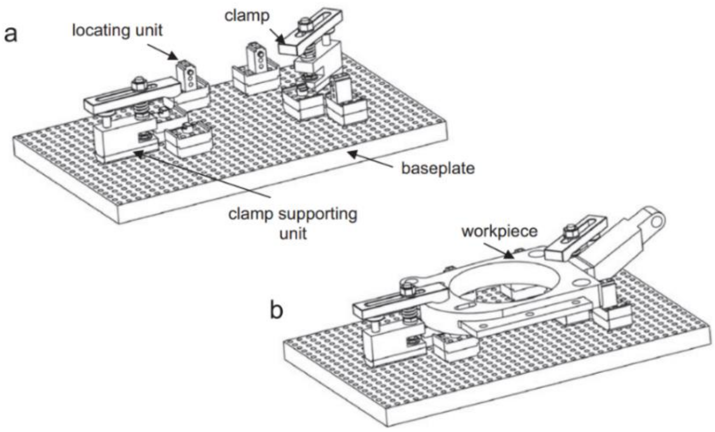


Fig. 3. A typical fixture (a) without and (b) with a workpiece [2]

Typical example of a fixture is presented in Fig. 3. Clamps hold the workpiece against the locators during machining thus securing the workpiece's location.

The locating units themselves consist of the locator supporting unit and the locator that contacts the workpiece. The clamping units consist of a clamp supporting unit and a clamp that contacts the workpiece and exerts a clamping force to restrain it [2].

2.2. Comprehensive analysis of fixture positioning errors and their implications for manufacturing quality

Fixture positioning errors refer to deviations in the placement or orientation of a fixture relative to its intended target or workpiece during machining or manufacturing processes.

The position errors of a thick block and a thin-walled workpiece in a fixture are presented in Fig. 4. In the locating stage, the locating error of the block and that of the thin-walled workpiece are the same δ_1. The difference is that the clamping deformation (δ_2) can be observed on the thin-walled workpiece in the clamping stage [3].

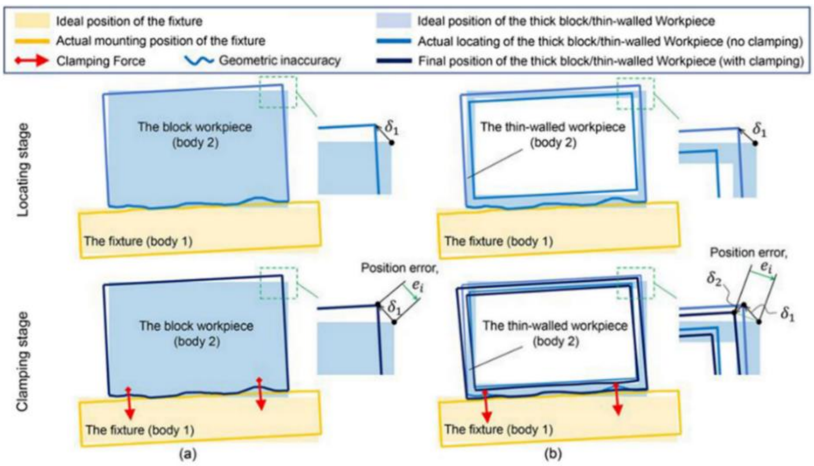


Fig. 4. Schematics of workpiece position error in the fixture emphasizing the key difference in deformation due to the clamping force: (a) thick block and (b) thin-walled workpiece [3]

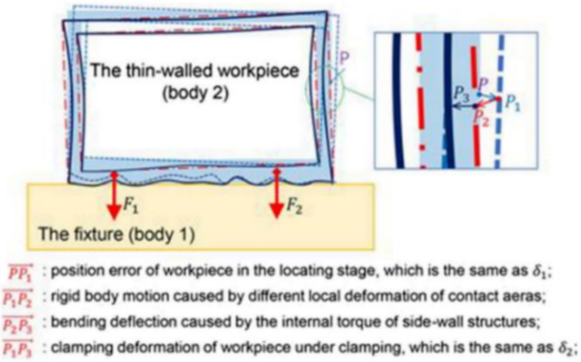


Fig. 5. The workpiece's deformation [3]

Further detailed analysis of the clamping deformation of the thin-walled workpiece is presented in Fig. 5. The position error of any point (P) of the thin-walled workpiece after the clamping stage can be given by [3]:

$$\vec{e_w}(P) = -\left[\vec{\delta_1} + \vec{\delta_2}\right] = -\left[\vec{PP_1} + \vec{P_1P_2} + \vec{P_2P_3}\right] \quad (1)$$

Basically, tolerance represents the upper limit of permissible actual deviation from the nominal characteristic associated with a certain, given characteristic [5]. Inaccuracies in a fixture's location scheme result in a deviation of the workpiece from its nominal specified geometry as shown in Fig. 6. For any workpiece, this deviation must be within the limits allowed by the geometric tolerances specified.

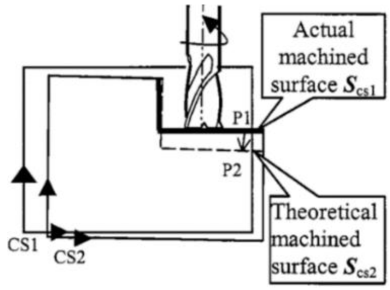


Fig. 6. Machined surface error [4]

2.3. Dynamic characteristics of thin-walled parts and analysis for compensating fixturing and machining errors

Thin-walled parts especially used in aerospace are difficult to machine due to their weak rigidity, complex shape, and structure. This makes the contact interface between tools and workpieces interact strongly. As material is removed during the machining process, the geometric structure of the workpiece changes continuously, leading to time-varying dynamic characteristics of the machining system. This makes it challenging to control the clamping deformation and maintain machining stability [6].

Quantitatively, rigidity, K, is the ratio between ΔF action force variation and ΔU generated deformation variation, i.e.,

$$K = \Delta F / \Delta U \quad (2)$$

where the action force F can be type of: weight, inertia force, fixing/ clamping force, machining/ processing force or a combination/ resultant thereof. The deformation U can be: elastic deformation, plastic deformation, displacement caused by clearences from joints or a resultant thereof [7].

Typical fixture configurations modeled to simulate transient thermo-mechanical analysis and to visualize workpiece non-linear behaviour during the material removal process due to its changing rigidity, in-elastic material properties and flexible fixture contacts are presented in Fig. 7.

Analysis is performed by applying appropriate boundary conditions such as clamping loads calculated using Eq. (3), fixturing constraints, etc. on the fixture-workpiece FEM model [8].

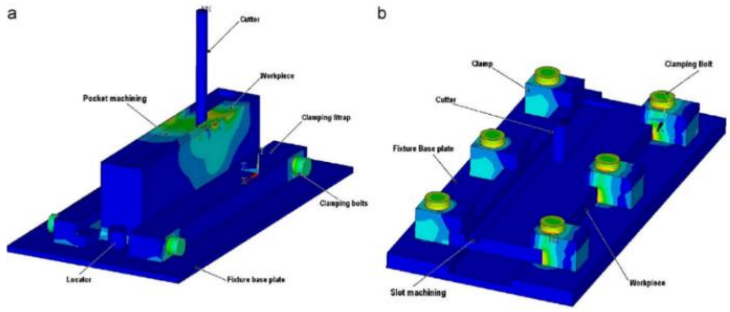


Fig. 7. Developed fixture configurations. (a) Fixturing using strap clamps (b) Fixturing using wedge clamps [8]

$$F_{clamp} = \frac{T}{0.2 * D_b} \quad (3)$$

where F_{clamp} is the clamping force (N), T - the applied torque (Nmm) and D_b the bolt nominal diameter (mm).

During the manufacturing process, clamping forces of active fixtures can be adjusted according to the FEA result to compensate for machining errors, or adjust suitable clamp forces to generate adequate contact forces and pressure distribution at the contact region to keep the workpiece in position during machining [1].

In a particular case, the existing clamping and machining strategy cause large local contact deformations as well as structural deformations of the part. As a result, the workpiece wall thickness and geometry are out of tolerance with poor surface finish. A static analysis is carried out in ANSYS, by modelling fixture elements and workpiece assembly using frictional contacts to investigate the workpiece deformations for various wall thicknesses and clamping pressures [9].

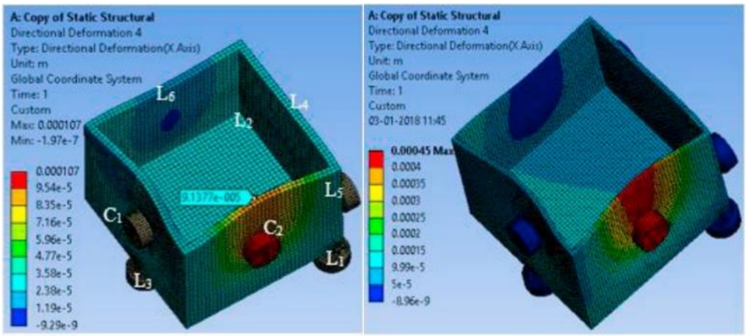


Fig. 8. Static FEA showing deformations of 4.5 mm and 2.5 mm thick workpiece subjected to localized pressure at contact in a 3-2-1 workpiece-fixture system [9]

3. Case study

The case study refers to manufacturing of a thin-walled aero engine part (Fig. 9) within a CNC machining system, with focus on fixture and machining operations design, including simulations.

One technological variant has been developed [7], with respect to the main technical requirements, namely maximum rigidity of the part - fixture subsystem, for minimizing deformation, and ensuring accessibility.

3.1. Fixture design

The proposed fixture design for orientation and fixing of the considered thin-walled aero engine part has been carefully developed based on a comprehensive analysis of the component's geometry, material properties, and machining process requirements.

The fixture design proposal effectively addresses the previously stated challenges posed by the complex geometries and lightweight material properties of the component.

The fixture assembly is shown in the Fig. 10 without a workpiece, allowing for a clear view of its components and construction.


Fig. 9. Part to be machined

Fixture consists of base plate, screws, bolts, nuts and washers [10]. The base plate features a platform shaped to match the external profile of the part, with a slight offset towards the center to prevent tool crashes and minimize friction during machining of features on the bottom side. The device, through its base plate, is securely fixed to the CNC machine table using screws that pass-through counter-bored holes beneath the surface and meet T-slot nuts, providing an unobstructed machining area for the tool.

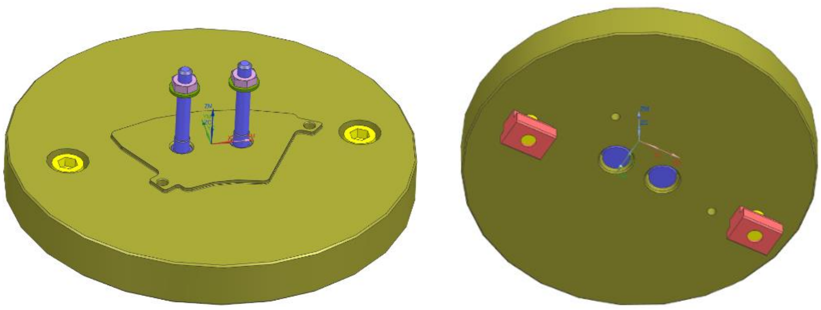
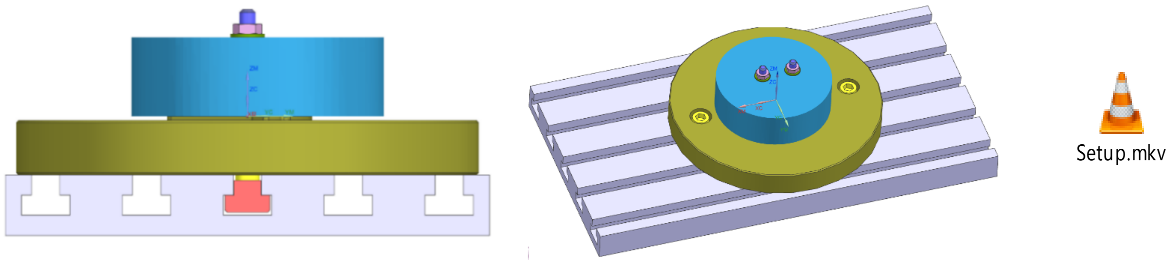


Fig. 10. Fixture without workpiece

Raw material initially went through turning, drilling and boring machinings to be prepared for CNC operations.

