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Content

THE STUDY OF FRAGILE DUCTILE TRANSITION IN METALLIC MATERIALS USING IMPACT TESTS

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ABSTRACT: The ductile/fragile character is a characteristic of materials that describes how they behave when subjected to external forces. A material is neither completely ductile nor brittle but follows a unique curve (the ductile-brittle transition curve) where the character of its deformation varies depending on the temperature. One method of checking the ductility of materials is the impact test. With the help of such a test, mechanical characteristics such as tenacity, resilience, elastic limit and yield limit, as well as hardness, ductility and ductile/brittle transition temperature can be checked. This transition temperature represents the limit temperature to which a material can be subjected to in order to preserve its mechanical properties.

KEYWORDS: fracture, temperature, impact, deformation, brittleness

1. Introduction

This paper aims to test the capabilities of an impact test developed in the 20th century and establish its relevance. We considered that the theoretical analysis would not provide the necessary details to support such an experiment, so we made a rudimentary test device with which to support the test in a more practical way. For economic reasons, the type of test we chose for analysis is the one inspired by Charpy's model [1]. The test consists of a body of high mass striking a sample of standardized sizes from the material under test. By calculating the energy absorbed by the sample during the impact and analyzing the fracture area, we can establish the type of fracture to which the material was subjected.

2. The test apparatus

The test device (hammer-pendulum, fig. 1) was constructed of rectangular metal profiles, made of construction steel S235J2. The exact dimensions of the frame do not have a major impact on the experiment, but we took into account the final length of the pendulum (from the axis of rotation to the point of impact). Then, the support table for the sample where the impact will happen was attached to the frame (fig. 2) and a metal chisel was mounted on the base of the pendulum that would act as the impact point. Finally, the entire construction was mounted on a rigid surface. The attachment of the parts was made by MAG welding (metal - active gas) and the stainless-steel rotation axis of the pendulum was provided with bearings to minimize frictional forces.

Fig. 1. 3D representation of the device

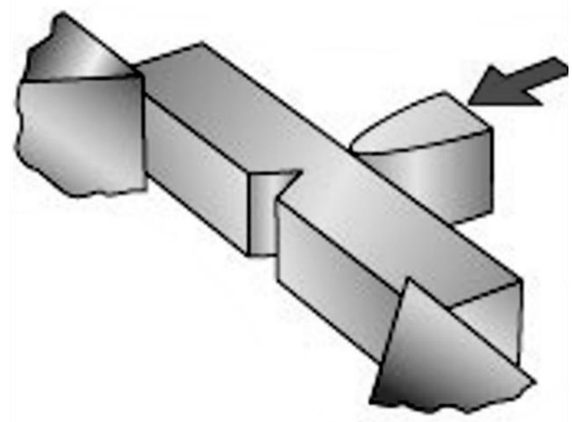

Fig. 2. The point of impact

Since the energy absorbed by the sample on impact is the first step in obtaining our results, the height and mass of the pendulum were chosen to maximize the impact energy and minimize costs. After an online study we found out that most of the metallic materials that we could subject to testing will absorb 200-300 J upon impact [3]. Starting from a reasonable length of 80 cm, the mass required to generate sufficient energy was calculated by the following method:

$$E_i = E_f \rightarrow E_p = E_c \rightarrow Mgh = E_c \quad (1)$$

$$h = l + l\cos\alpha\,;\ (\alpha = the\ angle\ with\ the\ vertical) \rightarrow h = l + l \rightarrow h = 2 \cdot l \quad (2)$$

$$E_c = M \cdot 9{,}81 \cdot (0{,}80 \cdot 2) \rightarrow E_c = M \cdot 15.69\,J \quad (3)$$

From the calculations it follows that any mass greater than or equal to 20 kilograms will develop the energy necessary to break. However, such a high mass could distort the entire test system. Wanting to use only the materials at our disposal and trying not to compromise the integrity of the instrument, we chose as a “high mass" element a hammer head with an exact mass of 4950g, creating together with the pendulum, a hammer with a total mass of 5200g.

$$E_c = M \cdot 15{,}69 \rightarrow E_c = 5{,}2 \cdot 15{,}69 \rightarrow E_c = 81{,}61\,J \quad (4)$$

However, the results we obtained at this point do not take into account frictional forces. Thus, in order to compensate them, we launched the pendulum without placing a sample (eliminating the energy variation at impact) and measured the total energy variation from the launch point (160cm) to the maximum point reached by the hammer. To calculate the final height, we first found out the angle that the pendulum makes with the vertical. This measurement was carried out by filming the pendulum with a camera with the "slow motion" function and by digitally measuring the angle with the help of a protractor type function (fig. 3).

$$\Delta E = Ef - Ei \rightarrow -L_c = E_{p_f} - E_{p_i} \rightarrow L_c = Mgh_i - Mgh_f \rightarrow L_c = Mg(h_i - h_f) \quad (5)$$

$$h_f = l + lcos\alpha; (\alpha = with\ the\ vertical) \rightarrow h_f = 80 + 80 \cdot \cos 1\,5^\circ \rightarrow h_f = 157{,}27cm \quad (6)$$

$$L_c = 5{,}2 \cdot 9{,}81 \cdot (1{,}6 - 1{,}57) \rightarrow L_c = 1{,}39\,J \quad (7)$$

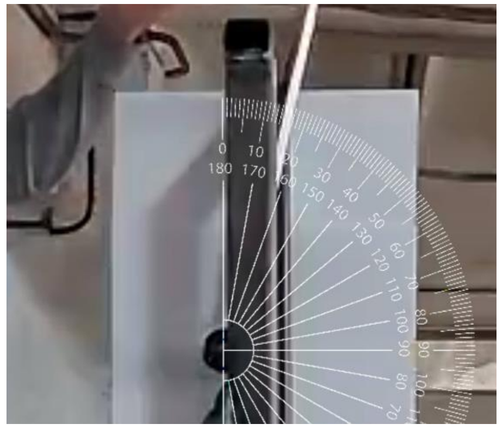

Fig. 3. Measuring the angles using the frames from the "slow motion" footage

Thus, the completed pendulum hammer develops over 80 J at the moment of impact (table 1). Although the obtained value is not close to the desired energy, we decided to conduct the experiment paying attention to this deficiency to see what kind of conclusions we can state.

Table 1. Characteristics of the test device

The mass of the pendulum	The length of the arm	The maximum angle before release	The maximum height before release	Total energy developed
5,2kg	80,0cm	180^0	160,0cm	>80,0 J

3. Tested materials

From the very beginning we noted the impossibility of testing samples made out of construction steel S235J2, the most common steel on the market, due to its property of resisting impact, including at temperatures below 0^0C. So, without the possibility of lowering drastically the temperature of the metal, making the transition curve for construction steel was not easy. However, analyzing the characteristics of the alloy, we managed to draw conclusions regarding possible materials with which we can verify this method of impact testing.

From the chemical composition of S235J2 steel [2] (table 2), two primary elements attract attention: the low carbon concentration (0.17%) and the high manganese content (1.40%).

Table 2. Composition of construction steel, S235J2

C	Mn	P	S	Cu
0,17%	1,40%	0,030%	0,030%	0,55%

Knowing that the tendency of ferrous alloys is to increase their hardness with increasing carbon concentration (fig. 4), the next step was to find a metal alloy with at least a medium carbon content (0.30<%<0.50). As for the manganese concentration, a brief online overview showed that a high manganese content "moves" the ductile-brittle transition temperature towards negative degrees (fig. 5). This feature gives our construction steel its high impact resistance, property caused by ductility.

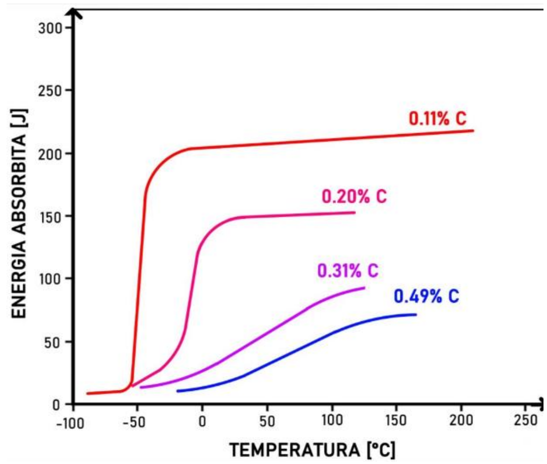

Fig. 4. Transition curve after %C [3]

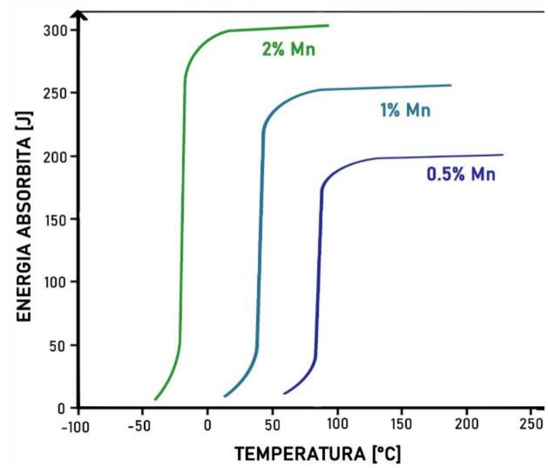

Fig. 5. Transition curve after % Mn [3]

Summing up what we learned, we concluded that the material we will test must have the following properties: medium to high carbon content, low manganese content, high hardness at room temperature (since heating the metal to reach the ductile character was not a problem).

The material we decided to test is a quality 10.9 steel [4] (according to the Romanian standard: SR EN ISO 898-1) with a high hardness and a medium carbon content (table 3). A problem arose when we discovered that the alloy is only used for screws and threaded rods. Trying to minimize the processing time and the amount of wasted material, we chose to work with DIN 933 screws (with thread up to the head) (fig. 6) to use the entire body of the screw.

Table 3. Composition of quality steel 10.9 [4]

C	P	S	B
0.40%	0.025%	0.025%	0.003%

The new sample will have to be adapted to the helical shape of the screw. After trying several variants, we decided on a final sample that is easy to process, to minimize the possibility of errors between different samples. The final shape involves removing the screw head (to obtain a 6cm threaded bar), cutting the thread on two opposite sides (to create a straight surface in contact with the pendulum and the support pillars) and making a cut centered on one of the flattened faces (like Charpy's model with a "V" cut, but with a "U" cut) (fig. 7).

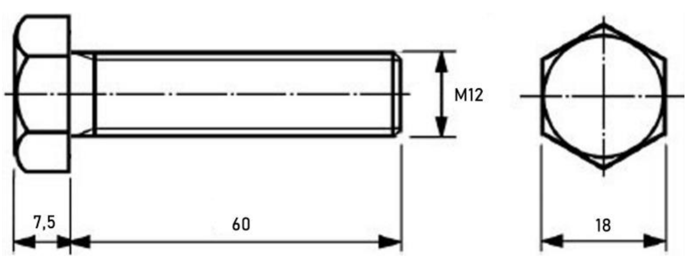

Fig. 6. Screw

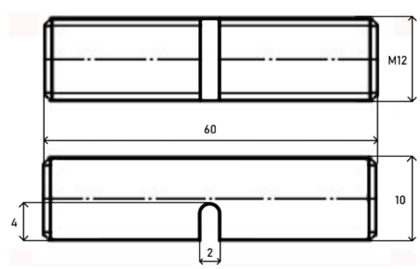

Fig. 7. Sample.

4. Testing

The testing of the samples takes place in the same way as the determination of the frictional forces in the system (this time with the sample positioned at the 0^0 point of the pendulum). The temperature of the metal sample is measured immediately before the hammer is launched. The pendulum is launched under the action of gravity and fractures the metal. Depending on the height to which the hammer-pendulum rises after the impact, the energy absorbed by the tested metal is calculated. After 3 tests at similar temperatures, the results are averaged and entered in a table to be represented later in a graph E[J](T[^{0}C]) (Energy absorbed/Temperature) (fig. 8). Each fractured sample is analyzed visually. Depending on the appearance of the fracture surface, we draw conclusions on the type of fracture (ductile/brittle).

Table 4. Test results

Test number	Temperature	Final angle	Final height	Absorbed Energy	Fracture type
1.	14^0C	82^0	69,41cm	46,21 J	fragile
2.	22^0C	79^0	65,06cm	48,43 J	fragile
3.	220^0C	70^0	52,85cm	54,66 J	fragile
4.	229^0C	81^0	66,87cm	47,51 J	fragile
5.	405^0C	77^0	62,45cm	49,76 J	fragile
6.	428^0C	68^0	50,03cm	56,10 J	fragile
7.	510^0C	43^0	21,88cm	70,46 J	fragile
8.	603^0C	No fracture	-	> 80 J	ductile
9.	652^0C	No fracture	-	> 80 J	ductile
10.	>800^0C	No fracture	-	> 80 J	ductile

As the sample heats up, the energy absorbed at impact increases. Given the nature of the material, after the temperature of ~600^0C the fracture with the help of the constructed system proved impossible. However, this impossibility does not in any way compromise the success of the experiment since the samples that were not fractured show severe plastic deformations, and the analysis of the deformation surfaces provides us with all the necessary information for our experiment.

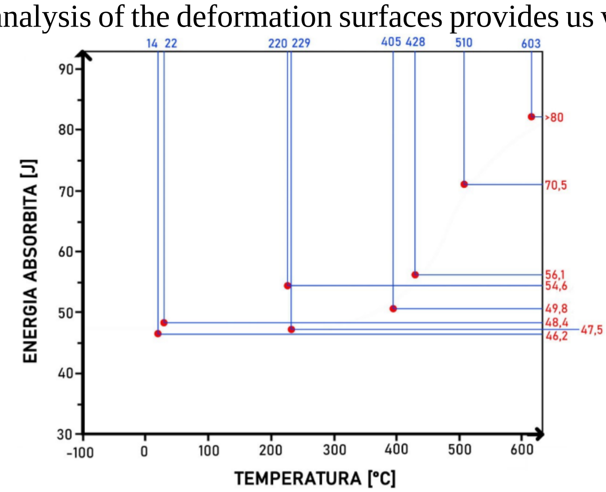

Fig. 8. Points generated by tests

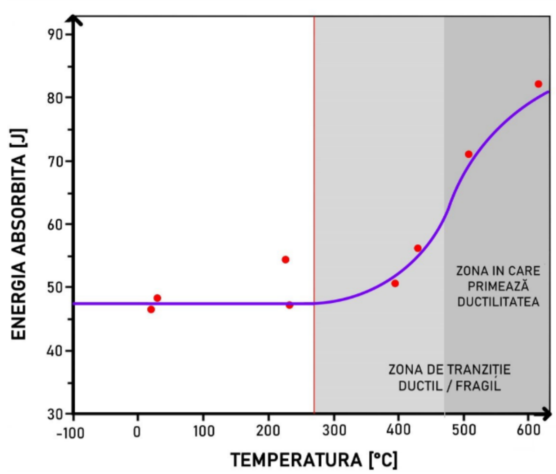

Fig. 9. Illustration of the transition curve

The point generated at the temperature of 220^0C does not follow the usual trend of the curve that we are analyzing, so we chose to ignore it in creating the curve (fig. 9). Following the trend of the graph as a function of temperature, we state that after the temperature of ~300^0C, the material starts to "soften", becoming more malleable (ductile). At temperatures higher than 450^0C-500^0C we can consider the steel to be ductile.

5. Conclusions

Although we failed to generate the desired energy for fracturing the samples, capping at 80 J, we accidentally developed enough breaking power to support our tests. Given the fact that not all the samples were completely fractured, by analyzing the only deformed surface (in the case of ductile samples), we managed to draw the necessary conclusions to state the following:

1. Standardization of the test for finding the ductile/brittle transition curve is not necessary.
2. Through the test in question, it is possible to determine the ductile or brittle nature of tough materials.
3. The analysis of the deformation surfaces is sufficient to characterize the samples (which have resisted the impact).

The Charpy impact test (or the "V" cut impact test), developed at the beginning of the 20th century, is even today the best-known impact test. Due to the simplicity with which it is supported and the low costs, the probability of developing such a test that offers better or cheaper results is small. Summing up the above, the Charpy impact test and its derivatives maintain their level of applicability even today.

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7. Notations

E_i = initial energy
E_f = final energy
E_c = kinetic energy
E_p = potential energy
M = mass of the pendulum
g = gravitational acceleration
h = height
l = length of the pendulum arm
ΔE = energy variation
L_c = mechanical work consumed

RESEARCH ON 3D PRINTING OF GEARS WITH FDM PRINTER

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ABSTRACT: *3D printing technology was patented in the 1980s, but has gained popularity relatively recent. New techniques have been developed and the possibilities of 3D technology have reached a whole new level. However, even today, the technique is not well known in all circles and not everyone knows what 3D printing is. In today's article, we will try to explain in detail and in simple terms what 3D printing is and where it is used.*

KEYWORDS: 3D printing, deposition modeling, laser synthesis

1. Introduction

In short, 3D printing is a technique for making three-dimensional products based on digital models. Regardless of the specific technology, the essence of the process is the gradual reproduction of objects layer by layer. The process uses a special device - the 3D printer, which prints certain types of materials.