The proposed fixture is implemented in the technological machining system for the first two CNC machining operations.

Thus, the workpiece is oriented through bolts and fixed to the base plate using the elements screw-nut, as shown in Fig. 11.



a. b. c.

Fig. 11. Fixture with workpiece (a, b); Set-up (c)

3.2. Technological operations structure and simulations

As the workpiece is subjected to the precision of machining, it undergoes a transformation from its initial cylindrical shape, with the gradual emergence of finely crafted thin walls, until it ultimately achieves the exacting form required.

To achieve this, a machining strategy is employed whereby the workpiece held by bolts in the central area, and the machining process is performed around the center as shown in Fig. 12. A thin wall is retained horizontally in the middle to keep this connection. lt will be removed in the final operation. This approach allows for precise machining of the part while maintaining structural integrity, as the thin wall acts as a support structure.

Operation 1 involves external and internal milling, centering, and drilling processes (Fig. 13, 14). The machined surfaces are indicated with thicker lines.

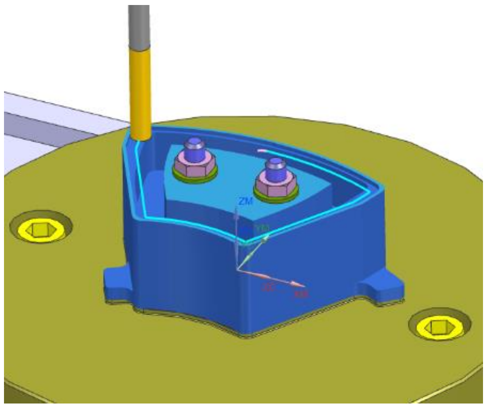


Fig. 12. Machining simulation

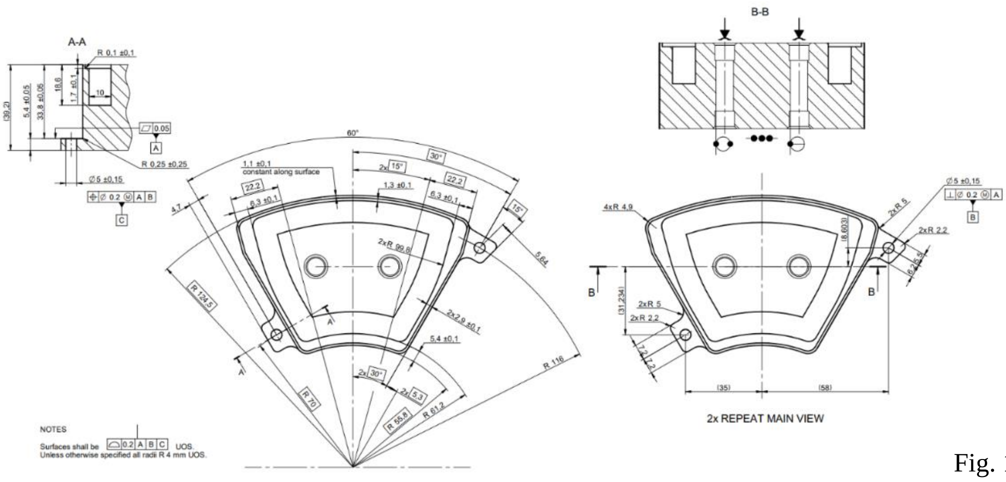


Fig. 13. Technological operation sketch 1

a.

b.

Fig. 14. Simulations:
a- Operation 1; b- Operation 2

In Operation 2, the part is placed upside down and internal pocket is machined, at this point the thin wall appears in the middle (shown in Fig. 14, 15) which will have the connection element role during all operations as previously stated.

After all machining phases including further ones simulated in Siemens NX, and part verified, the program is translated into machine-specific instructions meaningly the G-code is generated by post processing. Once the CAM programming is complete and the machine is set up, the manufacturing process can begin. The CNC machine executes the toolpaths generated by the CAM software to create the physical part.

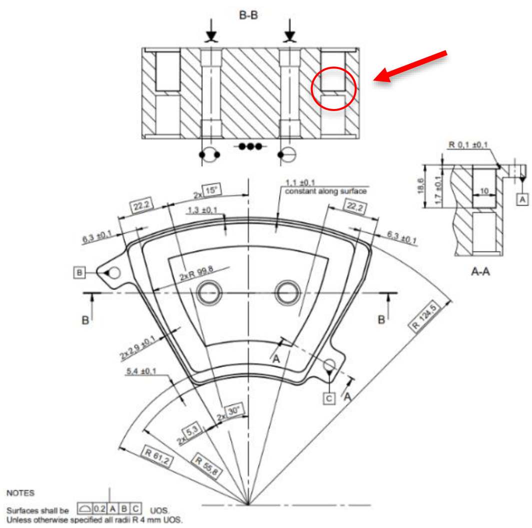


Fig. 15. Technological operation sketch 2

4. Conclusions

This study focuses on the advancements in precision manufacturing through research on orientation and fixing of thin-walled parts. Through analysing fixturing errors and investigating the dynamic characteristics of thin-walled parts, the need for specialized fixture to ensure accurate and stable positioning during machining has been demonstrated.

The proposed fixture design for the manufacturing of a thin-walled aero engine component within a CNC machining system serves as an effective variant of orientation and fixing device. The study's findings contribute to the body of knowledge on fixture design and its impact on manufacturing quality in the aerospace industry.

Furthermore, future research may consider optimizing fixture design with respect to the manufacturing technological process variants to enhance manufacturing efficiency, reduce costs, minimize waste, and improve product quality.

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RESEARCH ON THE DEVELOPMENT OF ROBOTS FOR RECYCLING SYSTEMS AND A CONSTRUCTIVE-FUNCTIONAL APPLICATION

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ABSTRACT: Because of the necessity for physical object sorting, single-stream recycling is currently an exceedingly labor-intensive operation. Soft robotics provides compliant robots which, in a congested environment, use less computing to plan pathways and grab things. Most soft robots, however, are not tough enough to handle the various sharp items found in a recycling center.

KEYWORDS: soft gripper, recycling, sustainability, advanced technology, technological system

1. Introduction

The soft gripper is designed to handle delicate or irregular shaped objects with precision and care, using a flexible, compliant material that securely grips a wide range of items thus being ideal for the recycling processes. The soft gripper design allows it to conform to the shape of the object providing a gentle yet firm hold thus minimizing the risk of damage or breakage. By the use of the advanced tactile sensing capabilities the gripper can adapt to various shapes, sizes and textures, thus being versatile for sorting and handling recycling materials such as paper, plastic, glass and much more materials that come in different size and shapes on the same sorting line.

2. General considerations

2.1. Gripper design and consideration for heavy payload jaw-style/ finger grippers

The parameterization and design of the soft gripper and its process application varies from application to application because of the many interconnected degrees of freedom [1, 2].

When a soft gripper grasps a workpiece a complex contact situation is caused by the actuation force due to the fact that the soft material deforms thus changing the surface area. The modified surface area is affecting the accuracy and holding force of the soft gripper to the specific workpiece, so, the geometry and shape of each jaw/ finger for the soft gripper must be made separately for each grasping situation in the envisioned product scenario in order to have low safety margins and suitable gripper for application. This is also taken into consideration because of the payloads of interests in the envisioned product scenario, and with this, two effects gain importance: first the deformation impacts the achievable assembly accuracy and second the inner forces in the gripper lead to overload or malfunction in elastic structure [1].

2.2. Material selection

A crucial part of a soft gripper is identifying the most suitable material for the jaws based on application. For most soft grippers, the soft material used is polyolefin thermoplastic elastomer, a material that compounds mixtures of various polyolefin polymers, amorphous elastomers and semicrystalline thermoplastics.

The balance in the elastomers composition it is found between polypropylene which is tough and rigid, and the ethylene propylene rubber which is a type of soft, rubbery material made from synthetic rubber. The material is characterized by the following properties:

- Stiffness: the ratio of force to deformation in an object
- Young's Modulus (E): material should be similar to that of soft tissues (E < 10 MPa)
- Toughness (T): total energy that the material can absorb before the material reaches rupture point
- High Degrees of Freedom at impact: the material should be able to deform well beyond what a human tissue can without damaging itself or anything nearby
- Ultimate elongation (γ_{ult}): the material should have a very high ultimate elongation so that even in cases of extreme stretching, it doesn't rupture.

Data for polyolefin thermoplastic elastomer are found in Tables 1-3 [1].

Table 1**.** Properties after Gamma Sterilization of RTP 2800 Series [1]

Material	Sterilization Level (kGy)	Tensile Strength (MPa)	Tensile Modulus @100% (MPa)	Tear (pli)	Shore A Hardness	Yellowness Index
RTP 2800 B-85A	Control	9.4	6.0	263	88	14.03
	25.0–26.1	8.4	5.8	239	86	19.13
	50.8–54.4	7.7	5.7	233	84	19.54
	75.1–76.8	6.9	5.5	218	87	20.42
RTP 2800 B-45A	Control	4.1	1.70	97	54	18.48
	25.0–26.1	3.6	1.59	95	52	21.32
	50.8–54.4	3.2	1.53	84	52	20.61
	75.1–76.8	2.9	1.34	79	51	21.78

Table 2. Residuals after Ethylene Oxide Sterilization and Aging in ExxonMobil Chemical Santoprene Olefinic Thermoplastic Elastomers [1]

Materials	EtO mgs/day		ECH mgs/day	
	1 Day	4 Days	1 Day	4 Days
Allowable limit per ISO 10993-7	20	20	12	12
Santoprene TPV 181-57W180	0.18	0.18	1.554	1.26
Santoprene TPV 281-45MED	0.32	0.18	3.91	1.48
Santoprene TPV 281-64MED	0.40	0.18	4.17	1.78
Santoprene TPV 281-87MED	0.35	0.18	4.13	0.96

Table 3. Effect of Steam Sterilization on Santoprene 281-45 and 281-55 Olefinic Thermoplastic Elastomers [1]

Material Supplier/Name	Santoprene 281-45					Santoprene 281-55				
Exposure Conditions										
Number of cycles	10	25	50	75	100	10	25	50	75	100
Properties Retained (%)										
Ultimate tensile strength	91	68	93	95	91	86	85	84	92	91
Ultimate elongation	103	77	103	101	96	86	81	81	78	80
100% Modulus	88	86	89	95	94	92	95	93	104	99

Depending on the process requirements, we can simulate specific payload of the gripper by means of the response force determined during the simulation. The workpiece adheres to the gripper jaw surface and is securely secured at the start of the simulation. The position is stable at that point, and there are no relative movements between the gripper and the workpiece. When static friction is broken down into sliding friction as a result of imposed displacement (pull-off to pull-out), a relative movement occurs that must be addressed in an application. This phenomenon is typically repeated by the continually enforced displacement and is referred to as stick-slip behavior, which is determined by the surface topology and the elastic/plastic characteristics of the contact surfaces (Fig.1).