3D printing has a wide application, so we can find it in: medicine, construction, creation of weapons, food industry, etc.

There are several types of 3D printers [1], each with different operating criteria such as fused deposition modeling (FDM) [2], laser stereolithography (SLA) [3], selective laser synthesis (SLS), etc. However, in our case, 3D printing is done using fused deposition modeling technology which involves an additive process where successive layers of material are added under computer control.

2. 3D printing industrial aplication

Using the FDM printing technique, we made 4 gear wheels to demonstrate the performance of the method in everyday applications.

The choice of this 3D printing model was inspired by the frequent use of cogwheels in domestic, industrial, transportation and other environments.

Tab.1. 3D printer parts

Printing nr.	Filling(%)	Printer	Score
1	10	Robofun 3D	3
2	30	Anycubic i3 Mega S	2
3	70	Robofun 3D	4
4	100	Anycubic i3 Mega S	1

The score is 1-4, 4 being the maximum score.

Stages of the work:

- Choose the desired model;
- Designing the model to be printed;
- Printing the model;
- Use the model to observe the resistance.

Two printers were used in the printing process, namely Robofun 3D Printer and Anycubic i3 Mega S to streamline the whole process.

Printing nr. 1

Printing nr. 2

Printing nr. 3

Printing nr. 4

Fig.1. 3D printer parts with different types of printers: printing nr. 1 - Robofun 3D; printing nr. 2 - Anycubic i3 Mega S; printing nr. 3 - Robofun 3D; printing nr.4 - Anycubic i3 Mega S

Printing parameters:

-Fused Deposit Modelling (FDM) printing, i.e. printing on layers;
-10%,30%,70%,100% filled 0.4mm nozzle printing;
-width = 40mm, thickness = 10mm;
-Nozzle temperature 220°C;
-Temperature bed 60°C;
-Printing speed 60mm/s;
-Each piece lasted about 30 minutes.
-Used to support all zigzag backing pieces and printing inside in honeycomb shape
-Material used is PLA;

The process of preparing 3D Printers was:

1.Preheat the bed and clean with 90% pure technical or isopropyl alcohol for better adhesion.
2.Preheat the printing nozzle and collect excess material at the time of starting the printing process.

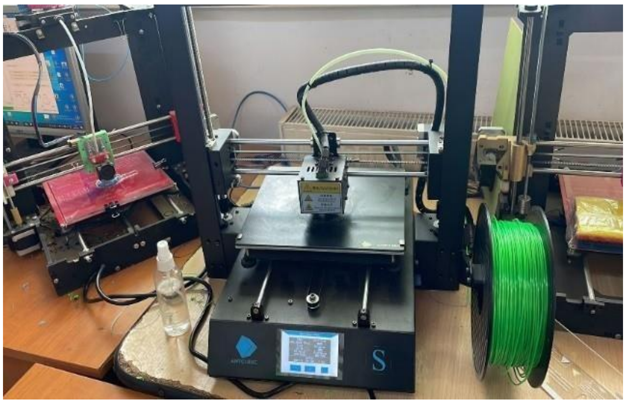

Fig.2. Printing process

Fig.3. Printing defects

The parts were designed in the Fusion 360 program in which the desired dimensions were entered after careful analysis of the part and the appropriate dimensions to fit it into a chain of function, thus forming a digital design of the part in space in order to anticipate the finished product and to determine the exact percentage of similarity with the original part.

In the printing process (fig. 2) we encountered some impediments with regard to air gaps, excess material and wrong sizing due to an error encountered during printing. As a result of that error, we ended up with some rejects (fig. 3).

In order to really see the functionality of these parts we decided to implement them one at a time in a bike's operating cycle to demonstrate their efficiency and to test the material strength.

Several tests were carried out on each sprocket until each one failed, after which we came to certain conclusions about the handling and efficiency that each of them had.

Fig.4. Printing nr. 1

Fig.5. Printing nr. 1 in the bicycle system

The experiment itself consisted of putting the sprocket in the bicycle system (fig. 5) under the action of a constant force over a fixed distance, observing the moment of breakage under the action of the same parameters, the force of pressure on the bicycle pedal being the same, the only parameter we were able to measure that made a difference in each situation was the distance the bike travelled before the sprocket was damaged or broke. We set up a 600metre circuit and started experimenting with each sprocket, the first being the printing nr. 1 (fig. 4) with 10% PLA material.

From the very beginning we can see the imperfections of the piece in terms of shape as well as printing imperfections where there are air voids, but also excess material especially in the lower part, surplus from the support created in the printing process.

All this leads to errors in the experiment and additional interventions in terms of grinding teeth and deepening the wheel pitch. For these interventions we used batteries, sandpaper and a biax (fig. 7).

After performing the experiment on the first model we could observe that the operating distance before breakage was 600 meters, exactly one full circle of the pre-determined route.

Fig.6. Printing nr. 1 after the test

Fig.7. The biax used

We can observe the damage of the teeth under the continuous tension of the chain on the surface of each tooth but also the breakage in the area of the axle (fig. 6) which led to the appearance of a play and a permanent trembling of the chain.

The next piece that was fitted to the bike's shifting assembly was the printing nr. 2 (fig. 8), with 30% concentration. We can also see on this piece the printing defects that led to the deformation of the surface of the piece, the teeth of the wheel not being perpendicular to the surface, having a small elongation towards the outside that led to the incorrect positioning of the chain on the wheel. This wheel also underwent some external work on the teeth and tooth pitch.

Fig.8. Printing nr. 2

Fig.9. Printing nr. 2 after the test

After performing the same experiment, under the action of the same parameters, the result did not differ much from the first test, the distance that the bike was able to achieve was just over 600 meters and the breaking point was still in the area of the central axis (fig. 9), noting that this area is subject to the greatest stress. Being a softer material, wear can also be seen on each tooth.

The printing nr. 3 (fig. 10) with 70% concentration was the piece with the fewest printing defects, the air voids being significantly reduced, the surplus of material existing only in the lower area where the support of the piece was created but also in some areas of the central axis. We can also notice the lack of imperfections in the teeth, being very close to the original piece.


Fig.10. Printing nr. 3


Fig.11. Printing nr. 3 after the test

With the increase of the concentration, the strength has increased significantly, coping with 3 cycles of operation,1800 meters, before it deteriorates and breaks, the breaking area being the central shaft area (fig. 11).

The last piece subjected to the experiment was the printing nr. 4(fig. 12) with 100% concentration. In this case we encountered difficulties in terms of sizing and printing defects. You can see the lack of material in the area of the central axis, which led to a premature breakage of the piece. Also in this case we noticed the same problem we faced with the 30% concentration piece, and in this case the teeth are not perpendicular, having a degree of elongation outwards. This problem with the wheel teeth may be due to the use of a different type of printer for the two parts.

Following the placement of the 100% concentrated part in the bike assembly the result was disappointing. The part only lasted 1200 meters, and even with maximum concentration, the gap in the axle area had a significant impact on the load resistance (fig. 13).


Fig.12. Printing nr. 4


Fig.13. Printing nr. 4 after the test

The appearance of that gap in the central axle has led to low resistance in the use of these wheels, even if we have increased the concentration of each, that gap area in the axle has remained fragile, leading to breakage. Thus the erroneous conclusion arises that the part with 70% concentration resists more to stress, because that part had a low degree of defects and a correct printing in the axle area.

In the course of the experiments we noticed another design flaw: wrong dimensioning of the spindle, with a play between the inner cylinder walls and the spindle leading to the excessive inner cylinder walls (fig. 16). The wrong sizing of the inner cylinder led to errors in the outer cylinder, making it impossible to place a protective sleeve on both the lower and upper side, in order to reduce friction of the part with other surfaces.

Fig.14. How it should look

Fig.15. How it should look

Fig.16. How it looks on the printing nr. 3

3. Conclusions

The experiment itself had an unexpected result given the design flaws as well as the printing defects. In conclusion it can be said that 3D printed parts cannot completely replace "traditional" parts, but, with a quality printer and material, they can contribute significantly to the development of certain products. What is certain is that 3D printing technology is constantly developing and the quality of the models will get better and better.

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FROM SIMULATION TO AUTOMATION: STREAMLINING CAD/CAM PROCESSES

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ABSTRACT: The research explores advanced technologies and software solutions that can improve Computer-Aided Design and Computer-Aided Manufacturing processes. The study emphasizes the importance of leveraging technological advancements to optimize these processes, which can lead to increased accuracy, efficiency, and cost-effectiveness. CNC Machine Simulation and 3D Scanning are two crucial technologies discussed in the research. CNC Machine Simulation enables manufacturers to create an accurate model of the manufacturing procedure, providing real-time feedback that can improve the fabrication process. Meanwhile, 3D Scanning allows capturing precise measurements of physical objects and convert them into digital models. The study also emphasizes the importance of optimization software for CNC Post Processor, Generative Design, and AI Solutions for CAM, which can automate and optimize the industrial process, resulting in faster and more efficient production. Overall, the research presents solutions that can help optimize the CAD/CAM processes and lead to significant improvements in the industry.

KEY WORDS: scanner, CNC, CADCAM, AI

1. Introduction

In recent decades, globally, the manufacturing sector has experienced a series of technological innovations that have changed the way design and manufacturing processes are carried out. In this context, the research with the theme "From simulation to automation: streamlining CAD/CAM processes" aims to present solutions and technologies that can be used to improve Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) processes within a local small and medium-sized enterprise.

3D scanning is one such technology that allows for precise modeling of production processes and provides real-time feedback, easily replacing conventional measurement methods. Additionally, simulating part processing reduces potential errors in Computer Numerical Control (CNC) machining centers, while the CAM post-processor verification and optimization program helps automate and optimize manufacturing processes, significantly reducing verification and manual code modification times. Furthermore, utilizing artificial intelligence for analyzing large volumes of data, identifying repetitive patterns, and recommending toolpaths for CAM represents another important solution for a domestic production system. This can significantly reduce the time required for CNC programming and improve the efficiency and accuracy of the manufacturing process. Additionally, solutions such as Generative Design and the implementation of Finite Element Analysis (FEA) in CAD software are particularly important as they greatly enhance common design and analysis capabilities.

Moreover, by integrating these solutions into production processes, significant benefits can be achieved in terms of increased productivity, improved quality, and reduced design and manufacturing time, all with minimal investment and simple implementation. Therefore, in an increasingly competitive manufacturing environment, these solutions can provide a major strategic advantage to companies seeking to enhance their production processes and achieve greater performance and profitability.

2. Current situation

The manufacturing industry is an extremely important sector for the global economy, and streamlining processes in this field is crucial to maintaining competitiveness and maximizing profits. In this regard, the use of modern CAD/CAM process optimization solutions could bring significant benefits to companies in this industry. Currently, many companies involved in the manufacturing of various objects still use traditional methods of measuring parts, such as calipers, which are relatively imprecise and can take a long time to complete. This can lead to errors in the production process and ultimately affect the quality of the finished products. In this context, the use of 3D scanners could bring significant improvement to the measurement process, thereby reducing the required time and improving accuracy. Additionally, modern CAM simulation solutions can be used to automate and optimize manufacturing processes, thereby reducing production time and costs. For example, using software to verify and simulate one's own machining center can reduce the time required for machining and allow for greater profitability and flexibility in production, helping to identify potential issues before the chip removal process begins, thus reducing costs associated with repairing or remaking products or replacing cutting tools.

Furthermore, implementing CAM post-processor optimization solutions can help reduce labor costs and increase production process efficiency, as many companies currently face challenges in modifying the code after using CAM software due to differences with the machining center. There is great potential for implementing modern CAD/CAM process optimization solutions in the manufacturing industry in Romania. The use of these solutions could bring significant benefits, such as improving precision and reducing production time and costs. It is important for companies to be willing to invest in these solutions and consider the long-term advantages of using them.

3. Actual methods of streamlining and their implementation

3.1. Measurement and design methods

3D scanning is one of the modern technologies used for design, inspection, and quality control. This contactless measurement technology converts a physical model into a digital 3D CAD design using various scanning programs. It becomes an essential tool for manufacturers who need precise dimensional inspection, virtual imaging, analysis, and even physical prototypes. This chapter focuses on the potential of 3D scanning for the industrial sphere, discusses practical industrial support 3D scanners, and develops the workflow of 3D scanners for industrial requirements. Additionally, the paper identifies major applications of 3D scanning from an industrial perspective. 3D scanners use sensors to perceive the details of any product. This technology can easily capture the virtual image of a physical object that can be analyzed, modified, and stored. 3D scanning is useful for reverse engineering, analysis, design, and measurement of complex curved surfaces, quality monitoring, prototyping, industrial tool development, and many more. This technology utilizes advanced software for precise measurements and analysis, which helps increase process flexibility and reliability.

These scanning technologies are used to scan physical components that often do not have drawings or CAD data. The geometric dimensions accuracy of the object can be quickly calculated and verified. It is beneficial for components with complex geometry, worn or damaged parts, being able to analyze construction accuracy and quality, such as integrity checking or different deviations resulting from use. The measurements of a part can be easily modified in CAD software. Initially, after scanning, the scanner program exports an .stl file, which will be opened in the design program as a mesh, and by selecting all the surfaces, a solid body can be created to which dimensional properties can be easily modified according to preference.

Laser-based 3D scanners [1] minimize the time required for designing a part and reduce the number of errors in data collection. A scanner rapidly captures details about the surfaces of objects and the environment, taking measurements in any direction. The process starts with placing the object to be scanned in the scanning area. The laser scanner (fig. 1) then emits a laser beam that scans the surface of the object and measures the distance from the scanner to the object's surface by emitting light pulses and recording the time it takes for these pulses to reach the surface and return to the scanner. This data is collected and processed by the laser scanner to create a 3D model of the scanned object. Depending on the type of laser scanner, this process can be achieved by using a rotating mirror to direct the laser beam in different directions, by rotating the object on a table, or by rotating the scanner around the object. Additionally, to remove surfaces we don't want to scan, markers can be placed on them, and the scanner's software will exclude them.

In addition to laser scanners, there are other types used in the industry:

Structured Light Projection Scanners (fig. 2), based on structured white light projection, use a projector to project a pattern of structured light onto the object we want to scan. A video camera will record how these patterns are reflected and distorted on the object's surface to create a 3D model. This is an efficient solution due to high-precision data capture and high speed. They are especially used for scanning small and medium-sized objects.

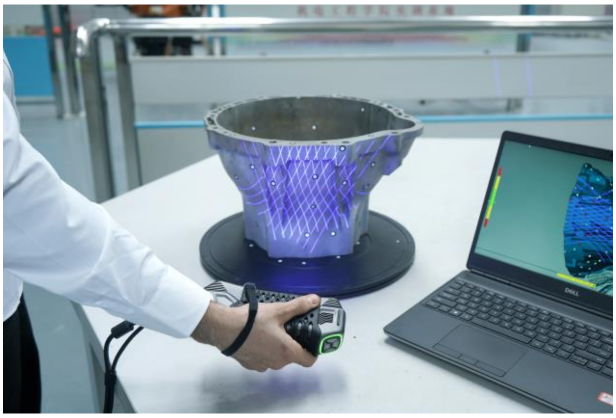

Fig. 1. 3D scanner based on laser projection, produced by Scantech [6]

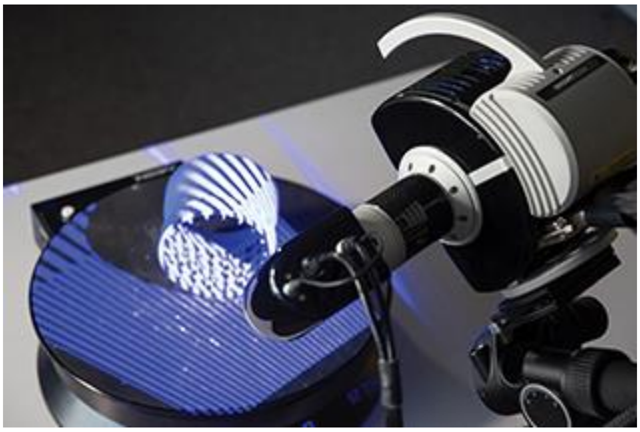

Fig. 2. 3D scanner based on structured white light, produced by Hexagon [5]

Photogrammetry-based 3D (fig. 3) scanners use multiple photographs taken from different angles to create a 3D model by analyzing and comparing common points on each photograph. The photogrammetry process involves using image processing algorithms and shape recognition technology to create a precise and detailed 3D model. The main advantage of photogrammetry-based 3D scanners is that they can create precise 3D models without the need to touch the object or have direct contact with it. They are also useful for objects or areas that are difficult to access or for creating 3D models of buildings and the surrounding environment.

Contact-based 3D scanners use a probe or a robotic arm to perform the scanning. They are useful for objects with complex shapes or that require high precision. The probe or robotic arm can be moved around the object to obtain a complete image of it, and the data is collected through a contact sensor that measures the distances between the probe and the object. Another advantage of contact-based 3D (fig. 4) scanners is that they can provide high precision, as the contact sensor can detect small details of the object. However, they are less suitable for fragile or sensitive objects, as the probe or robotic arm may damage or scratch their surface.

Fig. 3. 3D scanner based on photogrammetry, produced by Occipital [7]

Fig. 4. Contact-based 3D scanner, produced by Faro [8]

From personal experience (fig. 5), laser 3D scanning is the most efficient method for scanning objects of any size, providing high precision and ease of scanning. In the context of research and during an internship program at a company specializing in reverse engineering, I have scanned numerous metal parts to be later produced and distributed to clients. As such, scanning a part takes significantly less time than measuring all surfaces using traditional methods (calipers, micrometer, ruler, etc.).

Fig. 5. Personal experience laser 3D scanning

Furthermore, I have encountered parts with a complex structure that would have greatly hindered the production process if measured using traditional methods. Laser scanning has also highlighted structural defects in the parts, providing data for finite element analysis that I subsequently conducted. This has been a major advantage for further communication with the client regarding potential improvements to the part or issues encountered during use.

3.2. Fabrication simulation and the optimisation of CAM postprocesors

Simulation of machining and optimization of CAM post-processors are two key technologies in modern production processes. They play a crucial role in reducing errors in computer numerical control (CNC) machining centers, improving production efficiency, and enhancing the quality of produced parts. In this article, we will discuss how machining simulation and optimization of CAM post-processors are carried out, as well as their benefits in implementing these technologies in an enterprise.

Simulating the machining of parts to reduce errors in CNC machining centers is a technology that allows verifying the machining process of parts before it is launched into production (fig. 6). This technology utilizes virtual simulations to create 3D models of parts and the intended machining operations. As a result, CNC operators can verify the machining process before starting production, thus eliminating the risk of costly errors and improving the quality of produced parts.

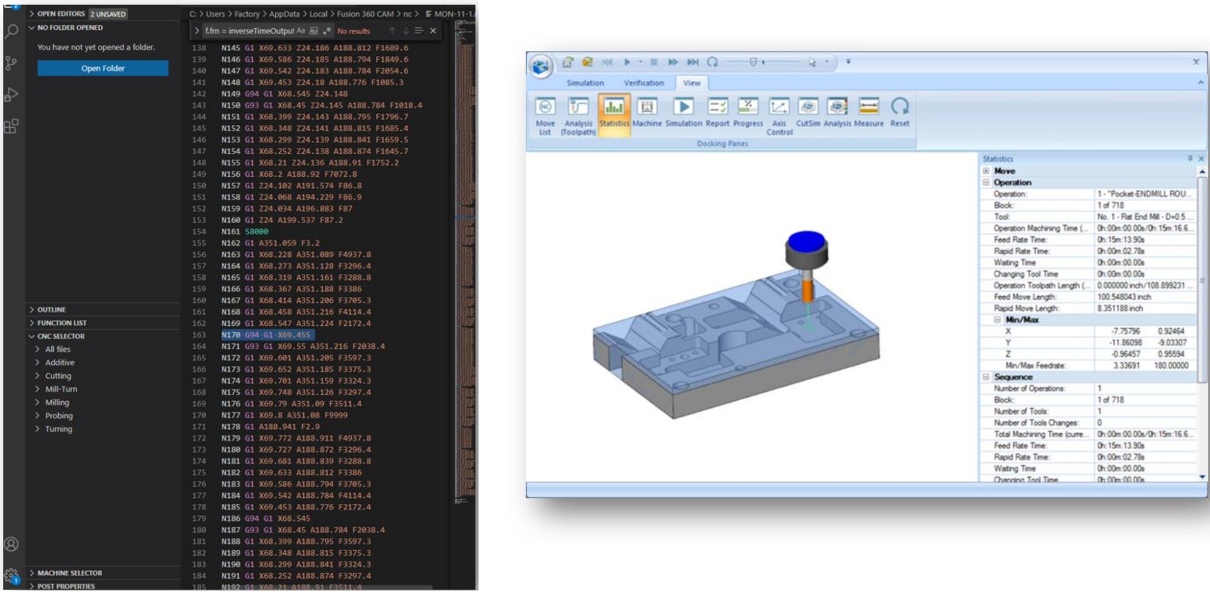

Fig. 6. Example of simulating the machining of parts

Implementing part machining simulation in an enterprise can bring several advantages. The first advantage is cost reduction by eliminating costly errors in production. Additionally, it can improve the quality of produced parts, and operators can be better prepared before launching production, thereby reducing the risk of human errors [4].

As for the optimization of CAM post-processors, it refers to the process of verifying and optimizing the efficiency of post-processors for G-code operations. One popular program for this technology is Vericut, which can be used to verify and optimize post-processors for a wide range of machines and controllers. Vericut allows operators to verify the CAM-generated G-code before it is launched into production, thus eliminating the risk of costly errors.

Implementing optimization of CAM post-processors in an enterprise can also provide several advantages. By verifying the G-code before production, errors can be identified and corrected, thereby improving the quality of parts and reducing costs. Additionally, operators can be better prepared before launching production, reducing the risk of human errors.

3.3. Using Artificial Intelligence to Improve Design Processes

An innovative approach in CNC machining is the use of artificial intelligence to analyze a large amount of data, identify repetitive patterns, and recommend the appropriate toolpath for machining [2]. These methods significantly reduce the time required to create the machining program and can enhance process efficiency. In this regard, companies like PTC have developed generative design tools that utilize AI to find optimized design solutions based on specified requirements. This process involves defining design parameters and specifying performance objectives for a part. The algorithm then explores various possible design variants and recommends the best structure for the given criteria.

Regarding CNC machining, the AI algorithm can be used to analyze and identify repetitive patterns in the machining process data. This can include using machine learning techniques to identify and recognize geometric shapes and machining patterns or analyzing historical data to identify trends and repetitive patterns. Based on this data, the algorithm can recommend an optimized toolpath for machining, which can reduce machining time and increase process efficiency.

4. Conclusions

The implementation of 3D scanners, simulation of machining, optimization of CAM post-processors, and the use of artificial intelligence for improving design processes represent modern methods to increase efficiency and accuracy in the field of mechanical machining. These technologies help reduce errors, eliminate manual processes, and reduce production time.

By using 3D scanners, companies can obtain precise and detailed three-dimensional models of parts, which can be used to create CAD models, verify the accuracy of manufactured parts, and perform finite element analysis. Simulating machining operations and optimizing CAM post-processors help reduce production time, eliminate errors, and increase machining efficiency. Furthermore, by utilizing artificial intelligence, the design and production process can be significantly improved by identifying repetitive patterns, recommending toolpaths for CAM, and optimizing part structures.

Implementing these technologies can bring numerous advantages, such as increased efficiency and quality, reduced production time, minimized errors, and eliminated manual processes. Moreover, these technologies can be integrated into existing production processes without major infrastructure changes.

In conclusion, the implementation of 3D scanners, simulation of machining, optimization of CAM post-processors, and the use of artificial intelligence represents a modern and efficient solution for improving production and design processes. These technologies can bring significant benefits in terms of reducing production time and costs, increasing efficiency and quality, and improving design and production processes.

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MEDICAL DEVICE MANUFACTURING TECHNOLOGIES

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ABSTRACT: This article aims to present the main technologies for medical device manufacturing, advantages and disadvantages of these technologies. A concrete example of a device made with 3D printing technology is also presented: the design and assembly of the prototype of a medical dispenser.

KEYWORDS: injection molding, 3D printing, drug dispenser, 3D design.

1. Introduction

The evolving technology is not only economically beneficial but also capable of creating new industries or transforming existing ones, thereby potentially exerting significant economic and industrial impact on our society. There exists a range of technologies available for the development of medical devices, which may vary depending on the type and purpose of the device. In general, medical devices are manufactured through the utilization of specialized technologies that enable the production of high-quality components and products that are safe and efficient for users. The technologies employed in the production of medical devices constitute a highly significant and continuously advancing field within the medical industry, with the primary objective of aiding in the improvement of health and the quality of life for patients. The main technologies utilized for device fabrication include injection molding, 3D printing, stereolithography, CNC milling, and electrical discharge machining.

Injection moulding is the technique of producing identical products from a molten material in a mould and is the most widely used polymer processing operation. [1] The main advantage of injection moulding is that it is a very economical method of mass production. Ready-made parts with close tolerances can be produced in one step, often fully automatically, and generally no further processing steps are required. It is also possible to integrate different functions into a single part to avoid different components that would be more costly. [2] Compatibility with a wide range of materials and colours is a benefit, there are currently over 25,000 manufacturing materials that are compatible with injection moulding, including thermoplastics, thermosets, resins and silicones. A primary disadvantage is the high initial costs because custom tooling must be created for each injection moulded part, initial start-up costs are high, and this is not economical for low-volume production runs. Injection moulding has a longer lead time, often taking 5-7 weeks to manufacture tools and 2-4 weeks to produce and ship parts. For the most part, this long lead time can be attributed to the complexity of the moulds themselves. Another disadvantage would be in changing the design, you will probably have to create a new mould from scratch, which means extra cost. [3]

Of the various manufacturing processes currently adopted by industry, 3D printing is an additive technique. It is a process by which a three-dimensional solid object of virtually any shape is generated from a digital model.[4] 3D printing has the advantage of quickly manufacturing custom medical models at a lower cost because no tools are involved. 3D printed organ models primarily help doctors perform surgical analysis and pre-operative preparation. Such implants and printed organs not only fit perfectly with the patient's damaged tissue, but can also have microstructures of engineered materials and cellular arrangements to promote cell growth and differentiation. Thus, implants allow the desired tissue repair to be achieved and could ultimately solve the problem of donor shortage. Customised medical models with complex shapes that are made using 3D printing can provide doctors and engineers with a means of

communication and help with surgical planning and diagnosis. There is no requirement for biocompatibility of materials in such applications, which include medical models and in vitro equipment for pre-operative planning, prosthesis design, testing standards and so on, as the printed parts will not enter the body. [5] While it is difficult to specifically assign a cost to a process when considering the potential to save or improve quality of life, it is clear that all technologies have associated costs. Even where there are clear benefits in terms of improved medical service, the approach can be cost prohibitive. Many 3D printing machines are expensive to run, particularly in terms of material costs. [6]
However, in addition to the higher price, issues such as limited print resolution, longer printing time and few available materials similar to the target organ or tissue during the process need to be addressed. [5] Many materials are not even suitable for sterilisation and transport to operating theatres. [6]

A concrete example of a device created using 3D printing technology is the medication dispenser, whose components are entirely designed. These devices are utilized to assist patients in timely and accurate administration of prescribed medications. Traditionally, such devices are manufactured using rigid materials like metal or plastic through milling and casting processes. However, the utilization of 3D printing technology enables the rapid and precise production of a customized medication dispenser with precise shapes and dimensions to suit the patient's needs.

2. The practical implementation of a medicine dispenser

2.1.Medicine dispenser design

In designing the medication dispenser, the basic idea was to create a simple but effective device that would allow patients to take their prescribed medication in an organised and accurate way.

In the first stage of the design, we made preliminary sketches of the medicine dispenser. Once we had established the desired models we started to make the 3D design of the parts in the Onshape application. We created 3D models to ensure that the device would work in a proper way and to help us identify possible design issues. We then generated 2D drawings with associated dimensions for use in the manufacturing process.

The medication dispenser is composed of several designed components, including its housing, which accommodates the feed chute tube, the screw mechanism inside the tube, the support for the Arduino board and motor, as well as the pill collection tray.

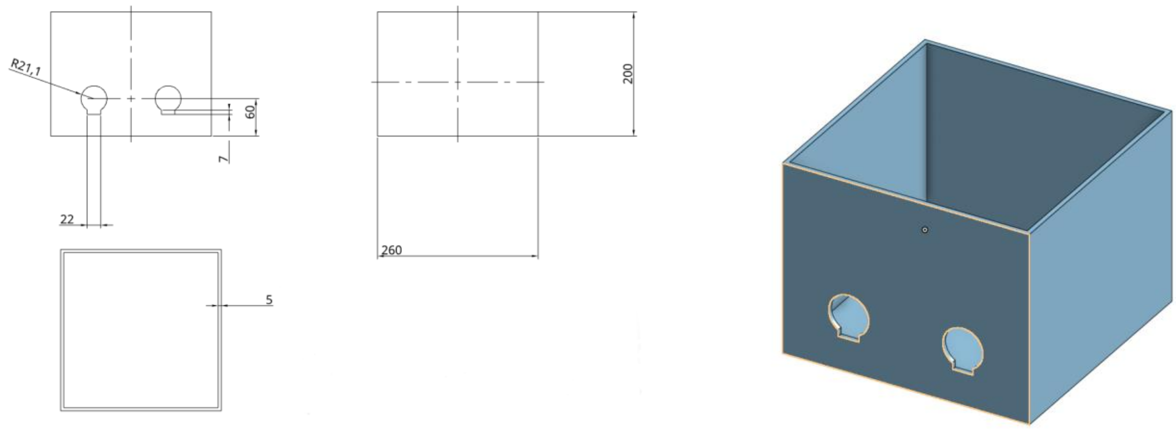

Fig. 1. 2D/3D medicine dispenser housing

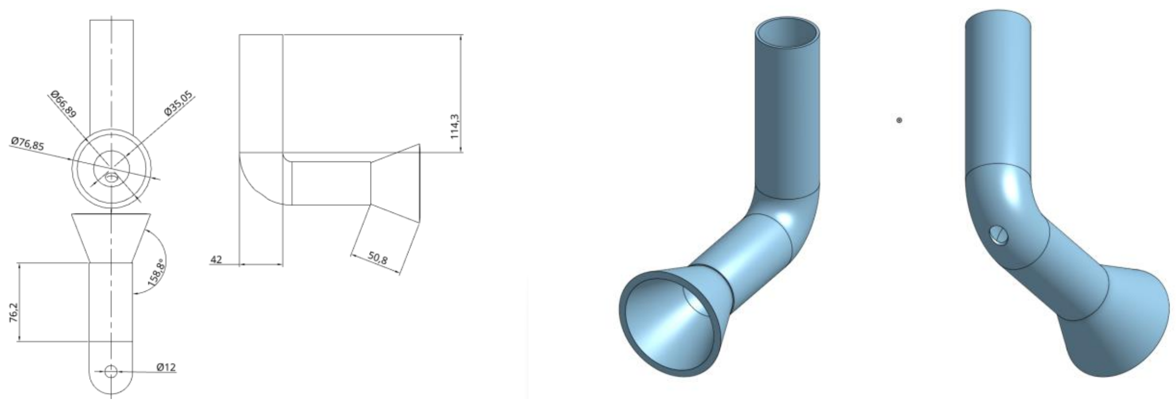

Fig. 2. 2D/3D medicine supply system

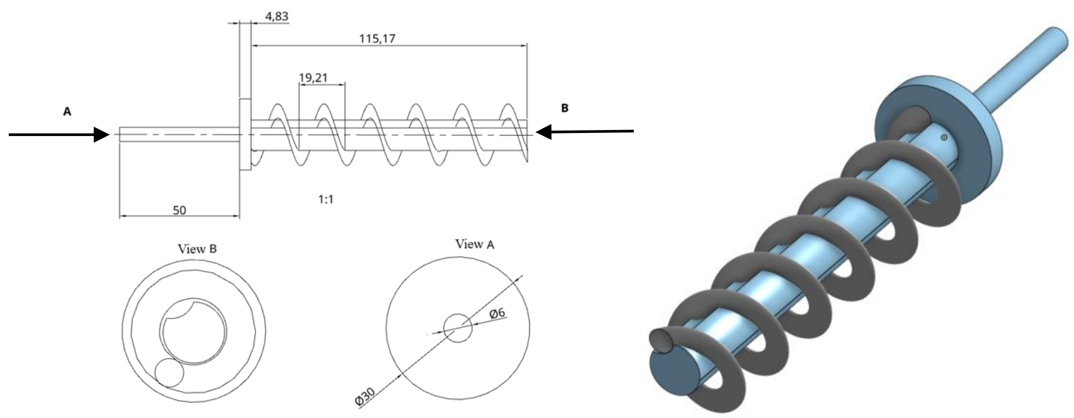

Fig. 3. The screw in 2D/3D

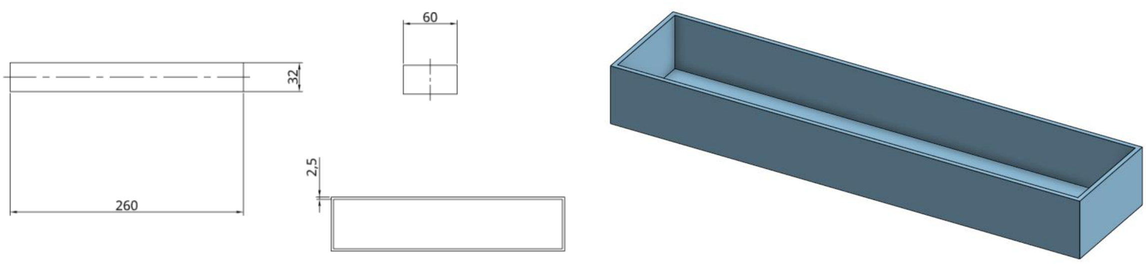

Fig. 4. 2D/3D pill collection tray

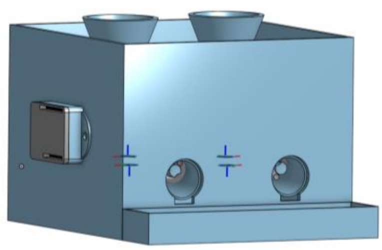

Fig.5 Assembled medical device

2.2. 3D printing of the medicine dispenser

We used 3D printing technology to create the prototype of the medicine dispenser. This process allows us to obtain a 3D image of the device so that we can analyse and adjust it before final manufacture.