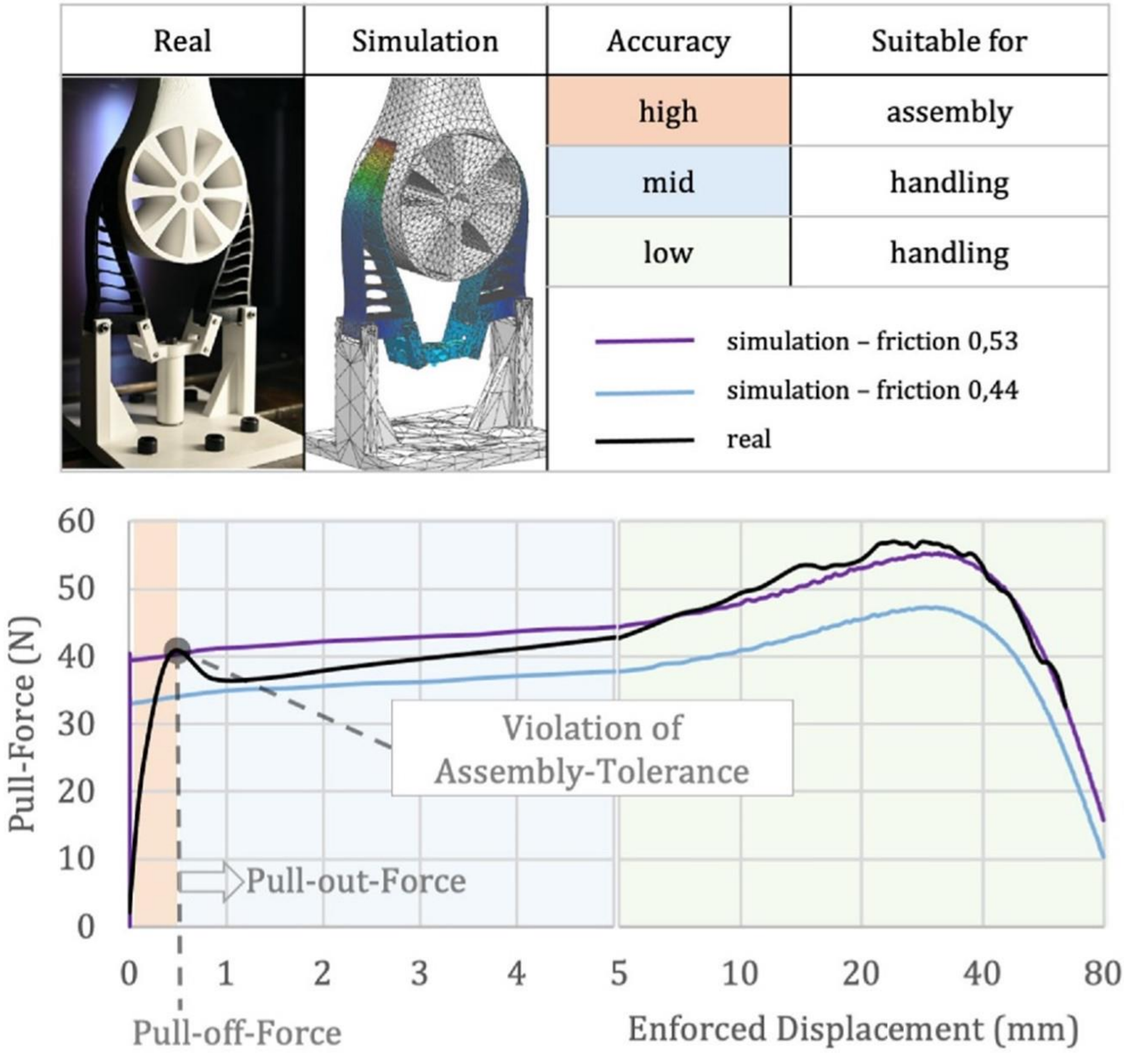


Fig. 1. Pull force and accuracy of soft gripper represented by enforced displacement [3]

Grip simulation assisted in automatically optimizing the configuration in assembly and handling conditions. The projected accuracy margins suit the experiments well enough that experimentation is no longer necessary. Ongoing study focuses on the gripped object's resilience in terms of contour variance (Fig. 2).

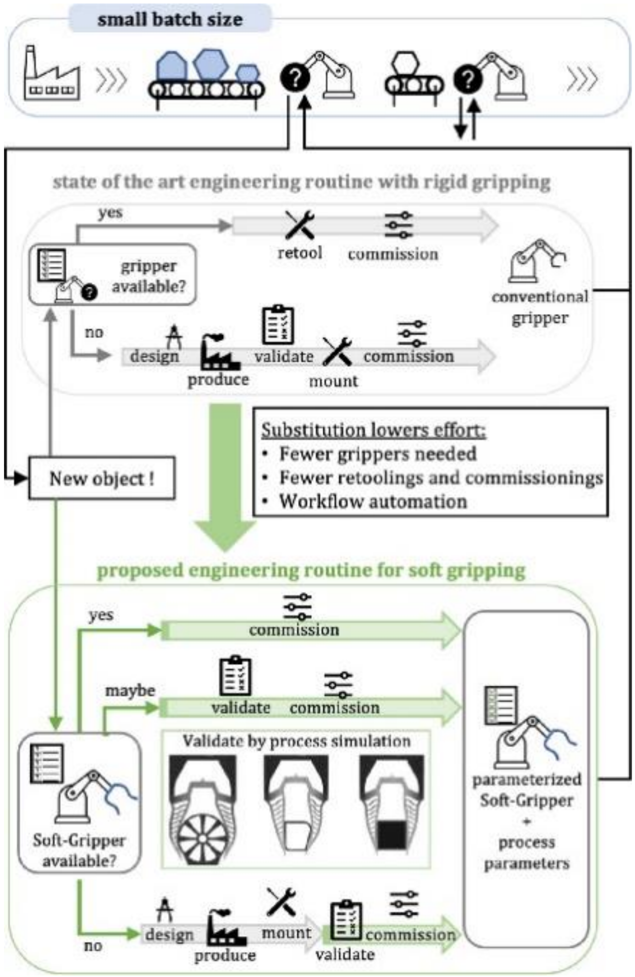


Fig. 2. Structural comparison between rigid gripping processes vs. proposed routine with automated validation for soft gripping [3]

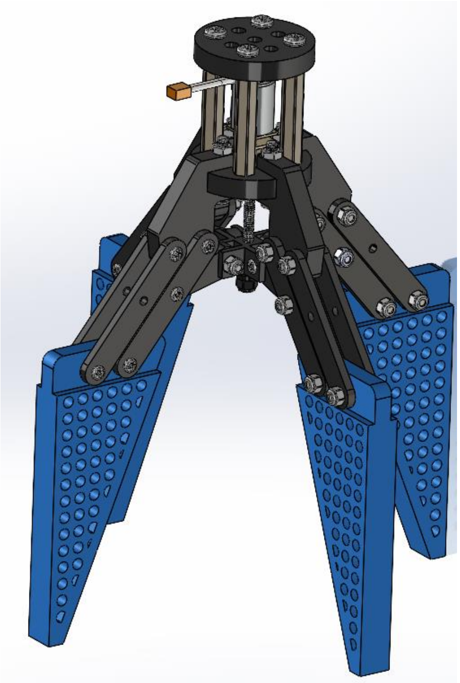
3. Case study

The present study case is concentrated on ways of improving and automatizing the process of sorting recyclable materials by use of robot intervention or independent grippers, as being the Soft Gripper SG 100.

The Soft Gripper SG 100 has been envisaged to be an independent soft gripper, for use in a variety of applications.

The Soft Gripper SG 100 assembly is designed, consisting of identical or distinct components as presented in Fig. 3.

Due to the fact that the recycling industry is in a continuous grow and have many different recycling sectors ranging from paper, cardboard and plastic to tyres, auto shredded residues ASR and so on, the soft gripper can be optimized to the desired application. The base plate is with holes at angular distance of 45°, and by installing another center nut with different geometry, the gripper can switch from a 4-finger soft gripper to 3-finger soft gripper. In the same manner, by changing the center nut and supplementing all parts apart from the base plate, top plate, and servomotor with screw the soft gripper can be with 6 fingers or 8 fingers.



Pos.	Designation	Qty
1	Soft Finger	4
2	Arm	16
3	Connecting Arm	4
4	Servo-motor with threaded screw	1
5	Top plate	1
6	Threaded Pillar	4
7	Connecting link	4
8	Center Nut	1
9	Base plate	1

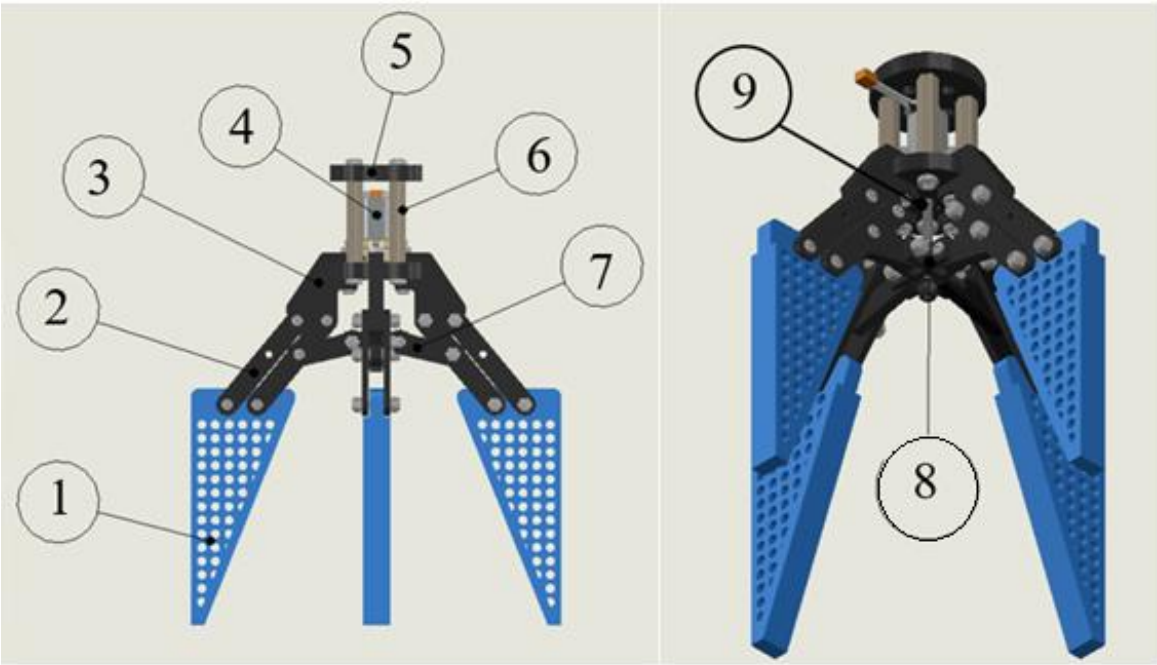


Fig. 3. Soft Gripper SG100

In order to develop an adaptive robotic gripper, compliant mechanisms with integrated actuators are utilized. The synthesis method for these systems involves defining problem specifications, parameterizing the design domain, and applying genetic algorithms as an optimization method to find the optimal solution. The goal of optimization is to find the optimal topology with integrated actuators so that the system achieves maximal structural controllability (adaptability) of its grasping surface [4].

An experimental model of the Soft Gripper SG 100 has been manufactured as presented in Fig. 4. For this model, the jaws are silicone based for easier fabrication.

a. b.