The printing of the components was done with the ANYCUBIC MEGA 3D printer which uses molten plastic filament to build the object in a layer-by-layer process. The printer has a print area of 300mm x 300mm x 305mm and can print in a variety of materials. In our case we chose TPU (Thermoplastic Polyurethane) filament, it is a flexible, soft and pliable material, but at the same time quite durable, impact and abrasion resistant.

In order to achieve a high quality print, we set the extrusion temperature at 180°C and set a print speed of 75 mm/s to ensure that the object is printed in a reasonable time, but without sacrificing quality. In total, printing took about 15 hours.

Fig. 6. ANYCUBIC MEGA 3D printer

Following the 3D printing process, we got the components needed to assemble the prototype medicine dispenser. These components were of high quality and quite accurate, so they could be assembled and tested to verify the correct functioning of the device.

Fig. 7. The printing process of the medicine dispenser parts

2.3. Medication dispenser programming

We connected the motors and infrared sensors to the Arduino board via digital pins. The motors are connected to digital pins 3 and 5 respectively and the power pins, and the infrared sensors are connected to digital pins 4 and 6 respectively.

The code is written in the Arduino Integrated Development Environment - or Arduino Software (IDE), which is a software platform specifically designed for Arduino boards, in which programs can be developed and created.

This code will cause the two motors to start 3 minutes apart and wait 5 seconds to reach maximum speed. If one of the two infrared sensors detects a signal while the motors are running, they will stop immediately and wait for the next start 3 minutes apart.

2.4. Electrical part of medical dispenser

In addition to the printed components, we utilized the following components for the operation of the device: two DC motors, two infrared sensors, and an Arduino board. The motors were connected to the Arduino board using a dual H-bridge, L298N, which enables us to control the speed and direction of rotation. The infrared sensors were connected to the board using jumper wires. The power supply can be provided either by batteries or directly from the power source.

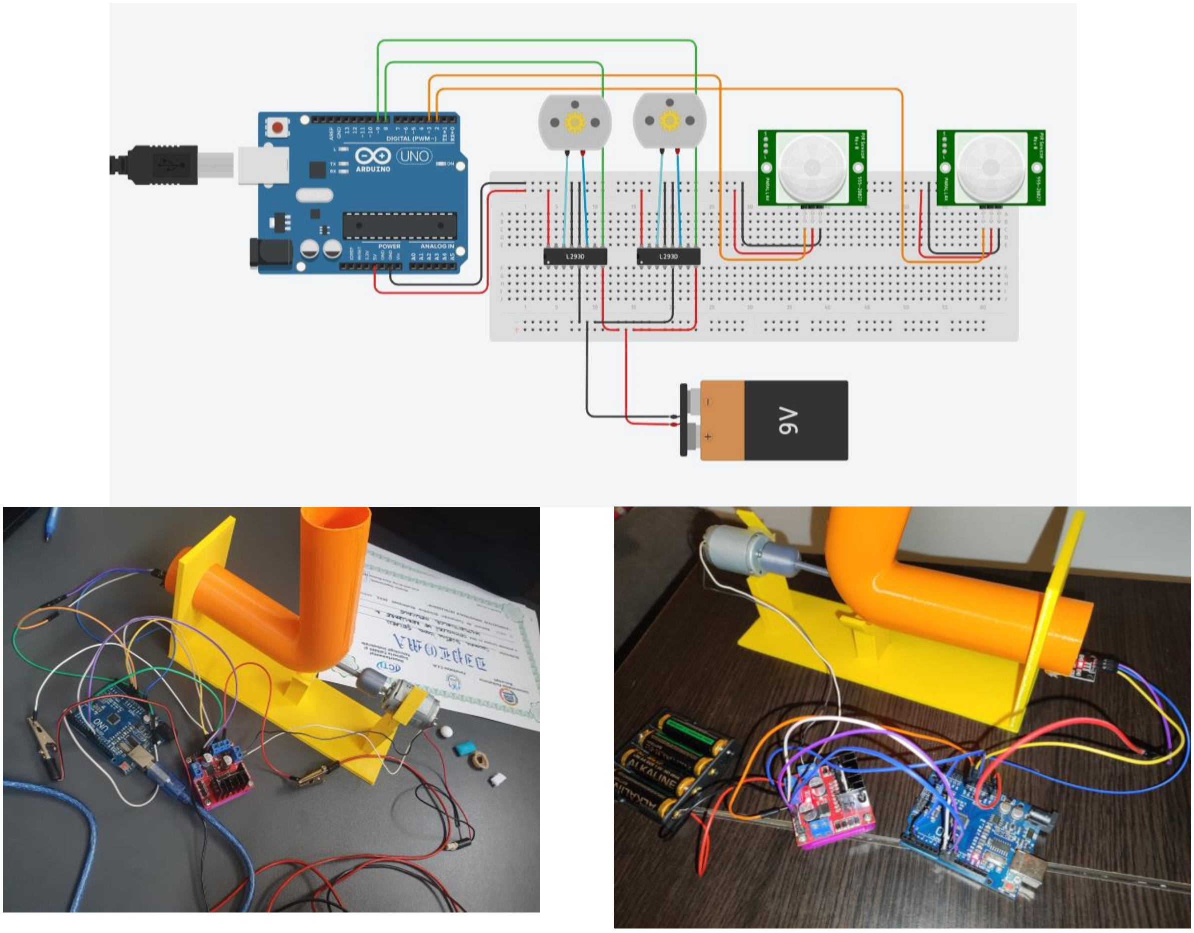

Fig.8. Electrical diagram with battery power/supply

3. Conclusions

The medication dispenser represents a precise method of medication administration, providing assistance for patients with daily treatment or elderly individuals. The device is designed for two types of pills and utilizes a motor-controlled screw to distribute the medications efficiently and in the appropriate dosage. Moreover, the components are crafted to ensure a pleasing aesthetic appearance while facilitating easy handling for the user, its dimensions allow for convenient storage. This type of device proves useful in hospitals and nursing homes, alleviating the burden on healthcare professionals. For instance, during the pandemic, this device could have been valuable for patients who did not require meticulous monitoring but only medication administration, thereby reducing contact with patients.

Regarding potential improvements, we believe that adding certain additional features could be beneficial. For instance, incorporating a touch screen interface would allow for personalization of the administration time and pill quantity, either directly on the device or through a remote programming application. Additionally, implementing an alarm system to notify both patients and caregivers when the medication is due or when pill supplies are running low would be advantageous. Expanding the capacity to accommodate a greater variety of pill types is another potential modification. Furthermore, integrating a notification system to alert users when the collection tray needs to be emptied and providing confirmation of medication intake could enhance the functionality of the device.

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TECHNOLOGIES USED IN CARBON CAPTURE AND STORAGE

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ABSTRACT: Carbon capture is a method in which carbon emissions resulting from industrial processes are stopped from polluting the atmosphere through specific technological installations. The collected carbon is then either reused in various industrial applications or, using the CCS process (Carbon Capture and Storage) or, compressed and transported to specially provided places in order to be stored deep underground. Other carbon capture technologies include collecting it in specific filters that can then be recycled. Carbon capture and storage technologies are being used both at international and, still sparsely at national level in various industrial applications.

KEYWORDS: carbon emissions, carbon flux balance, geological and oceanic storage, carbon capture from Li-Ion batteries, activated carbon filters.

1. Introduction

Carbon capture followed by storage refers to a range of technologies that capture carbon emissions at a certain stage from industrial processes such as combustion or gasification of materials. Although there is no specific legislation in Europe on carbon emissions, many industrial processes, in particular cement, iron and steel manufacturing and the treating of natural gases, intrinsically produce carbon emissions, hence the reason why equipping them with carbon capture technologies (and subsequently, its storage) is imperative [1].

Most often, these technologies involve capturing carbon dioxide (CO_2) emitted by industrial processes, compressing it to about 100 bar (or more) and transporting it to a special storage site where it is then injected and stored in certain geological or oceanic formations, thus preventing its subsequent emission into the atmosphere. This type of technology is called "carbon capture and storage process" and although it has been implemented for decades, it is still used on a small scale in industry [4].

The present paper aims to present the impact of carbon emissions resulted from industrial activities while highlighting the importance of implementing appropriate solutions for carbon capture and storage, and to uncover both classic and modern technologies used in carbon capture and storage in the industry.

In the following chapters will be presented: the influence on both the way we lead our lives and on the environment of industrial carbon emissions and, implicitly, the importance of capturing these emissions, the main solutions for storing carbon after its capture, the types of current technologies used in carbon capture and storage and a case study - "Technologies for capturing the carbon emitted in the manufacture of Li-Ion batteries at ROMBAT SA Bucharest".

The paper will wind up with the conclusions of the data, concepts and observations presented throughout it.

2. The importance of capturing industrial carbon emissions

Carbon is the 15th most abundant element in the earth's crust, its large natural distribution, the specific diversity of its organic compounds, and its unique ability to form polymers at normal temperatures allows it to be the most common chemical element of the living world. It is part of human DNA, it is present in food and products widely used by the population (fuels, building materials) and, most importantly, it is the foundation on which a great deal of the industry is built.The flow of carbon is continuous (in the atmosphere, oceans, vegetation and the earth's crust) but permanently in an imbalance caused by industrial activities:

In the last 20 years alone, CO_2 emissions have increased considerably, reaching in 2022 almost 4 times more than in the 1960-1970 period (36.8 billion tons compared to 9.39 billion tons in 1960).

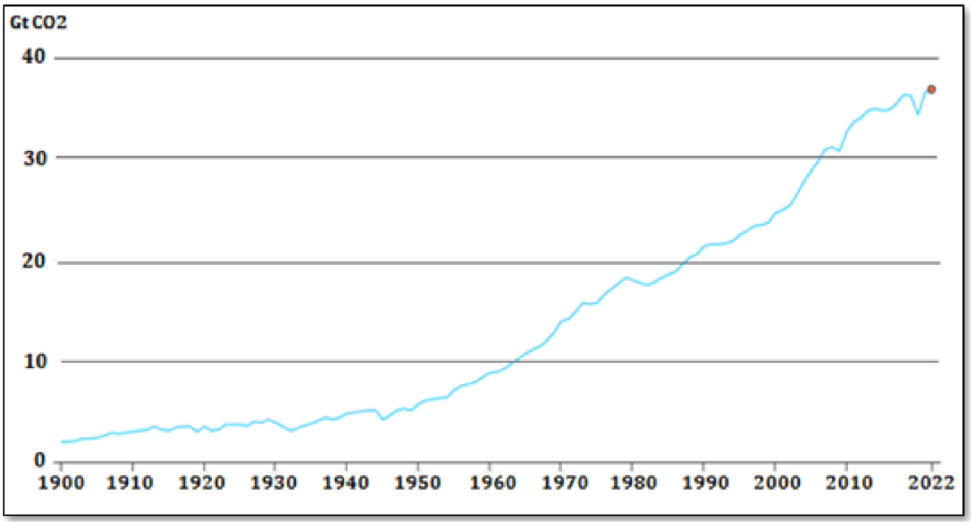

Fig. 1. Global CO_2 emissions resulting from industrial processes, 1900-2022 [8]

The great majority of these emissions come from industries such as: natural gas, synthetic fuels, electricity, oil, construction materials, cement, etc.

Therefore, in order to maintain the balance of the carbon flow, it is essential to implement carbon capture solutions for as many industrial processes that are producing carbon emissions as possible. If these emissions cannot be reused after capture, suitable carbon storage solutions must be sought.

3. Carbon storage solutions

Once captured, carbon that cannot be reused can be compressed and then transported in order to be stored deep underground - in geological formations, in the ocean or in carbonate minerals.

There are two main types of compressed carbon storage solutions, that have been used for over 50 years (the first large-scale project to inject CO_2 into the soil was launched in 1972):

a) Ocean storage

It involves direct release into the oceanic water column or seabed followed by industrial fixation of CO_2 in inorganic carbonates. This type of storage is less preferred because, according to recent studies, it could worsen the acidification of the ocean [2].

b) Geological storage

Geological storage is defined as placing CO_2 in an underground formation so that it remains safely conserved.

There are five common types of underground formations used in this geological carbon storage process:

- saline formations;
- empty oil and natural gas tanks;
- unworkable coal beds;
- organic shale formations;
- basaltic formations [8].

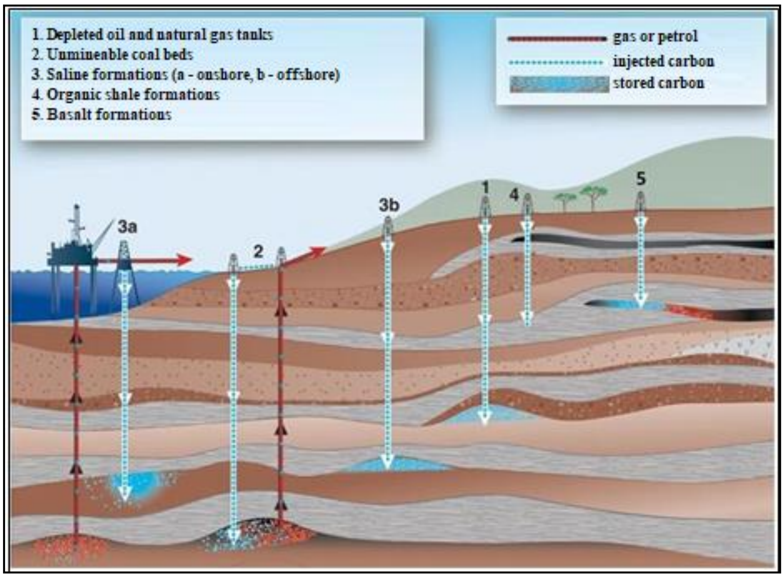

Fig. 2. Types of underground formations used in geological storage [1]

Oil and natural gas reservoirs are ideal geologic storage sites because, once oil and natural gas are extracted from an underground formation, they leave a permeable, porous volume that can easily be filled with CO_2. These reservoirs also offer an economic opportunity as CO_2 injection contributes to a process called enhanced oil recovery.

Saline formations are also a good carbon storage option. These are porous formations filled with salt water that extend over long distances and lie deep underground (below the shore or underwater). Coal beds with high permeability that cannot be exploited due to the fact that they are either too deep or too thin to be mined (due to geological, technological and economic factors) are another carbon storage solution. Coal seams can also contain methane, which can be produced in combination with CO_2 injection in a process called enhanced coal seam methane recovery.

Basalt formations can also offer a good alternative for carbon storage. These types of formations occur when a large lava stream spreads, cools and then solidifies.

Although recent studies offer insights on how these current storage methods can involve significant risks for the environment (pollution of ocean water or earthquakes in the event of leaks), so far no major accidents have broken out [2].Carbon capture technologies

There are various technologies that can be used to capture carbon, varying in efficiency, cost and level of development. These generally fall into one of three broad categories: post-combustion carbon capture, pre-combustion carbon capture and oxy-fuel combustion systems – the carbon captured through these technologies being compressed and transported through pipelines, vehicles or ships to a storage location.

a) Post-combustion:

This technology is commonly applied in the chemical, gaseous fuel, fertilizer and power generation industries and involves the separation of CO_2 from flue gases derived from burning fossil fuels – coal, natural gas or oil – in air.

b) Pre-combustion:

This technology involves the splitting of hydrocarbons by gasification of the fuel followed by the separation of carbon dioxide, representing a process often used in industrial processes (for example in the production of ammonia) due to its relatively low costs compared to other technologies. Compared to post-combustion technology, which removes dilute CO_2 (~5-15% CO_2 concentration) from flue gas streams and is at low pressure, the offset syngas stream in pre-combustion processes is rich in CO_2 and at higher pressure, which allows for easier removal before the H2 is burned off.