Fig. 4. An experimental model of the Soft Gripper SG 100 (a, b)

4. Conclusions

The development of robots for recycling systems has made significant progress with the introduction of soft grippers.

The soft gripper with 4 soft fingers has been shown to be a promising solution for handling a wide range of recyclable materials. Its ability to conform to irregular shapes and apply gentle pressure allows for safe and efficient sorting of materials without causing damage. Additionally, the use of soft grippers reduces the need for complex sensors and expensive machinery, making it a cost-effective solution for recycling facilities.

With further research and development, the soft gripper technology can continue to enhance the effectiveness and efficiency of recycling systems, ultimately contributing to a more sustainable future. The use of such systems offers several advantages over rigid-body mechanisms, including reduced complexity, easy manufacturing, and better scalability. The synthesis method involves defining problem specifications, parameterizing the design domain, and applying genetic algorithms for optimization.

An experimental model of the 4-finger gripper with integrated smart material actuators and sensors has been introduced, and it has been shown that such a gripper concept can realize controllable shape morphing of its grasping surface via pressure sensors.

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RESEARCH ON ECCENTRIC MACHININGS AND APPLICATIONS IN CNC INDUSTRIAL TECHNOLOGICAL SYSTEMS

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ABSTRACT: In order to perform eccentric machining, a detailed analysis of the technological system elements has to be unrolled, concerning technological characteristics of the CNC machine/ centre, part sizes and position, characteristics of tools, technological movements, etc. The machining travels must be determined relative to the reference axes. In internal eccentric machining, the adjusting and machining processes are more complex, because the tools are limited in size. In each particular case, there are specific constraints to be satisfied.

KEYWORDS: eccentric, CNC, machining, milling, boring.

1. Introduction

The need for quality products with the lowest possible cost is increasing, and also the need for complex processing, on parts. Eccentricity associated to the processing tools, orientation-fixing devices, but, above all, in the processing itself, is a method to respond to this demand for complex products at the lowest possible cost. Eccentric machining represents a special category, because the axis of the element to be processed is deviated by a certain value equal to the eccentricity from the initial axis and, thus, the tools must be properly dimensioned, the movements within the positioning phases must be accurately calculated, etc.

2. General considerations

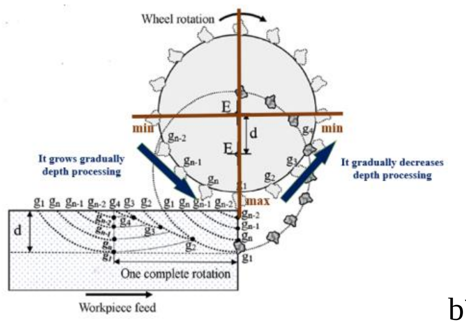
In the area of eccentric machinings, there are several methods and means. Examples are machining by internal or external turning, by milling or boring, etc., to which a distance from the initial axis equal to the eccentricity of the machining is applied. However, this type of processing must be treated separately and analysed for each individual situation.

In this regard, a machining proposal for fibre-reinforced polymers [1] is through an eccentric grinding wheel which presents several advantages compared to conventional grinding, such as: the depth of processing to vary progressively, periodicity in the alternation of cutting and non-cutting zones and the different trajectory for each abrasive grain on the disc (Fig. 1, a). Within this way of intermittent and progressive grinding, due to the eccentric disc, much more frequent cooling periods of the tool are allowed, thus resulting in a decrease in the machining temperature, as well as the use of much lower forces.

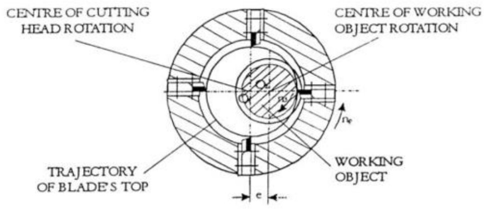
Another investigation of the eccentricity characteristic was studied on eccentric machining of external threads, on lathe (Fig. 1, b). Thus, it is highlighted that eccentric turning of threads is, in fact, the process of machining threads by milling [2]. In other words, during processing, the teeth of the milling tools are replaced by the turning knife, and due to the eccentricity between the axis of the workpiece and the axis of the lathe, these two tools alternate. External threading can be done in two ways, depending on the position of the workpiece and the turning head of the machine: the workpiece is inside or outside the cutting head. In this case [2], the part is in the lathe head.

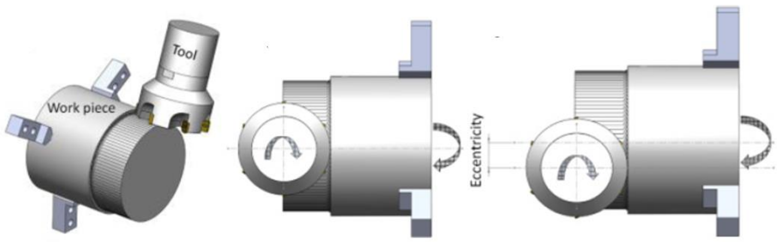
The cutting head, which has both milling teeth and 4 turning knives attached, has a rotational movement with respect to the workpiece and, due to the eccentricity between the two centres, the material is removed from the workpiece both by the cutter teeth, as well as by the turning knives, in a continuous alternation of the two types of tools. Thus, the machining of threads on an eccentric turning machine is a very productive cutting method [2], due to the very high cutting speed (contrary to conventional turning, where this speed is very low, i.e. 15-30 m/min [2]) and of the very good quality of the machined surface. In addition, this method decreases lead time by approximately 90% [2] compared to classical turning methods, the chip sizes are very small, and low power electric motors can also be used.

a)



b)





c)

Fig. 1. Eccentric machinings: a) eccentric grinding, after [1], b) eccentric external threading, on lathe [2], c) turn-milling machinings [3]

Another research [3] on turn-milling machinings (Fig. 1, c), highlights the fact that the additional eccentricity parameter between the tool and the axis of the part brings here also advantages such as low cutting temperatures and a lower tool wear. The experiments were carried out on a CNC machine and, thanks to its precision, had reliable results related to the fact that the use of such a model of combined eccentric machining of turning-milling brings the improvement of the material removal rate without influencing the quality of the surface to be processed.

In addition, a very important element to highlight through the experiment in is the fact that there is an optimal value for the deviation of the tool from the axis of the part and once this value is reached, its contribution to a uniform distribution of pressure on the turning tool is very high, leading to an increase of its durability [3].

3. Case study

The case study deals with the problem of machining eccentric channels of the HR01_SS02.01 valve body product.

3.1. Defining elements of eccentric channels and technological operation

The considered product has both the role of sealing the fluid or the air that circulates through it, and of allowing in certain areas of it an easy passage from one bore to another of the working fluid. A 3D image of this product is shown in Fig. 2, a. The bores are with reciprocally perpendicular axes (horizontal and vertical), at the intersection of which eccentric channels are defined (Fig. 2, b - d) as follows: the vertical bores represented in green are connected to the green horizontal bores through two eccentric channels, and the red vertical bores are it connects with the red horizontal bore through two more eccentric channels. A section through these bores highlights the position of two of the four eccentric channels (Fig. 2, b), which are symmetrically with respect to a vertical and middle plane of the part that crosses it longitudinally.

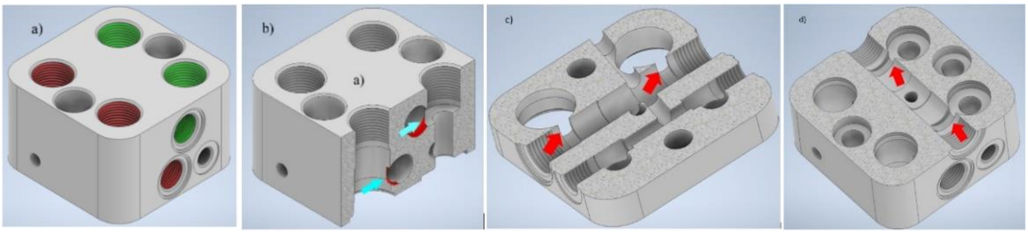


Fig. 2. Representations of the product: (a)3D part, (b, c, d) sections through eccentric channels

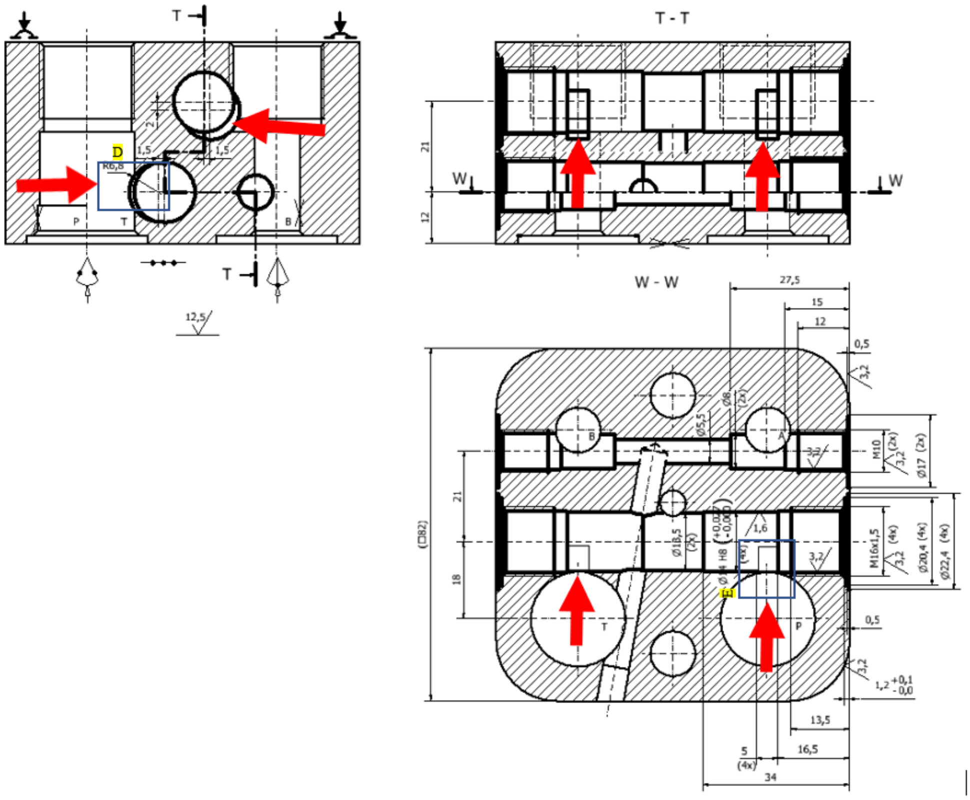


Fig. 3. Extended machining operation sketch

It is to be noted that, within the considered operation sketch, the workpiece orientation-fixation scheme includes base plate, movable smooth conical bolt and movable milled conical bolt.

Two applicative options for performing the eccentric machining from the considered operation are proposed. The first variant concerns the machining of eccentric channels with a boring head equipped with a metallic carbide monobloc cutter, and the second machining variant is with a side milling cutter.

It is emphasized that the prescribed radius of the eccentric channel is R 6.8, and its axis is defined through distance 2 mm or distances 2 mm and 1,5 mm with respect to the axis of Ø14H8 bore, as presented in Fig. 3, i.e., the rotation trajectory of a tool cutting edge is Ø13.6, and the accessing bore for the tool is of Ø14H8. Thus, all these geometrical elements are to be considered for calculus of main position coordinates defining the system adjustment and phase travels [4].

3.2. Machining of eccentric channels with a boring head

The boring head, for machining of considered eccentric channels, includes a cutter made of metal carbide type K20, of a specific shape, with an active edge of 5 mm width and Ø13.6 diameter of the rotation trajectory (Fig. 4).

A first adjustment movement is to position the tool axis on the axis of the Ø14H8 bore (Fig. 4, a). After this, in order to machine one eccentric channel, the entrance safety feed travel is of 0.2 mm (Fig. 4, a) and, then, the machining feed travel of 1.3 mm - for actual machining i.e., a total feed travel of 1.5 mm is unrolled (Fig. 4, b).

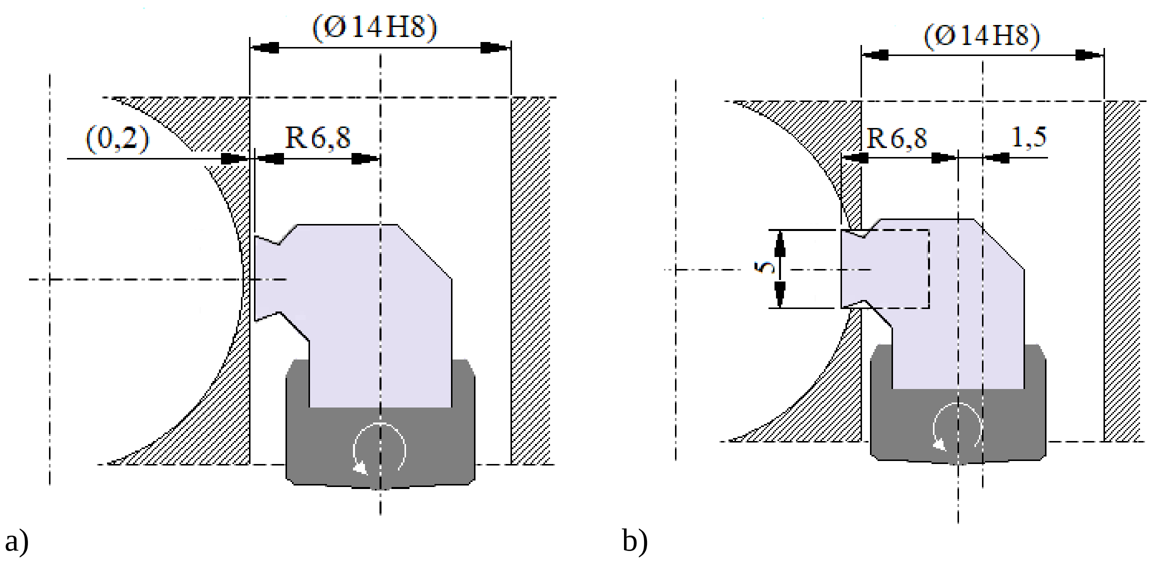
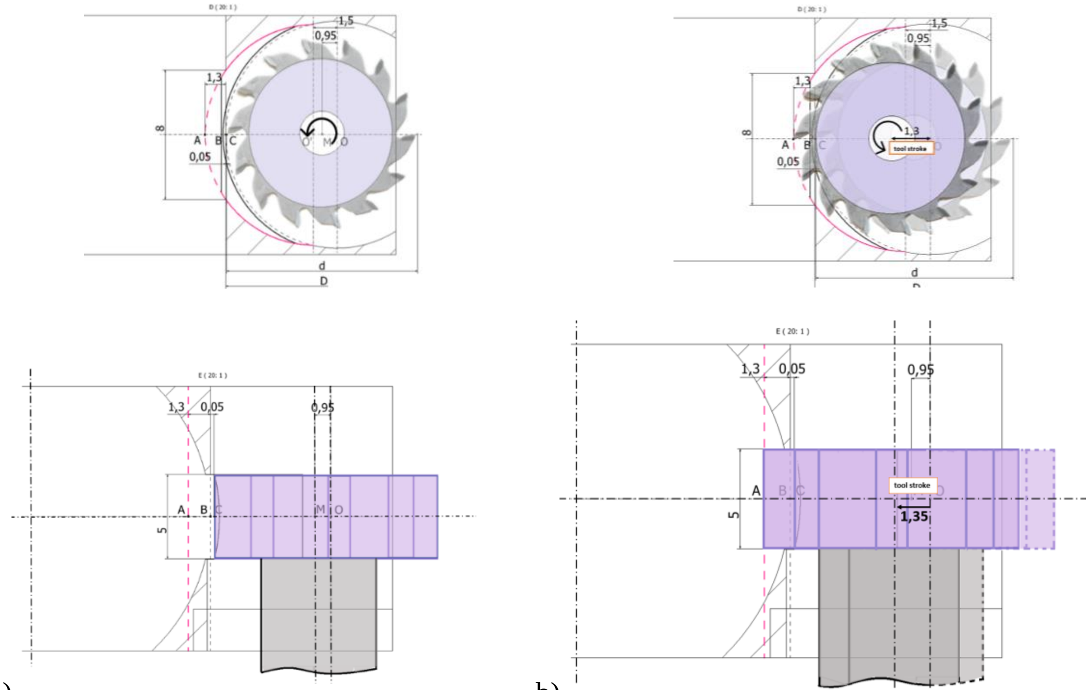


Fig. 4. Calculus elements for machining phase of one eccentric channel with a boring head:
a) initial position, b) final position

3.3. Machining with a side mill

The second variant of machining was applied in collaboration with Dr. Köcher S.R.L. company [5]. A side mill (Fig. 5) with the cutting diameter of Ø12 mm, width of 5 mm and 6 teeth was used. The adjusting movements, within the machining phase of the eccentric channel, have to achieve the tool axis positioning on the axis of the Ø14H8 bore and, then, radial approach travel on the distance of 0.95 mm from previous position. The machining phase can start: an entrance safety feed travel of 0,05 mm and, then, machining feed travel of 1.3 mm - for actual machining i.e., a total feed travel of 1.35 mm is unrolled (see Fig. 6).

Fig. 5. Side mill used for machining eccentric channels [4]



a) b)

Fig.6. Calculus elements for machining phase of one eccentric channel with a side mill:
a) initial position, b) final position

Simulation **e**lements of machining with a side mill of the considered eccentric channels are presented in Fig. 7.

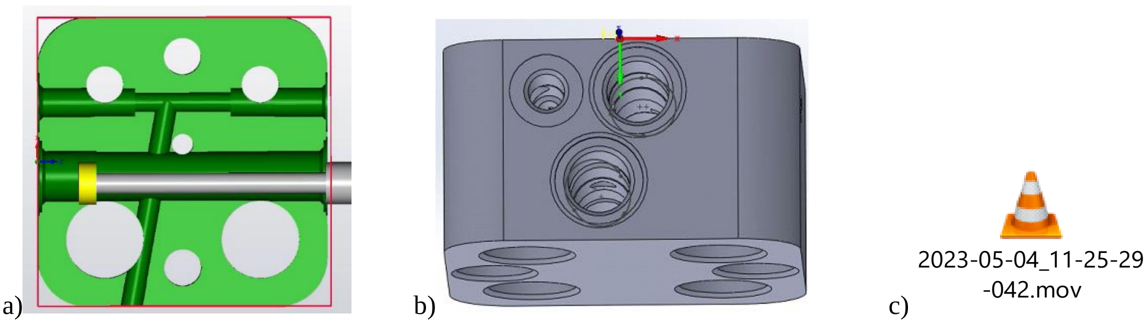


Fig. 7, a, b, c. Simulation elements of machining with a side mill of eccentric channels

4. Conclusions

There are a variety of eccentric machining – by turning, milling, turn-milling, grinding, etc.

Eccentric machining represents a special category. In the present paper, a number of elements were analysed - the type of tool, the working travel, the technological movements, etc.

The experimental research carried out demonstrates the fact that the machining of eccentric bores requires the consideration of specific elements, such as: the position between the surfaces of the part and the tool, components of the working travel, etc.

The development of theoretical and experimental research on eccentric machining leads to the thoroughgoing study of specific knowledge, in order to optimize the machining conditions in industrial conditions.

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RESEARCH AND APPLICATIONS ON THE SUSTAINABLE DEVELOPMENT OF PRODUCTS AND INDUSTRIAL ORGANIZATIONS

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ABSTRACT: The industrial organisations, as well as the industrial products, which are sustainably developing, meet a series of specific requirements. Sustainable development requires knowledge of influencing factors. There is evidenced a series of design and eco-design tools necessary for a sustainable product or industrial company. Also, the information and results of experimental research on the sustainability of the product or organization are presented within various methods and strategies.

KEYWORDS: product, sustainability, development, design, industrial organization

1. Introduction

Sustainability refers to the ability of a product to function in the long term, the same time minimizing the impact on the environment and providing social and economic benefits. Sustainable design solutions ensure an efficient management of the functional attributes of the product and balance the three dimensions of sustainability. It is important that all three aspects of sustainability are taken into consideration into the sustainable design process, although the environment has often been the only concern in product design.

2. General considerations

2.1. Sustainable and ecological design

The concept of sustainable design could be easily understood, taking into consideration the term ‘design’, which is a creative activity of choosing between different possibilities. It represents a broad concept that includes the generation and development of a product. There are four stages of a typical design process, as presented in Fig. 1.

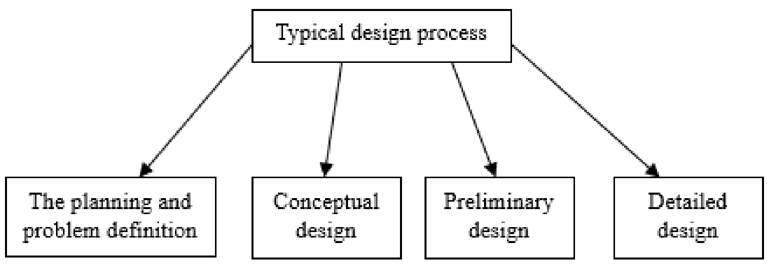

Fig. 1. The stages of the design process [1]

The sustainable design of a product considers the entire life cycle of the product, from the selection of raw materials and materials, conceptual modelling and detailed design, manufacturing and usage until the end of the product’s life, reuse and recycling.

Ecological design is a concept that aims to minimize the impact on the environment by selecting materials and resources used, as well as addressing end-of-life scenarios [1].

2.2. Eco-design tools

Eco-design is an innovative approach in the design of products and systems, which primarily aims to minimize the impact on the environment and the increase of durability. To implement this type of design, various tools and methods allowing designers to consider the entire life cycle of the product, from production to use and disposal, are used [2].

Some of the most commonly used tools of eco-design are presented in Fig. 4.

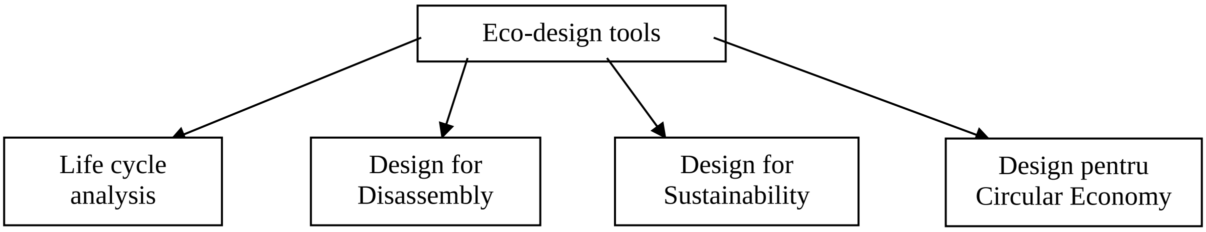

Fig. 4. Eco-design tools [2]

3. Partial sustainable product design (P-SPD) tools

Partial sustainable product design (P-SPD) tools cover one dimension of sustainability (economic or social) together with environmental aspects.