Due to the higher CO_2 concentration, pre-combustion capture is usually more efficient, but the underlying process costs are often higher than in traditional pulverized coal plants [3].

c) Combustion with oxy-fuel

In oxy-fuel combustion (oxycombustion), the fuel is burned in an environment consisting almost entirely of pure oxygen, to avoid the nitrogen in ordinary air, which results in a more concentrated stream of CO_2 emissions (which becomes lighter and, implicitly, cheaper to capture) [5].

However, these 3 methods, although the most often used, are not the only technologies that can be used to capture the carbon resulting from certain industrial processes, new technologies also allow faster and cheaper solutions, such as capture with the help of special filters.

4. Case study - "Technologies for capturing the carbon emitted in the manufacture of Li-Ion batteries at ROMBAT SA Bucharest"

Rombat SA company is recognized on the national market for the production of classic lead-acid batteries for cars with internal combustion engines, but, in recent years, following the increased interest in the European automotive industry for electric cars, the company has also begun to invest in the manufacture of Li-Ion batteries.

Thus, in 2019 Rombat in partnership with Prime Technologies announced the inauguration of the first Li-Ion battery production unit for electric cars in Romania. The unit was placed near Bucharest, in Cernica, occupying an area of approximately 5,000m2 and was supplied with unique equipment and technologies in Romania, designed and used in South Korea. Within this unit the manufacturing and assembly of the component parts of Li-Ion battery cells (anode, cathode, electrolyte, separator) was pursued. These types of processes automatically generate substances potentially harmful to the environment and the well-being of employees, either from emissions of carbon found in the component parts, or from the non-recycling of the solvent used in this type of procedure - NMP (N-methyl-2-pyrrolidone C5H9NO - an organic solvent used to the cathodic mixture).

To prevent the spread of these substances and to ensure the safety of employees and the environment, two large auxiliary systems are found within the facility: the NMP recovery equipment and the air filtration system.

The solvent recovery facility consists of a steam recovery and water supply piping system, pumps, three solution wash basins, a NMP collection and separation basin from water, and a recovered NMP storage basin .

In the manufacturing process of Li-Ion batteries, in the discussed unit, there can be found: black carbon of mineral origin and graphite. They play a role in electrical and thermal conductivity and are the material for the anode and cathode of Li-Ion batteries.

Fig. 3. NMP recovery equipment (1) and air filtration system (2) [source: personal archive]

In the filter installation, the carbon emissions resulting from the process of coating the aluminum foils corresponding to the cathode with cathode paste, are picked up by the fans located along the roller system that transports the cathode foil and then filtered.

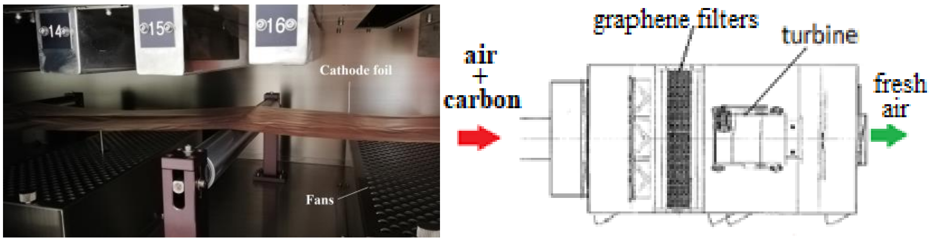

Fig. 4. Schematic of operation and related fans and filtration plant [source: personal archive]

Thanks to its graphene filters, the filter installation manages to efficiently capture the carbon resulting from the manufacturing and processing of the cathode, allowing clean air to be released into the atmosphere. Once full, the carbon-loaded graphene filters are taken over by a specialized company based in Poland that handles their recycling.

Rombat proposed the production of 100 Li-Ion battery cells daily. According to the average intensity of carbon emissions related to the production of these cells (about 475 grams of CO_2 eq/kWh), the production of 100 Li-Ion battery cells with a total capacity of about 13 kWh would produce, in a single day:

$$13\ kWh \times 100\ celule = 1300\ kWh \tag{1}$$

$$1300\ kWh \times 475\ gCO2eq/kWh = 617.5\ kgCO2eq \tag{2}$$

The filter system, put into operation, would reduce up to about 95% of the emissions associated with the production of battery cells, leaving about 30.88 kgCO2eq unfiltered:

$$617.5\ kgCO2eq \times (1 - 0.95) = 30.88\ kgCO2eq \tag{3}$$

Although Rombat Li-Ion was unable, due to the pandemic, to start its production at the established location, and only to made trial Li-Ion cells, the unique equipment and technologies found here, including the filtration solutions presented, remain sustainable solutions.

5. Conclusions

Capturing and reusing or, as the case may be, storing the carbon resulting from industrial applications is a way to reduce carbon emissions that continue to pollute the atmosphere, exacerbating climate problems and, implicitly, the imbalance of biodiversity.

Carbon capture technologies have been in use for over 7 decades (the first carbon capture facility was proposed in 1938, and the first large-scale CO_2 injection project into the soil was launched in 1972) and are mostly focused on the CCS process (Carbon Capture and Storage) that follows three main steps: carbon capture in the form of CO_2 (through one of three technologies: pre-combustion, post-combustion or oxycombustion), compression of CO_2 and its underground storage in geological or oceanic formations.

However, these classic capture and storage technologies involve significant costs and, more than that, the related storage solutions involve high risks: if an underwater tank leaks, the emissions will pollute the water, and if gas leaks occur underground, the pressure can cause earthquakes.

As presented in the case study, in recent years modern technologies have appeared on the market that help to capture carbon from certain industrial applications (in the present case, the manufacture of Li-Ion battery cells), such as installations equipped with fans that take the emitted carbon particles, then filtering the air loaded with them through special recyclable graphene or active carbon filters.

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THE POTENTIAL OF PIEZOELECTRIC MATERIALS REGARDING PRODUCTION OF ENERGY

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ABSTRACT: This article presents the possibility of using piezoelectric materials to efficiently produce electric energy by capturing lost energy, such as vibrations and movement, and converting mechanical energy into electrical energy. The article explains the concept of piezoelectricity and shows how piezoelectric materials can be used in the street pavement to collect the micro-energy generated by heavy traffic. Thus, the practical implementation of this concept can lead to reducing the electricity consumption costs of a given structure. This prevents the use of piezoelectric materials as a viable solution for obtaining electric energy from alternative sources, contributing to protecting the environment and reducing energy consumption.

KEYWORDS: piezoelectric materials, piezoelectric generator, energy production, piezoelectricity, piezoelectric roads

1. Introduction

In recent decades, the interest of researchers and enthusiasts of renewable energy towards the problems related to the global energy crisis and the impact on the environment has increased significantly. As a result, the focus on developing solutions with a low environmental impact and optimal energy performance has intensified. Thus, many efforts have been made on finding a viable alternative power source to power energy production technologies. The process of harvesting or capturing energy consists in the conversion of ambient energy (mechanical, solar, thermal, wind, from the movement of fluids, etc.) into electrical energy, by means of various materials or techniques for the transmission and storage of electrical energy, for later use [2]. Research into piezoelectric materials for micro-energy harvesting is constantly developing, with several recent studies exploring new materials and technologies to improve piezoelectric performance.

The piezoelectric effect was first discovered in 1880 by French physicists Jacques Curie and Pierre Curie. Piezoelectricity is electricity generated by applying pressure. Energy harvesting from piezoelectric materials is quite well known and has been studied for the last few decades, but recently, many new advances have been made in using piezoelectric materials in order to produce electricity.

Piezoelectric energy is a type of small-scale energy harvesting based on "lost energy" such as vibration, motion, sound and heat sources. Normally, energy from moving objects, machines that produce vibrations, or other sources that produce mechanical energy is not captured, being dispersed and thus wasted. In order to efficiently use this lost energy, piezoelectric materials can be used as a means to absorb that mechanical energy and convert it into electrical energy. Piezoelectric materials play an essential role because the amount of pressure applied is directly proportional to the electrical energy generated. The practical implementation of the concept of piezoelectricity can have a significant impact, by reducing the cost of electricity consumption of a given structure [3].

In this article we want to highlight the possibility of using piezoelectric materials as a way to generate electricity with the help of increased traffic in heavily populated areas. Incorporating piezoelectric materials into pavements could lead to higher efficiency when it comes to micro-energy harvesting.

2. The concept of piezoelectricity

By definition, the piezoelectric effect is the electric charge that accumulates in certain solid materials under the action of mechanical stress. Applying a strain to a piezoelectric material causes a voltage to appear between the electrodes. Piezoelectric materials can be configured so that the mechanical stress is perpendicular or parallel to the electrodes. As a result of compressive and tensile forces, stresses of opposite polarity can be produced, proportional to the applied force [3].

The piezoelectric effect converts mechanical stress into electrical stress. In general, there are two effects that manifest piezoelectricity, namely the direct piezoelectric effect and the reverse piezoelectric effect. When it comes to the direct piezoelectric effect, materials have the ability to convert mechanical stress into electrical charge (these materials can be used as sensors or energy transducers), while in the reverse piezoelectric effect, materials have the ability to convert an applied electrical charge into voltage energy mechanics. The direct and inverse piezoelectric effects can be mathematically expressed by two linearized equations [1,3].

The direct piezoelectric effect:

$$D_i = e_{ij}^{\sigma} E_j + d_{im}^{d} \sigma_m \quad (1)$$

The reverse piezoelectric effect:

$$\varepsilon_k = d_{jk}^{c} E_j + S_{km}^{E} \sigma_m \quad (2)$$

In these equasions Di is the dielectric displacement, measured in N/mV or C/$m2$ and εk is the stress/solicitation vector. Ej represents the electric field applied in volts per meter and σm is the tension expressed in N/$m2$. The piezoelectric constants are piezoelectric coefficients d_{im}^{d} and d_{jk}^{c}, measured in m/V or C/N, the permittivity of dielectric materials e_{ij}^{σ} in N/$V2$ or F/m, while S_{km}^{E} represents the elastic compliance of said materials, measure in $m2$/N. The exponents c and d denote the reversed effects, respectively direct and the exponents σ and E highlight the subjection of the coefficients to continuous stress and to a continuous electric field respectively.

2.1. Piezoelectric materials

Piezoelectric materials are a type of materials with unique properties that allow them to convert mechanical energy into electrical energy and vice versa, making them valuable in a wide range of technological applications. Some materials exhibit piezoelectric properties, including synthetic and natural materials such as natural crystals, ceramics, or synthetic crystals, piezoceramics, polymers, and organic nanostructures. They are divided into three categories according to their structural characteristics: inorganic piezoelectric materials, bio-piezoelectric materials, and piezoelectric polymers.

Inorganic piezoelectric materials can be divided into ceramics and single crystals. These ceramics are composed of small, irregular collective grains, and piezoelectricity occurs when a large electric field is applied to align the orientations of the crystals in a polarization process. Piezoelectric crystals, such as quartz film and ZnO, have a simple crystal structure and exhibit natural piezoelectricity. The stability and mechanical quality factor of quartz crystals are relatively higher than that of ceramics.

Bio-piezoelectric matter consists of some microorganisms and biological tissues such as silk, bones and certain viruses.

In comparison to inorganic piezoelectric materials, a piezoelectric polymer such as PVDF can carry a much higher load due to its intrinsic flexibility, having a lower electromechanical coupling constant than that of inorganic piezoelectric materials. However, the piezoelectric strain constant of piezoelectric polymer is relatively small, which has limited its application in transducers [1].

3. The concept of energy production utilizing piezoelectic materials

Energy recovery by means of piezoelectric materials represents a promising field of research, based on the ability of these materials to transform mechanical energy into electrical energy. This transformation is achieved by means of piezoelectric converters, which are composed of thin plates or piezoelectric crystals, subjected to mechanical deformation. The generated electrical voltage can be stored in batteries or other storage devices, having a variety of practical applications. These include powering monitoring and measurement devices in environments where an electrical power source is not available, powering sensors and smart devices for health and environmental monitoring.

One area of research where this technology is especially promising is harvesting energy from road traffic. The vibrations generated by vehicles traveling on the roads can be converted into electricity by means of piezoelectric plates, without using fossil fuels and without producing harmful emissions to the environment. This electricity could be used to power traffic lights, billboards and other roadside devices.

Global research has evaluated the performance of different types of piezoelectric materials, conversion technologies, and strategies to improve system efficiency and reliability. These studies aimed to identify current trends, challenges and opportunities in this field [3,6,7].

4. The operating principle of piezoelectric generators embedded in asphalt

A study by Najini et al. presents various analyses of existing piezoelectric elements and shows why PZT-5H is the most adaptable material in the process of power generation with the help of road traffic. The article presents two ways of implementation, one of which is in direct correlation with our own research, an implementation based on embedding piezoelectric transducers in asphalt to produce energy directly, with the help of vehicles (Fig. 1).

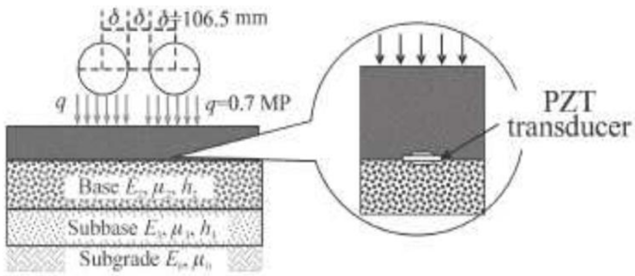

Fig. 1. The transducer’s placement in the asphalt [7]

While the piezoelectric effect is observed in various materials such as quartz, tourmaline and Rochelle salt, synthesized polycrystalline ferroelectric materials usually produce more electricity [7]. Therefore, Najini et al. used lead zirconium titanate (PZT) because it is the most robust commercially produced crystal compared to naturally occurring crystals. They have found PZT-5H (a ceramic material) to be the most suitable element of used in the process of energy recovery by the piezoelectric method (Fig. 2).

This ceramic exhibits increased tolerance to applied pressure with high piezoelectric properties. Thus, the properties presented in the study denote it as the most viable option for conducting research by introducing piezoelectric transducers into the pavement surface.

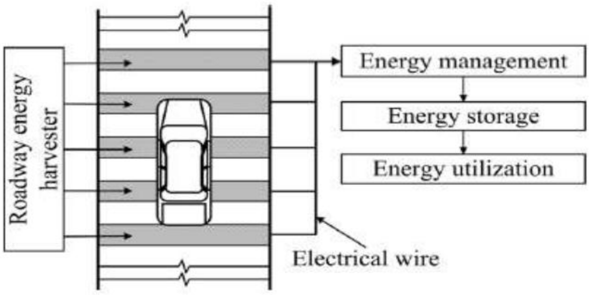

Fig. 2. Overview of the piezoelectric generator's placement [7]

The work of Yang et al. put this concept into practice, aiming to design a piezoelectric energy generator (PEH) for use in pavement and asphalt, with the goal of creating a sustainable and reliable energy source that can withstand the millions or billions of load cycles that it will experience during its lifetime. The PEH was designed to be 30 cm x 30 cm with a thickness of 8 cm and contains 12 piezoelectric units, an internal rectification circuit and two cables for the electric current. The core component of the PEH is the PZT-5H piezoelectric ceramic, with three strips overlapped and connected in parallel to form each unit. The protective structure of the PEH includes three layers: an upper layer that directly supports the vehicle load, an intermediate layer that contains the piezoelectric units, and a lower layer that withstands the ground reaction force. The intermediate layer also includes channels for the wires and the internal circuit board, as well as holes for the piezoelectric units.

After connecting the piezoelectric units to the circuit board, the generated power is drawn by the cables. The rectifier bridge is sealed with electronic glue to prevent water leakage and short circuit. This design ensures that PEH will have fatigue resistance, waterproofing and a good performance when subjected to compression (Fig. 3). During installation in the previously prepared pavement, the PEH positions were recorded and marked to facilitate the core extraction process. The process involves cutting the pavement, creating PEH pits and wire slots, levelling the bottom of the pits, installing the PEH, placing the wires along the slots, and filling the joints with modified asphalt mixed with diatomite [6].