These tools do not take into account all three aspects of sustainability, nor are they limited only to the impact on the environment [3].

Partial sustainable product design tools are as follows [3]:

- Method for sustainable product development (MSPD – Fig. 5)
- Multi-objective material selection method
- Quality function deployment and LCA based method (Fig. 6)
- Normative decision analysis method for the sustainability-based design of products
- Design framework for a customized service system.

Fig. 5. Sustainable development [3]

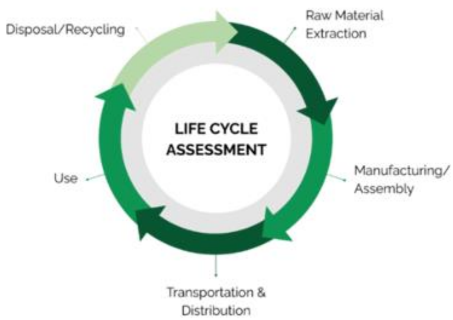

Fig. 6. LCA method [3]

3.1. Life Cycle Assessment method

Life Cycle Assessment (LCA) is the most frequently used method for the ecological design [7]. LCA provides quantitative data about a product's impact on the environment throughout its life cycle, from material extraction and production to the end of the product's life, considering multiple environmental indicators [8, 9]. Simplified LCA is a way to conduct evaluations in a shorter amount of time and with fewer resources, but which provides uncertain results.

MSPD Method

This qualitative method, for sustainable product development, extends the existing eco-design tools (manuals and matrices) by using the back-casting system (a modular system for guided questioning), to cover the fundamental principles of sustainability throughout all stages of the life cycle, including the environmental and social ones (Fig. 7). This tool provides valuable perspective and assistance in the early stages of product design, before conducting more detailed analyses [11].

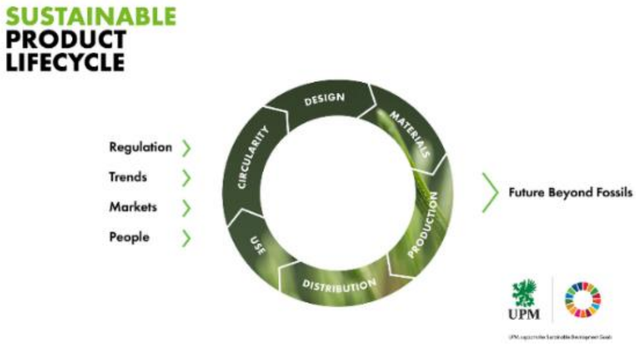

Fig. 7. MSPD Method [11]

3.2. Sustainable product design (SPD) tools

Sustainability considers that social, economic and environmental concerns should be addressed simultaneously in the product development process [4]. This characteristic implies that the term ‘sustainable’ should only be used for those tools that take into consideration all three aspects of sustainability. In retrospect, it has been observed that the majority of the analysed P-SPD tools have only taken into account a limited economic analysis. Similarly, the SPD tools, the structures of the majority of the reviewed sustainable product design (SPD) tools were based on the integration of different tools from various fields.

Examples of SPD tools

- Decision support system for the sustainability index of machine tools
- Product sustainability index method
- Integrated product life cycle management

Decision Support System

A decision support system (DSS) is a computer application used to improve decision-making capabilities (Fig. 8). It analyses large amounts of data and presents the best possible options to organisations [5].

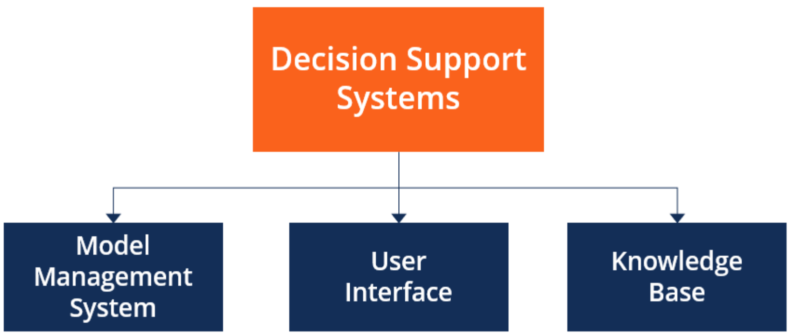

Fig. 8. Decision Support System [5]

Product's sustainability index

This quantitative method generates a sustainability index based on a set of product sustainability indicators.

Product sustainability index evaluation implies a series of stages: data scaling and normalization, score weighting and aggregation, as shown in Fig. 9.

Data scaling and normalization is used to convert measured data in dimensionless scores, whose basis is specified for each considered criterion. There are commonly used two normalization methods: objective normalization and subjective normalization. The weights are assigned based on the relative importance of certain specific indicators, using one of the three weighting methods: (i) equal value, (ii) subjective weighting, and (iii) analytical weighting approaches. Based on the assigned weights, normalized data are ultimately aggregated into a conclusive and corresponding product sustainability index [6].

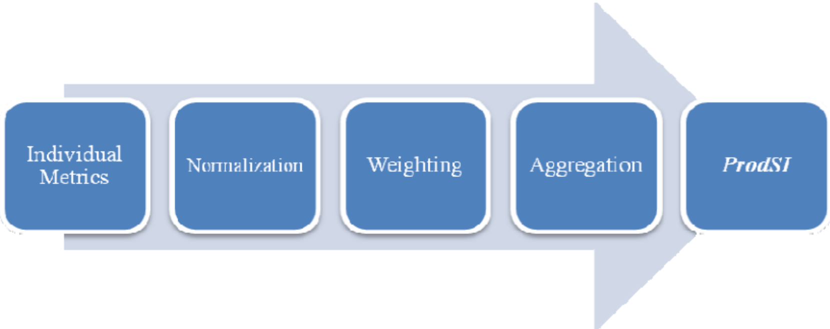

Fig. 9. Product sustainability index [6]

4. Case study

This case study focuses on identifying the sustainable strategies necessary for Madelman SA company to assure a sustainable development in the future.

Certain examples of products that Madelman SA company manufactures are presented in Fig. 10 and Fig. 11.

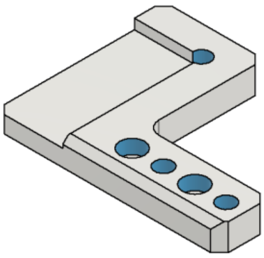

Fig. 10. DK21 DS01.04 Panel

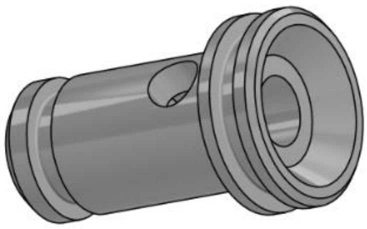

Fig. 11. Adjustable chair HR01 SSB02.12

The main sustainability action directions are analysed, and, by consequence, different ways in which the company can become sustainable. In the final part, four strategies that the company can adopt to increase its level of sustainability are proposed.

Objective: sustainable development means meeting the needs without compromising the ability of future generations to meet their own needs.

Method: the company must adopt life cycle evaluation method and method of sustainable development of products.

Material selection: it is proposed the usage of recycled materials for its products.

Also, the investments into a series of energy efficiency initiatives, such as solar systems, would reduce costs and carbon emissions.

Another method for helping the company to make good decisions regarding its development is represented by design and implementation of the decisional support system, as well as the four strategies of sustainability: sustainability management, sustainable innovation, ecoefficiency, sustainable competitive advantage [10].

All of the life cycle analysis, design for sustainability and circular economic design can be taken into account for the evolution of the company.

The case study develops a system that provides a product sustainability index. Sustainability index is limited in the case study to the impact created by the selection of raw materials and materials.

Within this case study, the evaluation of the sustainability development level is proposed as presented in Table 1. For each criterion, C_i, the objective is maximization or minimization, as the case.

Table 1. Sustainability evaluation (example)

Criterion, C_i	Objective	Significance
The carbon footprint from the extraction and use of biomass, fossil fuels, ferrous and non-ferrous ores	↓	↑ - the criterion is aimed to be maximized, ↓ - the criterion is aimed to be minimised
The consumption rate of domestic materials (that are not sourced through a supply chain or imports)	↑	
The involvement of hazardous/toxic substances or waste	↓	
Raw materials/materials sourced from recycling	↑	
The utilization degree of the energy from renewable sources	↑	

Through analogy with an evaluation method applied for audit team assessment [12], the contribution of certain criterion C_i to the objective achievement is evaluated by a factor $E(C_i)$ that could have the value of 1, 3 or 9, i.e., 1 - if the criterion has no contribution, 3 - if the criterion has a moderate contribution, and 9 - if the criterion has a strong contribution. Further, if $E(C_i)$ is the evaluation factor associated to the criterion C_i, the calculus of correspondent sustainability index, SI, is proposed for each considered type of product, P, and each design version, v, as:

$$\mathrm{SI}_{\mathrm{P-v}} = \prod_{\mathrm{i}} \mathrm{E}(\mathrm{C_i}) \tag{1}$$

and the sustainability index of the design stage is considered of value SI_P^*,

$$\mathrm{SI}_{\mathrm{P}}^{*} = (\mathrm{SI}_{\mathrm{P-v}}) \tag{2}$$

5. Conclusions

Sustainable development is important for ensuring a prosperous and balanced future for both our planet and the following generations. This implies a balance between economic development, social development and environmental protection.

It is important to take immediate action to reduce the negative impact on the environment by adopting sustainable and innovative business practices. It is essential to promote changes in individual and community behaviour to reduce the carbon footprint to which humanity is subjected and to support a sustainable lifestyle.

In order to achieve sustainable development for a company or its products, it is necessary to analyse various directions, methods or strategies in relation to a series of product characteristics: the nature of the material, the environment in which the piece is manufactured, etc.

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INJECTION OF POLYMERIC SANDWICH STRUCTURES

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SUMMARY: This research examined the use of polymeric sandwich structures with bimaterials in the production of toys. The advantages and disadvantages of using bimaterials were analyzed, as well as examples of bimaterials used in sandwich polymeric structures. The results suggest that using bimaterials in sandwich polymeric structures can improve the properties of toys by combining the different properties of the materials and improving the quality and durability of the final products.

KEYWORDS: Injection, sandwich, polymeric, bimaterial, toys.

1. Introduction

The production of toys has evolved significantly in recent years, especially due to the development of technology and new materials. The use of polymeric sandwich structures in the production of toys is an innovative method of improving the quality and durability of the final products. These structures are composed of two thin material sheets with an insulating core in between, thus providing superior mechanical properties compared to ordinary materials. In addition, the use of bimaterials in sandwich polymeric structures can offer additional advantages by combining the different properties of materials.

The purpose of this research is to examine the use of polymeric sandwich structures with bimaterials in the production of toys. The advantages and disadvantages of using bimaterials will be analyzed, as well as examples of bimaterials used in sandwich polymeric structures. Finally, it will be highlighted how the use of these structures can improve the quality and durability of toys by combining the different properties of materials.

The research was conducted by studying specialized literature, scientific publications, and technical reports on the use of polymeric sandwich structures with bimaterials in the production of toys. Practical examples of using these structures in toy production were also analyzed. The obtained information was synthesized and analyzed, and the results of the research are presented in this document.

2. Current status

The current state of research regarding the injection of bimaterial polymer sandwich structures in toy production is in continuous development and exploration. This field benefits from increased interest as ways to improve the quality and durability of toys are sought.