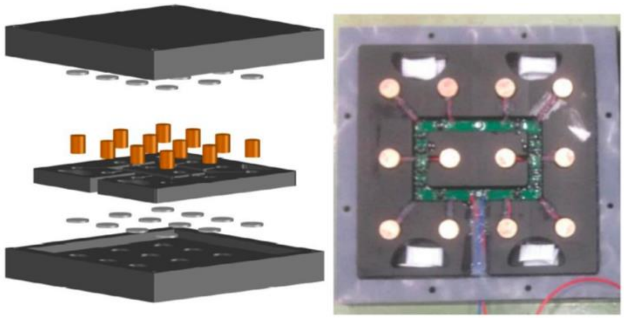

Fig. 3. The interior structure of the PEH [6]

In practice, the generators made by Yang et al. were tested by installing twenty of them on a section of about 50 meters long in the Ma-Zhao highway (Yunnan Province) and evaluating the performance under the action of real traffic (Fig. 4.). The test results concluded that the generator had an excellent performance in producing electricity with an open circuit voltage of more than 250 V under real road traffic conditions. The output voltage of the generator increased with the speed of the vehicle, thus providing a reliable solution for supplying electricity to street lighting. The electrical energy generated by the vehicles was supplied to the road facilities, the solution being in accordance with the concept of sustainable development [6].

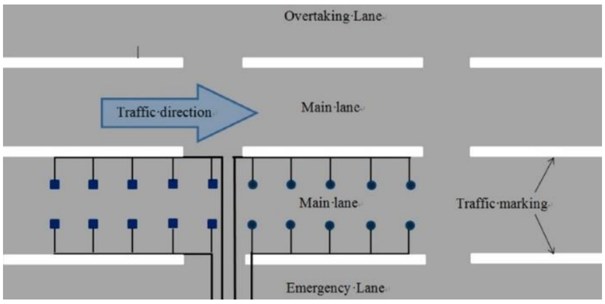

Fig. 4. The mounting area of the piezoelectric generators [6]

Another such trial was carried out by Nyamayoka et al, who analyzed the feasibility of using a piezoelectric generator on the N1 highway in South Africa (specifically at the Pumulani Plaza toll station). Various parameters such as vehicle mass, axle load and rolling resistance force were considered in the study to estimate the average power output of the generator (Fig. 5.). The generated mechanical energy, energy conversion efficiency and charging time are also calculated. According to the study, the total average electrical energy generated by a piezoelectric generator on the N1 highway would be 1.576587613 kWh. This energy can be used to power six High Pressure Sodium (HPS) streetlights for one hour. The article also discusses the need for an energy storage system to be able to store the energy generated during the day [3].

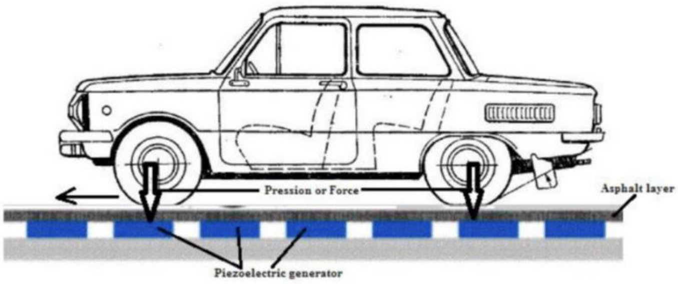

Fig. 5. Method of testing the piezoelectric generators [3]

5. The advantages and disadvantages of using piezoelectric materials for energy harvesting

The use of piezoelectric materials for energy harvesting is a technology that possesses advantages such as long lifespan, high reliability, and relatively low installation costs. They can be used in various applications, such as harvesting energy from traffic, human movement or the vibrations of machinery and industrial equipment. However, their use may be limited by the size and shape of piezoelectric devices, sensitivity to vibration frequency, ambient temperature, and data security issues. Research in this field and the development of new materials and technologies can help overcome these obstacles and improve the performance of piezoelectric materials for energy harvesting [4,5]. Combining piezoelectric converters with other energy harvesting technologies, such as solar cells and wind generators, can increase efficiency and ensure a constant supply of electricity.

In terms of energy harvesting from traffic, there is significant progress in the development of piezoelectric converters, but there are still challenges to be overcome. The high cost of piezoelectric materials and conversion technologies may be a major obstacle to their large-scale implementation, but researchers continue to work on developing new materials and more efficient production technologies to reduce costs and make the technology more accessible [4 ,5].

6. Conclusions

In conclusion, piezoelectric materials are a promising option for energy harvesting due to their advantages such as long lifespan, high performance, and relatively low installation costs. However, the use of piezoelectric transducers in practical applications faces several challenges, including relatively low efficiency and sensitivity to external factors such as vibration frequency and ambient temperature.

Current and future research in this area could help overcome these obstacles and develop more efficient and versatile piezoelectric transducers that can be used in a wide range of applications. In particular, the development of new materials and advanced manufacturing technologies, together with the integration of piezoelectric converters into multiple energy harvesting systems.

Finally, energy harvesting with piezoelectric materials is an important component of current efforts to develop renewable technologies and reduce dependence on fossil energy sources. Although further research and development is still needed in this area, it is clear that piezoelectric materials have significant potential in this regard and deserve to be considered as an important option for the future of energy harvesting.

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THEORETICAL STUDIES REGARDING THE VIBRATION OF THIN PLATES

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ABSTRACT: During the manufacturing process of materials and assemblies, structural defects can occur. Thin plates used in industrial engineering typically have thicknesses of a few millimeters or less, making it impossible to use conventional non-destructive testing methods such as ultrasound or eddy currents. As a result, knowledge of their internal integrity is not possible.This study highlights the natural vibration modes of the plates by identifying specific frequencies in modal analysis to avoid overlapping in operation, which can lead to resonance and rapid destruction of the structure when it exits the assembly's service. In addition, a source study of variable frequency vibrations was conducted to observe the design (arrangement) of nodes and antinodes on the thin plates studied. This is necessary to prepare the technical framework that validates the use of vibrations for non-destructive testing of thin plates.

KEYWORDS: plates, vibrations, Matlab.

1. Introduction

This research falls under a major field of interest regarding the vibration behavior of mechanical structures. The information contained in vibration signals for assessing the severity and location of defects can be used in the early detection of structural defects, allowing for scheduled maintenance. In this study, a dynamic modal analysis method for defect identification was proposed, with the major advantage being that it does not require access to the affected area. Essentially, a defect in a structure represents a deviation from the material or geometric properties of the structure, which alters its modal behavior through vibrations that produce displacements and stresses that modify certain mechanical and dynamic characteristics. Thus, the monitored parameters are: natural frequencies, modal shape, stiffness or flexibility.

Defect detection can also be performed through an algorithm. In this case, the algorithm's ability to detect defects, practical applicability, repeatability of the experiment for verifying results, extrapolation of the characteristic, and graphical representation can be optimally utilized through the dynamic analysis of plates.

2. Methods and Materials used in simulations:

• Modal Analysis

The theoretical framework of the modal analysis method involves the following elements:

a. Equation of Motion:

The equation of motion is a partial differential equation that describes the dynamic behavior of a structure or mechanical system. For linear systems, the equation of motion can be written in the form:

$$F(t) = M \times x''(t) + C \times x'(t) + K \times x(t) \quad (1)$$

where:

M = mass matrix

$x(t)$= displacement vector

$x'(t)$= velocity vector

$x''(t)$ = acceleration vector

C = damping matrix

K = stiffness matrix

$F(t)$= vector of applied external forces

For linear and isotropic systems, the equation of motion, using the equilibrium equations for a continuous material, can be written as follows:

$$\rho\times\frac{\partial^2 u}{\partial t^2}=\nabla\bullet\sigma+\mathrm{f} \tag{2}$$

where:

ρ = material density

u = displacement vector

σ = stress tensor

f = vector of applied external forces on volume

∇ = gradient operator

• = divergence operator

$\frac{\partial^2 u}{\partial t^2}$= second derivative with respect to time

The gradient operator is an operator that acts on a scalar field and produces a vector field. The gradient of a scalar field (a scalar function with spatial variables) indicates the direction and maximum rate of change of the scalar function in space. In three dimensions, the gradient of a scalar function f(x, y, z) is defined as:

$$\nabla \mathrm{f}=\left(\frac{\partial f}{\partial x}\right)i+\left(\frac{\partial f}{\partial y}\right)j+\left(\frac{\partial f}{\partial z}\right)k \tag{3}$$

where:

- ∇f gradient of function f

-$\frac{\partial f}{\partial x},\frac{\partial f}{\partial y},\frac{\partial f}{\partial z}$ partial derivatives of the function f

- i, j și k unit vectors in the directions of x,y and z

The divergence operator acts on a vector field and produces a scalar field. The divergence of a vector field measures the rate of change of the vector flux in an infinitesimal volume around a point. In three dimensions, the divergence of a vector field A(x, y, z) is defined as:

$$divA=\nabla\bullet A=\frac{\partial A_x}{\partial x}+\frac{\partial A_y}{\partial y}+\frac{\partial A_z}{\partial z} \tag{4}$$

where:

- $divA$ divergence of a vector field A

-A_x, A_y,A_z the components of the vector field in the directions of x, y and z

- $\frac{\partial A_x}{\partial x},\frac{\partial A_y}{\partial y}$ $și$ $\frac{\partial A_z}{\partial z}$ partial derivatives of the vector field components A with respect to x, y and z.

b. Eigenvalue problem: To determine the natural frequencies and mode shapes, the equation of motion is transformed into an eigenvalue problem. This is generally done by applying a Fourier or Laplace transform, followed by the elimination of terms containing time derivatives. The resulting eigenvalue problem takes the form:

$$(K-\omega^2\times M)\times x=0 \tag{5}$$

where:

ω = angular velocity (rad/s)

x = modal shape

c. Solving the eigenvalue problem: Solving the eigenvalue problem involved in modal analysis can be done through numerical methods such as the Jacobi method or the Lanczos method. These methods produce pairs of eigenvalues and eigenvectors that correspond to natural frequencies and mode shapes.

d. Interpretation of results: The natural frequencies and mode shapes obtained from solving the eigenvalue problem can be used to characterize the dynamic behavior of the structure or mechanical system.

For example, modal analysis can be used to evaluate the effects of design changes, to identify resonance issues, or to develop active or passive vibration control strategies. The theoretical framework of the modal analysis method involves formulating the equation of motion for the structure or mechanical system of interest, transforming this equation into an eigenvalue problem, solving the eigenvalue problem to obtain natural frequencies and mode shapes, and interpreting the results to understand and control the dynamic behavior of the system. This method can be applied in a variety of contexts, such as civil structure analysis, aircraft and ground vehicle vibration analysis, as well as the study of the dynamic behavior of mechanical or electronic components.

Modal analysis can be performed both experimentally, by measuring the response of the structure to external excitations and identifying modal parameters, and numerically, using finite element techniques or finite difference methods to efficiently solve eigenvalue problems.

The methodology used by ANSYS for modal analysis includes the following steps:

- Creating the geometric model:

The geometry of the first thin plate with sub-millimeter thickness (0.6 mm) is modeled in ANSYS, with dimensions of 240 x 240, in rectangular form.

- Defining the material:

The material for the plate is chosen, S235 steel for the plate with dimensions of 240x240x0.6 mm.Steel S235 is a construction material from the carbon steel family, with medium tensile strength and high elasticity. It is used in various industrial applications, such as the construction of metal structures, machinery and equipment, as well as in the automotive industry.The mechanical and physical characteristics of the material from which the rectangular plates are constructed are:

1) Longitudinal elastic modulus or Young's modulus, E = 210,000 MPa
2) Transverse elastic modulus, G = 81,000 MPa
3) Poisson's ratio, ν=0.3
4) Density, ρ=7850 kg/m^3 .

3. General description of the vibration study setup

The proposed vibration study setup consists of the following main components:

- Frequency generator: capable of generating a wide range of frequencies between 50 Hz and 20 kHz, with coarse adjustment at the hertz level and fine adjustment at the 0.1 Hz level.

- Threaded rod with a diameter of 5 mm and a length of 50 mm, fixed at one end to the frequency generator, and the other end threaded for 5 mm to allow for fixing of the sample in the setup.

- Fixing washers: Two fixing washers are required, one at the bottom and one at the top, with an outer diameter of 10 mm and a thickness of 0.3 mm. They serve to place the thin plate on the rod. They ensure a safe and stable fixing of the plate on the rod without affecting the plate's modes of vibration.

- Front control panel: includes an electronic display indicating the working frequency of the generator, a button for coarse frequency adjustment, a button for fine adjustment, and a switch button.
- Steel sample: with dimensions of 240 x 240 x 0.6 mm, fixed on the rod using fixing washers and a nut. Salt will be sprinkled on its surface to highlight the plate's natural modes of vibration.

4. Analysis of experimental results and discussions

The first natural mode of vibration that provided a clear arrangement of talcum powder on the steel plate was at a frequency of 1054 Hz (see Fig.1). A regular pattern is observed on both sides of the plate's axes of symmetry. This arrangement may contribute to the symmetry of nodal and ventral arrangements in the plate's natural vibration modes at its own frequencies of vibration for S235 steel.

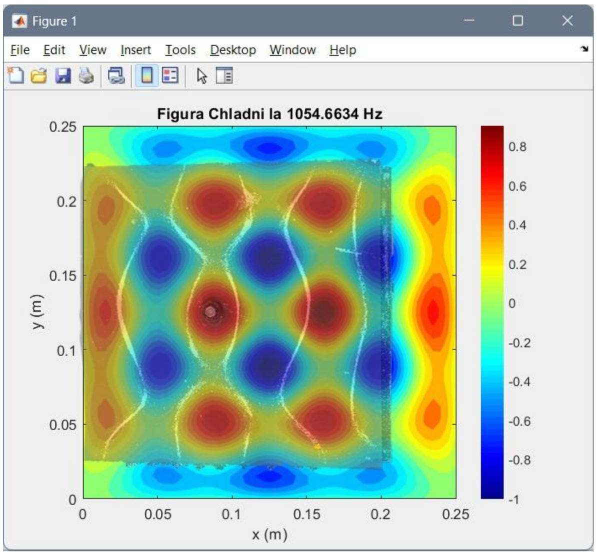

Fig. 1. Figura Chladni la 1054,6634 Hz

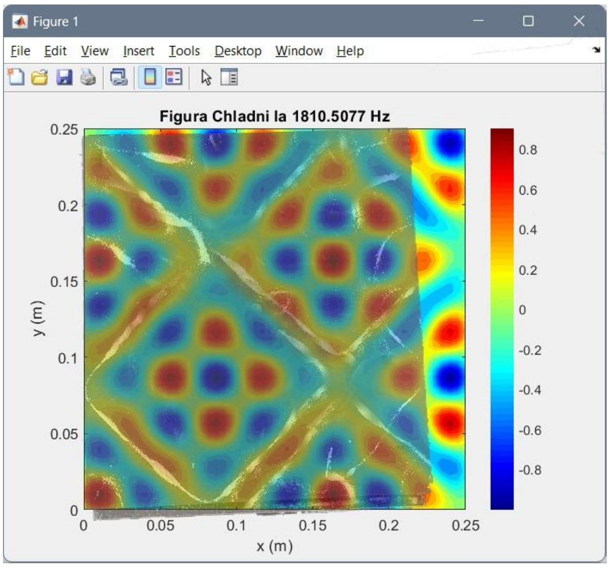

Fig. 2. Figura Chladni la 1810,5077 Hz

The way energy is applied can influence the vibration modes and the arrangement of nodal and ventral lines in modal analysis. For example, when applying a sustained vibration at a constant or variable frequency, the general vibration modes may be similar, but small differences may exist in terms of the frequencies and amplitudes of these vibration modes. These differences can influence the design of nodal and ventral lines in modal analysis.

In general, the symmetry and arrangement of nodal and ventral lines in a steel plate are influenced by several factors, such as the type of crystal lattice, crystal orientation, plate size and shape, how it is fixed, and how energy generating vibration is applied.

The next vibration mode that provided a clear arrangement of talcum powder was obtained at 1810 Hz (see Fig.2). At higher frequencies, the number of nodal and ventral lines present on the plate increases due to the reduction in the wavelength of the mechanical oscillation produced by the generator.

The next vibration mode that provided a clear arrangement of talcum powder was obtained at 1297 Hz (see Fig.3).

The experimental setup was validated by comparing the same vibration modes, for the same eigenvalues of frequency, in both the real and numerically simulated versions using the MATLAB program.

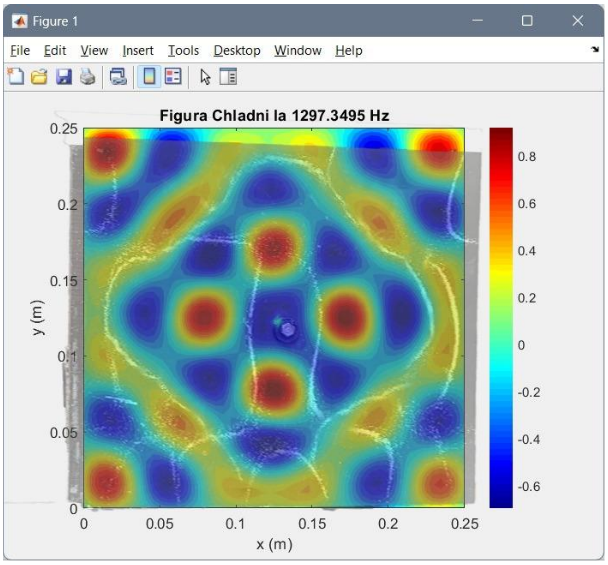

Fig.3. Figura Chladni la 1297,3495 Hz

5. Conclusions

There are several factors that can influence the arrangement of nodal and ventral lines in thin steel plates, including crystal orientation, plate size and shape, how energy generating vibration is applied, and the type of crystal lattice. Symmetry can be explained by using the cubic crystal system with a centered volume of the material, which produces a symmetric arrangement of nodal and ventral lines in the S235 steel plate, regardless of size or shape. Modal analysis and numerical simulation are important methods for understanding the vibration modes of thin plates and for detecting defects in various industries. This study can be extended to include other types of thin plates and to analyze the vibration modes of three-dimensional structures. Furthermore, ongoing research in the field of composite materials can offer new solutions for improving the performance of thin steel plates by combining them with other materials with complementary properties. Additionally, the development of new technologies for analyzing and monitoring the vibrations of thin plates can contribute to improving the safety and efficiency of structures in various industries, such as construction, transportation, or the aerospace industry. In conclusion, the study of the vibrations of thin steel plates is essential for the development and improvement of technologies in various fields and can lead to significant innovations in the future. In addition, by using advanced technologies such as X-ray tomography or electron microscopy, it is possible to obtain detailed images of the internal structure of thin plates, which can lead to a better understanding of how they vibrate and how their performance can be improved. In conclusion, the study of vibrations in thin steel plates is an important and complex subject, with many possibilities for further research and development.

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RESEARCH ON DEVELOPING AND BUILDING AN AUTONOMOUS ROBOT FOR SURFACE CLEANING

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The study "Research on developing and building of an autonomous robot for cleaning surfaces" aims to develop an autonomous robot capable of industrial cleaning large surfaces after various processes, such as the machining process. The robot will be equipped with a sensor system and navigation algorithms that will allow it to avoid obstacles and move autonomously in the workspace. Additionally, it will be equipped with an efficient cleaning system that can be adapted to different types of surfaces. A prototype of the robot has been built on a limited budget, and the cleaning brushes will be interchangeable to meet different cleaning needs. Developing such an autonomous robot could bring multiple benefits to the metal processing industry, such as reducing cleaning time and cost, as well as improving working conditions for employees.

KEYWORDS: autonomous robot, sensor system and navigation algorithms, prototype of the robot, benefits to the metal processing industry

1. Introduction

Certainly, robotics is one of the most interesting and promising branches of modern engineering. In recent years, autonomous robots have started to penetrate various fields, from the automotive and aerospace industries to medicine and space exploration. In this context, research on the design and development of an autonomous surface cleaning robot is particularly important in the metal processing industry, where surface cleaning is a recurring and necessary task.

Our objective was to develop an autonomous robot capable of performing industrial cleaning on large surfaces after various processes, such as the machining process. For this purpose, we used a scaled-down prototype constructed with different materials and equipped it with Arduino as the microcontroller and front sensors. We programmed the Arduino to enable the robot to operate using its onboard sensors and perform surface cleaning efficiently and autonomously.

Fig. 1. Arduino Microcontroller

2. Current stage

The current stage of research regarding the design and development of an autonomous surface cleaning robot has led to the development of a prototype robot capable of performing industrial cleaning operations. This robot is constructed using various components such as Arduino, ultrasonic sensors, and an efficient cleaning system [3].

Over the past few years, research in the field of robotics has progressed rapidly, enabling the development of increasingly advanced robots. Regarding cleaning robots, the market is already saturated with models that are manually or semi-automatically controlled but lack the ability to autonomously navigate and perform cleaning operations on large surfaces.

The prototype of the autonomous surface cleaning robot developed within this research represents an innovative solution to this problem. By utilizing a system of sensors and navigation algorithms, this robot can avoid obstacles and autonomously navigate in the working space.

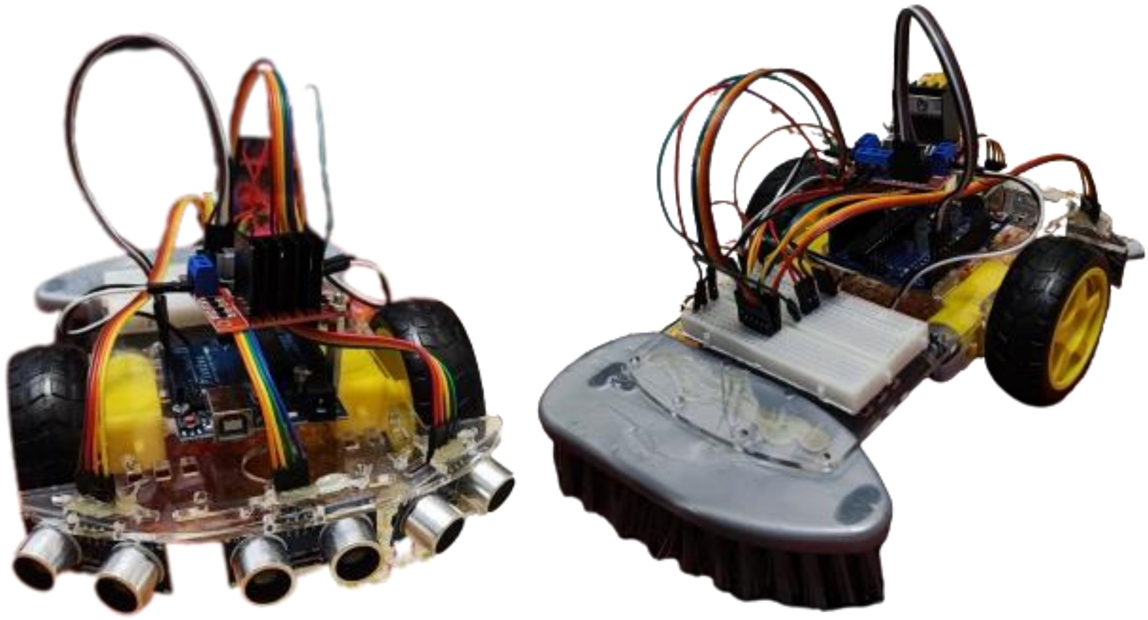

Fig. 2. Prototipul de robot autonom

In the robot's code, we have utilized a multitude of functions to achieve the current efficiency of the autonomous prototype robot. An important equation used in the prototype's code is equation (1), where d represents the distance at which the sensor is from the obstacle, expressed in centimeters, Δt is the time in which the sensor receives the reflected sound from the obstacle. We multiply it by 0.034 to convert the speed of sound to centimeters and divide by 2 for one-way duration since the sound needs to travel back to the sensor to provide information, similar to echolocation. Additionally, lines of code (2,3) are crucial to the functioning of the prototype as they implement a way to avoid obstacles. These lines of code check if the distance detected by the front sensor is smaller than the maximum allowed distance and if the distances detected by the side sensors are also smaller than the maximum allowed distance. If these conditions are met, the prototype is programmed to avoid the obstacles by rotating in the opposite direction of the obstacle and then moving forward. This approach enables the prototype to detect obstacles in a timely manner and efficiently avoid them, preventing potential collisions and damage to the robot.

As improvements, we intend to incorporate infrared sensors in the next version of the prototype as they offer higher performance and lower margin of error compared to the current ultrasonic sensors. We also plan to replace the brush at the back of the robot with a rotating brush to further enhance the cleaning process. Optimizing the code, replacing Arduino with a more powerful microcontroller or even a mini-computer are also part of our plans. Additionally, to accommodate these enhancements, we will install a more powerful motor to compensate for the added weight.

$$\mathrm{D} = \frac{\Delta t \cdot 0.034}{2} \quad (1)$$

$$\mathrm{distancef} < distance\_max \ \&\& \ distanced < distance\_\mathrm{max} \quad (2)$$

$$\mathrm{distancef} < distance\_max \ \&\& \ distances < distance\_\mathrm{max} \quad (3)$$

3. Robot Production Technology

The prototype of the autonomous surface cleaning robot was developed using a series of key components to ensure proper functionality and performance. Among the components used are an Arduino board, three HC-SR04 ultrasonic sensors, an L298N motor driver, and two motors. These components were carefully selected to meet the specific requirements of the robot and enable precise control of movement and obstacle detection in the working environment.

An important aspect of the prototype is its power system. It utilizes two 1850mAh batteries, which provide sufficient energy for the robot to operate for an extended period of time. The choice of suitable batteries was crucial to ensure the autonomy and mobility of the robot during the surface cleaning process.

Regarding the cleaning brush, it should be mentioned that the prototype was equipped with a standard brush, which is commonly available in the market. Due to cost constraints during the prototype development stage, we did not have the opportunity to order or design a specialized brush tailored to the specific needs of the robot. However, even with a standard brush, the prototype has demonstrated satisfactory capabilities in terms of surface cleaning.

4. Construction stages

I. Hardware Development

We initiated the construction process of the autonomous surface cleaning robot by starting with a robot chassis kit [2], which we purchased at a budget-friendly price from a specialized robot parts website. This kit included two electric motors and the mounting system for the chassis, providing us with a sturdy foundation for building the robot. Additionally, the kit included a small wheel, similar to a caster wheel, which served the purpose of supporting and balancing the robot. However, we decided to replace the wheel with a brush, considering its dual role in our prototype: both cleaning and supporting the robot.

The first step in constructing this robot was to mount the Arduino board to facilitate any potential replacements in case of short circuits or malfunctions. The Arduino board was securely attached to the chassis using two screws, ensuring stability and accessibility. The next step involved mounting a breadboard, a board that facilitates connections and allows for modifications within the prototype. To ensure power supply, we proceeded with mounting the power source. Due to space constraints, we opted to mount the power source on the lower part of the chassis, with a switch directly connected to it.

Another crucial step was the installation of the motor driver. Initially, we considered using an L298D motor driver shield, which would have allowed us to connect multiple motors for future enhancements. However, we encountered an issue with the shield blocking all digital pins. Our solution was to use a standard motor driver, L298N. This alternative allowed us to bypass the restrictions imposed by the previously mentioned shield. Regarding the installation of the motor driver, we faced the same challenge as with the power source, but we found a solution by mounting it above the Arduino board using a pillar to ensure stable fixation.

The last hardware components mounted on the chassis were the three HC-SR04 ultrasonic sensors, placed underneath the chassis for better visibility. One sensor was oriented directly in the direction of the robot's movement, while the other two were mounted laterally to cover a wider angle of visibility. After mounting all the components on the chassis, we proceeded to establish the connections between them (Fig. 3.). This process involved connecting the Arduino board to the motor driver, ultrasonic sensors, and power source, ensuring correct interaction and efficient operation of all components.

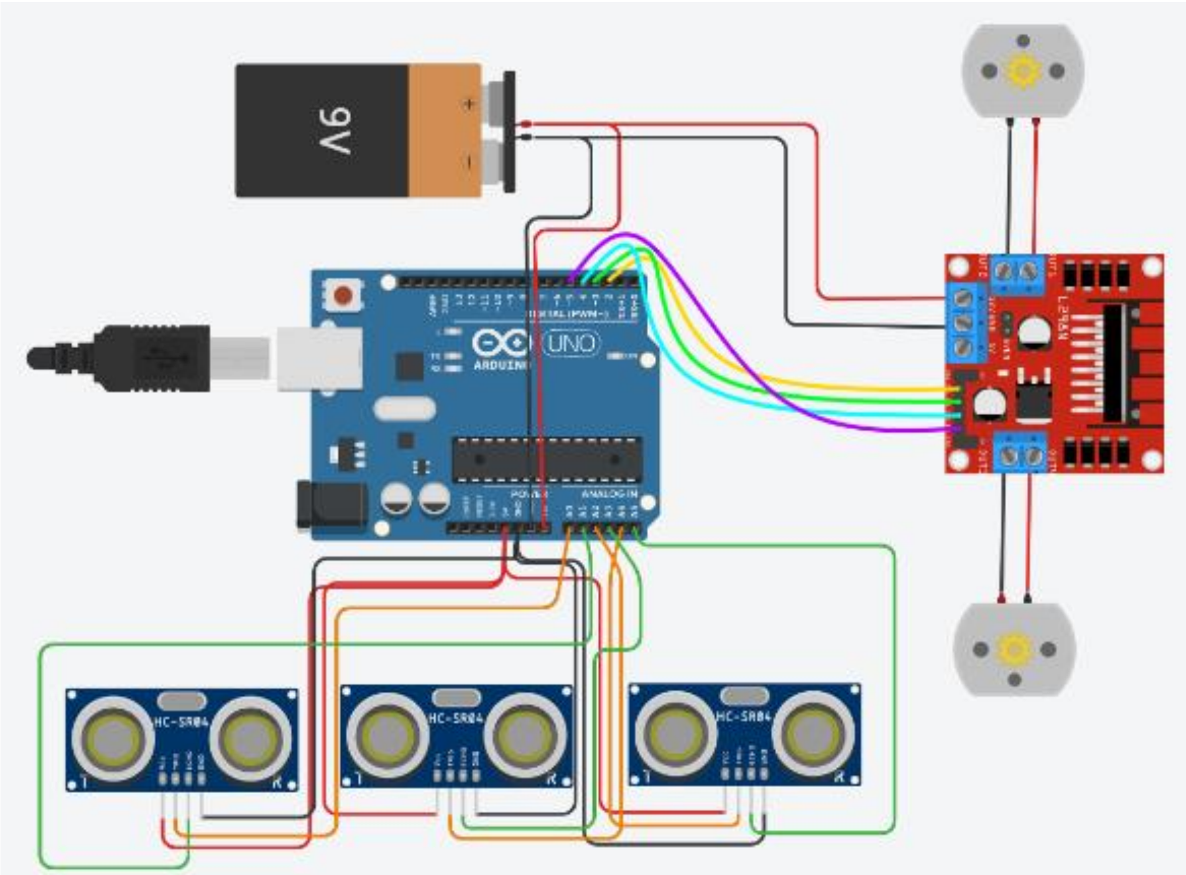

Fig. 3. Wiring diagram

II. Software Development

Regarding the software part, we used two essential libraries for controlling the motors and ultrasonic sensors, namely the "Servo.h" and "NewPing.h" libraries [2]. These libraries provided us with the necessary functionalities to interact with these key components of our autonomous robot.

To control the movement of the motors, we initialized each motor using a specific pin and set a maximum speed for the robot. We also defined and properly initialized the ultrasonic sensors in the code. Using the "Servo.h" library, we assigned a specific role to each pin of the Arduino board, whether it was an input or output, to ensure the correct functioning of the components.

In the next stage, we implemented a function that continuously repeated during the Arduino board's power supply. This function started by reading the values provided by the sensors and calculating the distance in centimeters. Then, we had a series of comparisons between the read distance and the maximum allowed distance, and based on the obtained results, the corresponding movements were initiated to avoid obstacles encountered by the robot.

Throughout the software development process, we encountered a few specific issues. The first problem was related to correctly reading the values from the sensors, and to solve it, we had to repeatedly rewrite the code responsible for reading them. The second issue we faced was accurately instructing the robot and making precise comparisons between the read distance values. This problem was also addressed by repeatedly rewriting the code to achieve the desired results and ensure the optimal functioning of the prototype.