An important aspect of current research is the identification and development of new materials suitable for bimaterial polymer sandwich structures. A wide range of materials are being analyzed, including polyurethane foams, expanded polystyrene, polycarbonate, nylon, and others. Materials that offer superior mechanical properties, impact resistance, wear resistance, and low weight are sought.

Regarding the injection process, research is focused on optimizing injection parameters to achieve high-quality polymer sandwich structures. Aspects such as injection temperature, injection pressure, cooling time, and others are considered to ensure even material distribution and to avoid defects in finished products.

Another important aspect of current research is the evaluation of mechanical properties and durability of toys produced with bimaterial polymer sandwich structures. Bending tests, impact tests, tensile strength tests, and other tests are performed to evaluate the performance of finished products. Safety and toxicity aspects of the materials used in production are also evaluated.

In addition to theoretical and experimental research, advanced simulation and analysis models are being developed to better understand material behavior and optimize manufacturing processes.

3. Bimaterials in polymeric sandwich structures

3.1 Definition and characteristics of bimaterials:

Bimaterials are materials composed of two or more different materials that are bonded together in an integrated structure. These materials are designed to combine the properties and advantages of each material, while minimizing their disadvantages. Thus, bimaterials offer a number of advantages compared to single materials.

3.2 Advantages and disadvantages of using bimaterials

The main advantages of using bimaterials in sandwich polymer structures include:

• Combination of the mechanical and physical properties of the two materials, such as stiffness and impact resistance

• Cost and weight reduction by using a cheaper and lighter material in combination with a more expensive and heavier one

• Increased durability by using a wear and corrosion-resistant material in combination with a material that is resistant to tension and bending

As for the disadvantages, the use of bimaterials can be more challenging in terms of design and manufacturing processes. There may also be difficulty in selecting the appropriate materials to achieve the desired properties and good adhesion between them.

3.3 Examples of bimaterials used in sandwich polymer structures [1]

There are a variety of bimaterials that can be used in toy production to achieve specific properties and improved performance. Here are some examples of bimaterials used in toy production:

1. ABS (Acrylonitrile Butadiene Styrene) + TPU (Thermoplastic Polyurethane): This combination of materials provides superior mechanical strength and durability. ABS provides impact resistance and rigidity, while TPU provides flexibility and elasticity. This bimaterial is often used in toys that require shock resistance and flexibility, such as action figures or components of interactive toys.
2. PP (Polypropylene) + EVA (Ethylene Vinyl Acetate): This combination offers a unique combination of strength, lightness, and cushioning ability. PP provides strength and

rigidity, while EVA provides shock absorption and flexibility. This bimaterial is often used in baby toys, such as teething toys or soft toys.

3. PVC (Polyvinyl Chloride) + PU (Polyurethane): This combination of materials provides strength, durability, and flexibility. PVC provides strength and rigidity, while PU adds flexibility and elasticity. This bimaterial is often used in the production of inflatable toys, such as air mattresses or beach balls.

These are just a few examples of bimaterials used in toy production. Custom combinations of materials can be made to achieve the desired properties and performance based on the specific needs and requirements of the toy.

4. The injection process of sandwich polymer structures with bimaterial in toy production

4.1 E The process of injection of sandwich polymeric structures with bimaterial in the production of toys involves the following stages in the injection process [2]:

1) Mold preparation: The mold is prepared in advance to form the sandwich polymeric structures. This includes cleaning and preparing surfaces, mounting mold components, and ensuring a polymer material feeding system.
2) Heating the polymer material: Polymer materials, whether granules or powders, are heated in a cylinder of the injection machine until they melt and become liquid. Typically, two cylinders are used for the two bimaterials used in sandwich structures.
3) Injection of the first material: The first polymer material is injected into the mold cavity to form the outer layer of the sandwich structure. Injection pressure and speed are controlled to achieve uniform and complete cavity filling.
4) Completion with the second material: After injection of the first material, injection of the second polymer material begins immediately. It is injected simultaneously or in a subsequent stage, filling the remaining space in the mold cavity to form the core or inner layer of the sandwich structure.
5) Cooling and solidification: After both materials have been injected, the mold remains closed for a period of time for the structure to cool and solidify. This allows the material to maintain its shape and stability.
6) Separation and finishing: After solidification, the sandwich structure is separated from the mold. Any excess material or burrs are removed through cutting, grinding, or milling processes. Then, the finished product can be subjected to additional finishing operations, such as polishing or applying colors and decorations.

4.2 Equipment used in the injection of bimaterial polymer sandwich structures [3]:

a. Injection molding machine: This is the main equipment in the injection process. The injection molding machine is responsible for heating and melting the polymer materials, as well as injecting them into the mold cavity. It consists of a material feeding system, a heated cylinder, and an injection system such as a screw or a piston, which controls the injection speed and pressure.

b. Mold: This is a tool used to shape and determine the final geometry of the polymer sandwich structures. The mold is made of steel and consists of two or more parts that can be opened and closed to allow the polymer material to be injected. It includes the main cavity, where the sandwich structure is formed, as well as the feeding channels and cooling system.

c. Temperature control system: This is essential to maintain the proper temperature of the mold and polymer materials during the injection process. It includes heating and cooling units such as resistors or water pipes, which ensure that temperatures are precisely controlled according to the requirements of the materials used.

d. Auxiliary equipment: Depending on the specific requirements of the injection process, other auxiliary equipment may be necessary, such as material dosing and mixing systems, material pre-treatment equipment (such as granule dryers or release agents), excess material recovery systems, or process control and monitoring equipment.

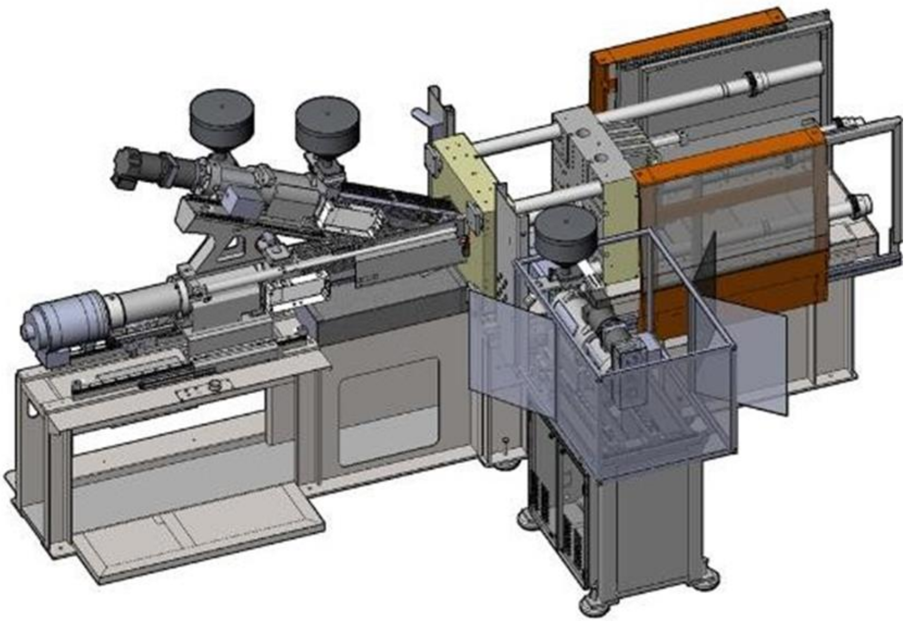

Fig.4.1. Polymer sandwich structures injection machine

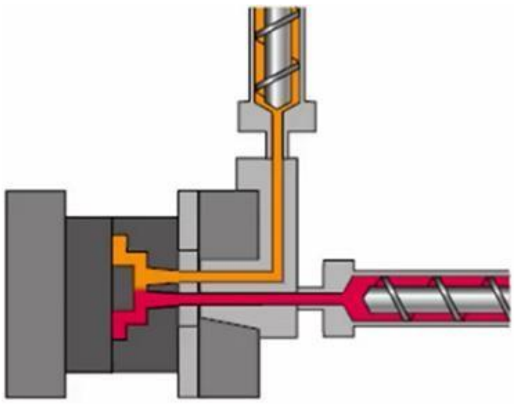

Fig.4.2. Polymer sandwich structures injection representation

5. Applications in toy production

Advantages of using bimaterial polymer sandwich structures in toy production [4]:

The use of bimaterial polymer sandwich structures in toy production brings numerous advantages, including:

• Lightweight: Polymer sandwich structures are characterized by their lightweight, making them ideal for toys. They provide children with a comfortable and easy playing experience, allowing them to handle and play with toys without difficulty.

• Impact resistance: Polymer sandwich structures are known for their impact resistance. This aspect is essential in toy production as toys are frequently subjected to falls and shocks during use. The use of polymer sandwich structures ensures better protection of toys and reduces the risk of damage or tearing due to impact.

• Durability: Toys produced with bimaterial polymer sandwich structures are durable and resistant to wear. They can withstand time and maintain their appearance and functionality for a longer period. Toy durability is essential to ensure long-term satisfaction for children and to reduce the need for frequent toy replacement.

• Versatile design: Polymer sandwich structures allow for great flexibility in toy design. They can be manufactured in different shapes, sizes, and colors, allowing manufacturers to create attractive and innovative toys that appeal to children. Additionally, complex details and textures can be created to provide a pleasant visual and tactile experience.

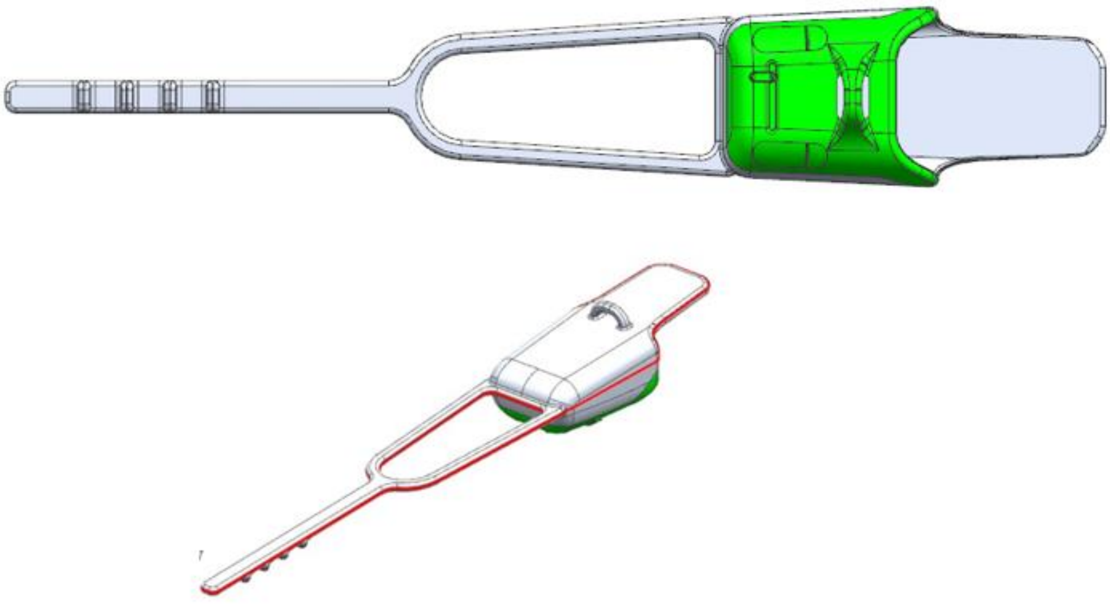

Fig.5.1. Example of a toy made by bimaterial injection

6. Conclusions

Based on the research regarding the injection of bimaterial polymer sandwich structures in toy production, it can be concluded that this technology has great potential and a series of advantages for toy production. The use of these structures can provide toys with superior mechanical properties, such as impact resistance and stiffness, while maintaining low weight and high design flexibility.

The injection process of bimaterial polymer sandwich structures is a complex process that requires specialized equipment and technologies, but high-quality products can be obtained by using modern equipment and superior materials. However, to further improve this process and contribute to greater sustainability in toy production, future research can focus on the use of ecological and renewable materials, as well as the development of more efficient and energy-saving technologies. Additionally, further efforts are needed to ensure the safety of toys produced with bimaterial polymer sandwich structures, by adhering to appropriate safety standards and regulations.

Overall, research on the injection of bimaterial polymer sandwich structures in toy production has shown that this technology has enormous potential and can contribute to the development of more durable, safer, and more attractive toys for children.

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VIRTUAL INSTRUMENT FOR CALCULATING THE MAXIMUM LOAD SUPPORTED BY A FLAT STEEL BAR CONSISTING OF TWO PORTIONS

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ABSTRACT: This paper describes the results obtained by designing and creating a virtual tool made in the LabVIEW graphic programming enviroinment with the help of which material resistance calculations are performed. The virtual tools allows the calculation of the largest axial load that can be safely supported by a flat steel bar consisting of two portions connected by fillets under a normal stress.

KEYWORDS: LabVIEW, axial load, stress concentration factor, allowable stress, normal stress.

1. Introduction

Solving problems in the strenghts of materials domain requires complex and laborious mathematical calculations. Mistakes can be made, most of the times, in means of solving the calculations, which lead to wrong results. Besides, the time required to solve these calculus and making the diagrams is pretty long.

This vitual tool allows us to precisely, and under a very short time, make the calculus of the reactions for a flat bar consisting of two portions connected by fillets, based on the formulas given by the speciality literature. These calculation formulas are made up according to the diameters of the bars, the fillet's radius and the stress concentration factor.

2. Current status

The flat steel bar consisting of two portions, connected by fillets is represented in figure 1.

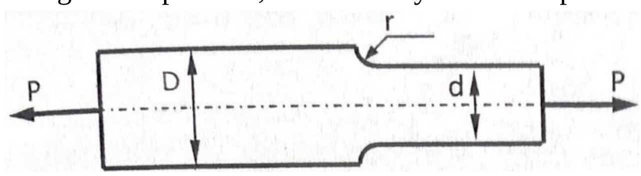

Fig. 1. Flat steel bar consisting of two portions

For the steel bar made up by the two portions we assume an allowable normal stress. The two portions that make up the entire bar consist of two different dimensions $\boldsymbol{D}$ and $\boldsymbol{d}$, of a thickness $\boldsymbol{t}$, and the fillets of radius $\boldsymbol{r}$ that connects them together.

To determine the stress concentration factor $\boldsymbol{K_\sigma}$ the following formulas were used:

$$\frac{D}{d} \quad (1)$$

$$\frac{r}{d} \quad (2)$$

where:

$\boldsymbol{D}$ – the big dimmension of the steel bar

$\boldsymbol{d}$ – the small dimmension of the steel bar

$\boldsymbol{r}$ – fillet radius

After determining the two geometrical ratios , the stress concentration factor can be found in the chart given for a filleted shaft in tension, figure 2.

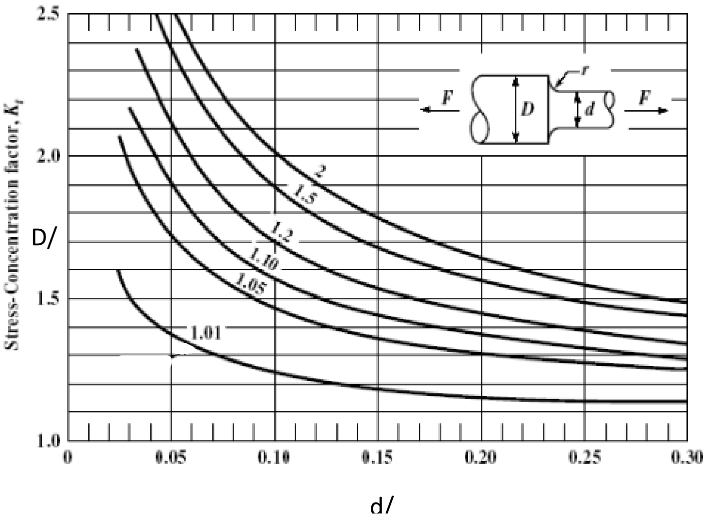

Fig. 2. Stress concentation factor sheet for a filleted shaft in tension

The next step is to determine the allowable average normal stress using the material allowable normal stress and the stress concentration factor:

$$\sigma_m = \frac{\sigma_{max}}{K_\sigma} \tag{3}$$

where:

$\boldsymbol{\sigma_m}$ – allowable average normal stress

$\boldsymbol{\sigma_{max}}$ – allowable normal stress

$\boldsymbol{K_\sigma}$ – stress concentation

The last step is to apply the definition of normal stress the find the allowable load, for which the following formulas were used :

$$\boldsymbol{A = d \times t} \tag{4}$$

$$\boldsymbol{P = A \times \sigma_m} \tag{5}$$

where:

$\boldsymbol{A}$ – area of the smaller section

$\boldsymbol{P}$ – axial allowable load

3. Description of the virtual tool's functions

The following controls are available on the front panel, necessary for specifying input data: a table element where specific values should be written, every column getting its name corresponding to its measurement : **D**, **d**, **t**, **r**, **Smax** ($\boldsymbol{\sigma_{max}}$), **Ks** ($\boldsymbol{K_\sigma}$), and three elements of horizontal pointer slide type available to convert the output values depending on the user's needs.

In order to display the resulting data, another table was added to the program . The variables **D/d**, **r/d**, **A**, **P**, **Sm** ($\boldsymbol{\sigma_m}$), are displayed in the first column, followed by their numerical values on the second column, and the units corresponding to them.

Figure 3 represents the front panel of the virtual tool, with the control elemnts and the tables used to input and display the values in order to solve the problem.

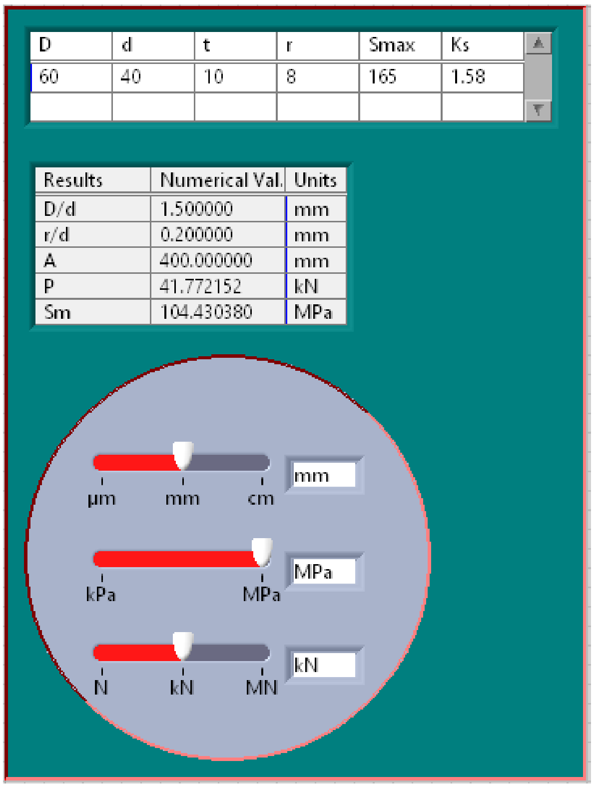

Fig. 3. Front panel of the program

4. Description of the virtual tool's algorithm

In the virtual's tool diagram, the **Formula Node** structure was used to calculate the results of the problem. Inside the **Formula Node** structure, formulas 1 – 5 were inserted. Each expression was ended with a semicolon.

The input table was connected to the **Fract/Exp String To Number** string element in order to interpret the string input into a number, specified the row to be taken in consideration with an **Index Array**, and then, parted the column with another **Index Array** in order to output the measurements values.

Figure 4 represents the diagram with the programming algorithm of the calculus.

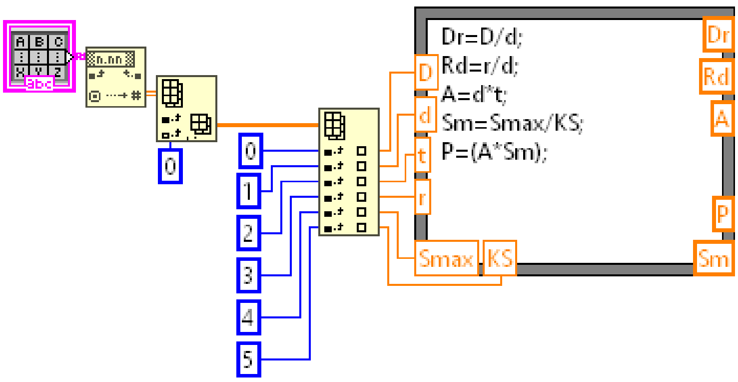

Fig. 4. Algorithm used for the calculus

In order to convert each of the values to different sizes of the value, **Case Structures** were used to make the conversion possible . Every value is taken and inspected inside the case structure, depending on the horizontal pointer slides, and it outputs the values into a **Build Array** function, connected to a **Number To Fractional String** in order to convert the numbers back into a string data type.

For each of the result, a specific unit is given, and for this to be possible **Array Constants** were used, filled with **String Constants** followed by **Index Array** functions bounded to the Horizonal Pointer Slides in order to determine the required sizes, and then, connected to **Initialise Array** functions to specify the number of rows where the units should be displayed.

After using a **Array Constant** with **String Constants** to name the results, everything was coneccted to a **Build Array** function and the output data went into a **Transpose 2D Array** function in order to place every value, name and unit into its place.

The whole algorithm used for conversion and displaying the values into the table is represented in figure 5.

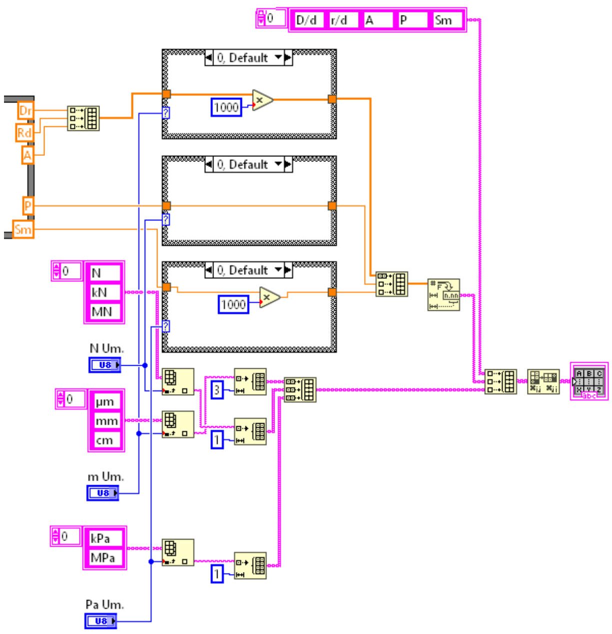

Fig. 5. Algorithm built for conversion and displaying values.

5. Conclusions

The virtual tool created is able to accurately solve this kind of calculus required in strenght of materials, under a matter of seconds, and it is very efficient in need. It has a simple and interactive interface, and it can be used by everybody, even by users that do not have any knowledge about programming.

As future upgrades, the interface will get to gain more functions such as graphical representations, Picture type functions, and even more functions in the algorithm to allow one time click solving.

Additionally, saving the pictures and findings in a report or files means that everyone can acces them without having to use the LabVIEW software.

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