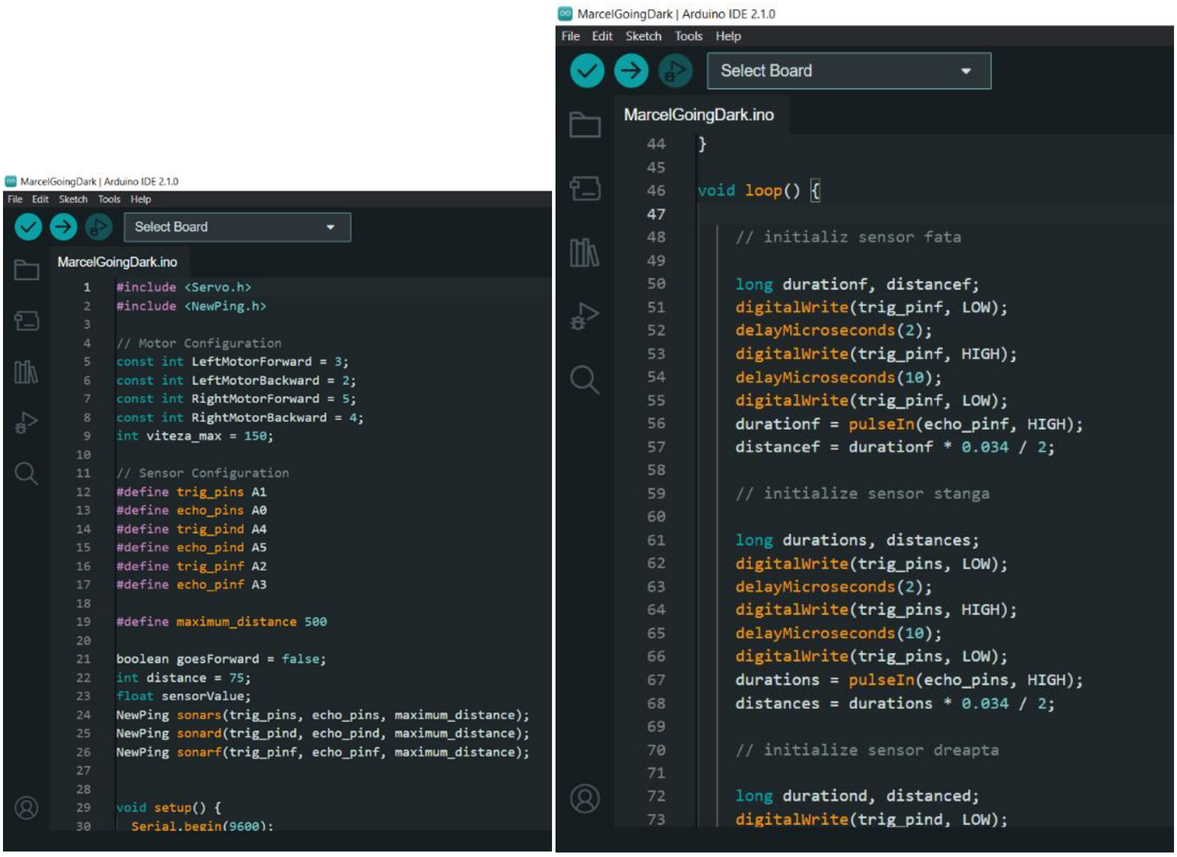

Fig. 4. Lines of code

5. Conclusions

The design and development of an autonomous robot for surface cleaning have been a complex and challenging research stage, where various issues and obstacles were encountered. However, the developed prototype has far exceeded our initial expectations in terms of performance and results achieved.

Nevertheless, it should be noted that the prototype is not without imperfections. A significant aspect is that due to the limited performance of the used sensors, the robot stops at a shorter distance than initially programmed. To address this issue, adjustments were made to the control code parameters. It is important to mention that ultrasonic sensors face difficulties in detecting objects that cannot adequately reflect sound waves. These limitations can be overcome by replacing ultrasonic sensors with infrared sensors, which offer superior capability in detecting and avoiding obstacles.

Thus, the identification and resolution of these issues represent a future research direction to enhance the functionality and performance of the autonomous robot for surface cleaning. By implementing new technological solutions and optimizing control algorithms, we can achieve higher precision and efficiency in the cleaning process, thereby improving the prototype's performance. We have ambitious plans for the future of the project, including a modern navigation system for autonomous and efficient movement, an adaptable cleaning system for industrial applications, improving energy consumption and increasing motor power, as well as implementing a safety system to prevent damage in case of an accident. Additionally, we aim to upscale the product, provide easy replacement of wearable parts and their separate acquisition, and integrate an AI system for automatic learning of new cleaning spaces.

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PHONE CONTROLLED CAR

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Scientific leader: prof. Andrei Mario IVAN

SUMMARY: This project is a Bluetooth controlled car, controllable using a phone. This means it is an extensible base for many different applications.
KEY WORDS: car, robot, Bluetooth.

1. Introduction

Due to the extensibility of the platform, this car can be used for multiple tasks, like:

- RC car
- car that can go through labyrinths
- car that can avoid obstacles
- line follower
- robot with an arm

2. Current stage

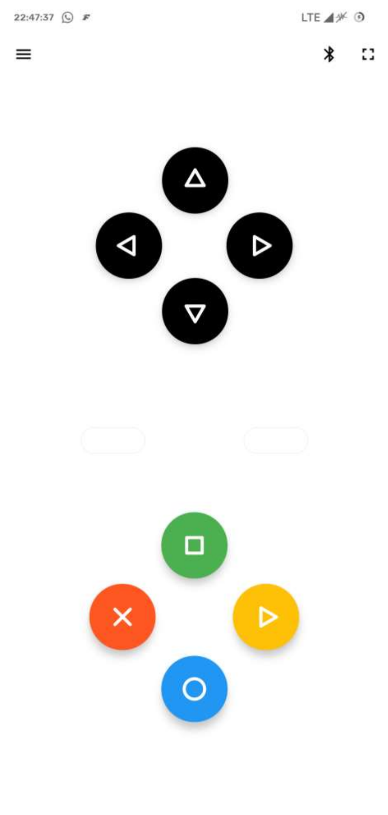
In order to use this project, you need a device capable of sending Bluetooth signals, using the RFCOMM protocol. Any computer with a Bluetooth adapter will suffice, but, for ease of use, it is recommended to use an Android phone, with one of the specialized apps for using with an Arduino. Here are some of the apps that can be used this way:

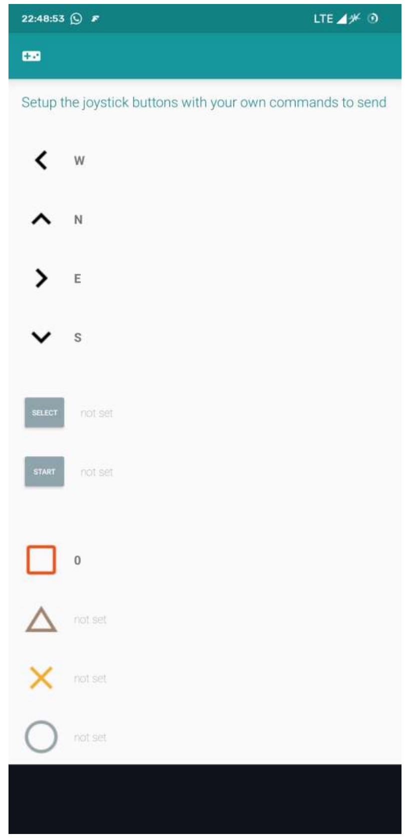
- https://play.google.com/store/apps/details?id=uncia.robotics.joystick
- https://play.google.com/store/apps/details?id=com.giumig.apps.bluetoothserialmonitor
- https://play.google.com/store/apps/details?id=strikesoftware.bluetooino
- https://play.google.com/store/apps/details?id=com.arbl.arduinobluetooth

2.1. App configuration

All that needs to be done is to set four buttons in the program that send the **N**, **S**, **W** and **E** characters to the car for the directions front, rear, left and right respectively, and another button that sends the **0** char, which will stop the motors.

2.2. Configuration example





2.3. Hardware components

These are the main components on the robot:

- 4 motors with reducting gears and wheels: https://www.optimusdigital.ro/ro/motoare-altele/139-motor-cu-reductor-si-roata.html?search_query=motor&results=663
- Motor driver module L298N: https://www.optimusdigital.ro/ro/drivere-de-motoare-cu-perii/145-driver-de-motoare-dual-l298n.html?search_query=l298n&results=4
- Bluetooth module HC-05: https://www.optimusdigital.ro/ro/wireless-bluetooth/153-modul-bluetooth-master-slave-hc-05-cu-adaptor.html?search_query=hc05&results=2
- Batteries of type 18650: https://www.optimusdigital.ro/ro/acumulatori-li-ion/3152-acumulator-samsung-li-ion-3000-mah-18650-inr18650-30q.html?search_query=18650&results=59

- Development board Arduino Uno: https://www.optimusdigital.ro/ro/placi-avr/4561-placa-de-dezvoltare-compatibila-cu-arduino-uno-r3-atmega328p-atmega16u2-cablu-50-cm.html?search_query=uno&results=316

3. Source code

Since we used an Arduino-compatible development board, the chosen programming language is Arduino.

The source code uses simple concepts, like serial communication between the development board and the Bluetooth module, and the interface with the motor driver is made through four digital pins and is simplified through the usage of the **L298N** library: https://github.com/AndreaLombardo/L298N

```
// {{{ Libraries
#include <L298NX2.h> // library for the motor driver
// }}}

// {{{ Variables
// Declare pins
const int IN1 = 2, IN2 = 3, IN3 = 4, IN4 = 5;
L298NX2   motors(IN1, IN2, IN3, IN4); // Declare motors on the L298N
int       state; // Bluetooth state
// }}}

// {{{ Setup
void setup()
{
  // {{{ Set pin modes
  // For the L298N inputs
  pinMode(IN1, OUTPUT);
  pinMode(IN2, OUTPUT);
  pinMode(IN3, OUTPUT);
  pinMode(IN4, OUTPUT);
  // }}}

  // {{{ Initialize serial communication
  Serial.begin(9600);
```

```
  // }}}
}
// }}}

// {{{ Loop
void loop()
{
  if(Serial.available() > 0) state = Serial.read(); // Save the state into a varable

  switch(state)
  {
    case 'N':
        motors.forward();          // move forward
        break;
    case 'S':
        motors.backward();         // move backward
        break;
    case 'E':
        motors.forwardA();         // rotate right
        motors.backwardB();
        break;
    case 'W':
        motors.backwardA();        // rotate left
        motors.forwardB();
        break;
    case '0':
        motors.stop();             // stop motors
        break;
  }
}
// }}}
```

6. Conlcusion

In conclusion, this project is useful and extensible through its simplicity, from the simplicity of the source code to the simplicity of the physical model.

Carthesian Robot used for Drone Landing, Charging & Storing

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Conducător ştiinţific: S.L. Dr. Ing. Mario Andrei **IVAN**

The work consists of a modular Cartesian robot designed to intercept and store drones. The robot is electrically powered by 3 electric motors controlled by an Arduino microcontroller. It has 2 video cameras. The first camera captures the x and z coordinates of the drone, while the second camera captures the position on the y-axis. These cameras transmit the position of the drone to the Arduino board, which controls the axes to make the drone land on the pallet. After landing, the drone is stored in a dedicated space together with the pallet, which will also facilitate its charging.

1. Introduction

We wanted to build a robot that will be able to perform like a helipad that also will facilitate its charging. The robot is electrically powered by 3 electric motors controlled by an Arduino microcontroller. It has 2 video cameras. The first camera captures the x and z coordinates of the drone, while the second camera captures the position on the y-axis. These cameras transmit the position of the drone to the Arduino board, which controls the axes to make the drone land on the pallet. After landing, the drone is stored in a dedicated space together with the pallet, which will also facilitate its charging.

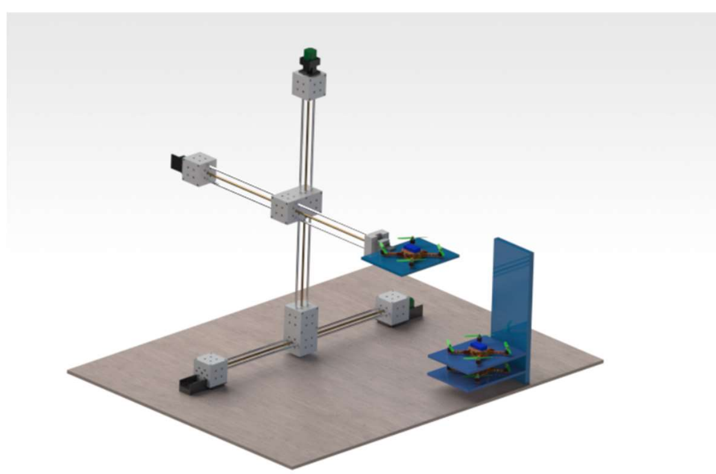

Figure 1 The CAD representation of the Project

2. Current Stage

The Robot is ready from an electro-mechanical standpoint. The computer vision software works very good in recognizing the elements that we’ve set it up for. We still need to do the serial communication between the cameras and the Arduino board, and also the Arduino processing for manipulating our data.

Each one of the 3 Axis is converting rotational energy from their own motors into prismatic movement. This is realized by having a nut lead-screw mechanism accompanied by 2 guiding rails, each having longitudinal bearings for a smoother action. The leadscrew has also 2 bearings attached for a smoother operation

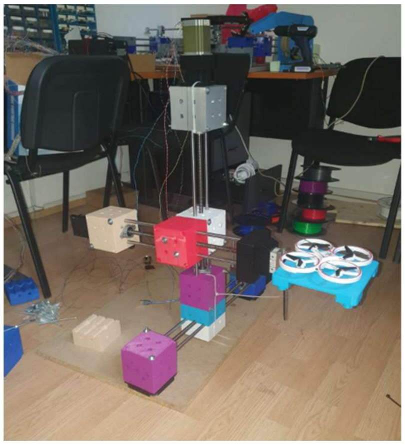

Figure 2 The State of the Project

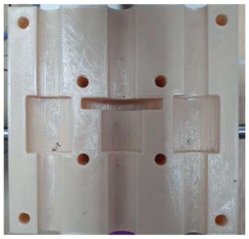

Figure 3 The Case for the Nut and Liniar Bearings

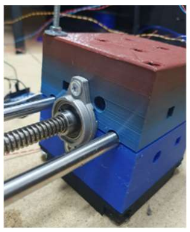

Figure 4 The Screw Bearings

Each one of the 3 motors is paired with an elastic coupling to be able to engage the screw, which also has been milled to the preferred diameter. Electric Motors will be driven using an Arduino Board and 3 TB6560 drivers.
To be able to triangulate the correct position of the drone in space we have used 2 cameras. One for obtaining the x and z coordinates and one for obtaining the y component. In the below example, the program is set to recognize the color bright green. After it finds it, it stores the desired values and sends the ones that we need into a file.

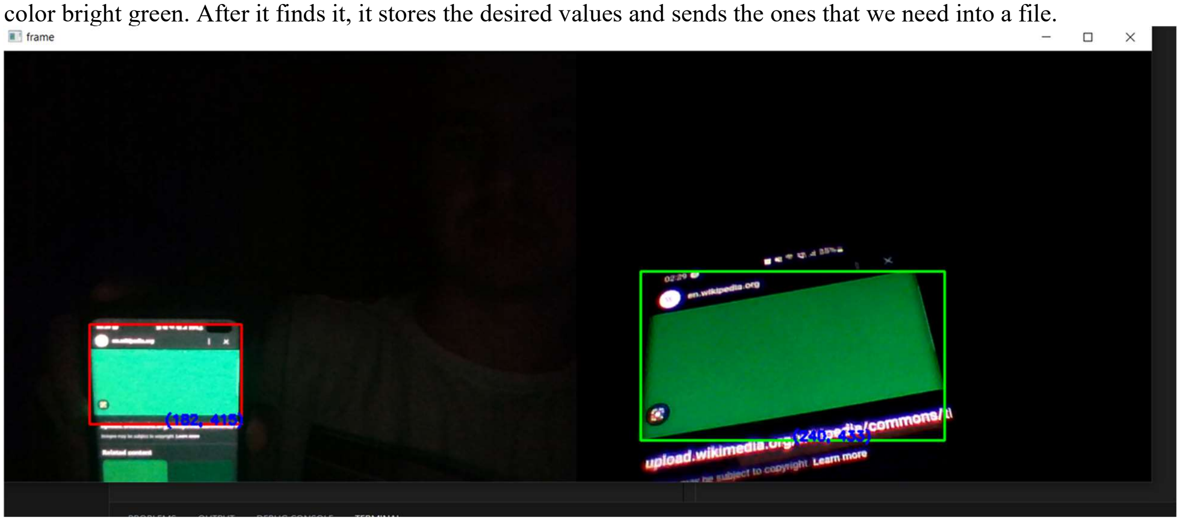

Figure 5 The GUI with 2 views and their respective coordinates

```
ret, frame = cap.read()
ret_usb, frame_usb = cap_usb.read()
width = int(cap.get(3))
height = int(cap.get(4))


if not ret or not ret_usb:
    print("Error: Could not capture frame")
    break

frame = cv2.resize(frame, (640, 480))
frame_usb = cv2.resize(frame_usb, (640, 480))


hsv = cv2.cvtColor(frame, cv2.COLOR_BGR2HSV)
hsv_1 = cv2.cvtColor(frame_usb, cv2.COLOR_BGR2HSV)

lower_green = np.array([60, 50, 50])
upper_green = np.array([90, 255, 255])

mask = cv2.inRange(hsv, lower_green, upper_green)
mask_1 = cv2.inRange(hsv_1, lower_green, upper_green)

contours, _= cv2.findContours(mask, cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE)
contours1, _= cv2.findContours(mask_1, cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE)

largest_contour = max(contours, key=cv2.contourArea, default = 0)
largest_contour_1 = max(contours1, key=cv2.contourArea, default = 0)
```

Figure 6 Code for sizing the view and defining preliminary contours.

```python
if contours:

    contour = contours[0]
    x, y, w, h = cv2.boundingRect(largest_contour)
    cv2.rectangle(frame, (x, y), (x + w, y + h), (0, 0, 255), 2)

    x_center = x + int(w / 2)
    y_bottom = y + h
    cv2.putText(frame, f'({x_center}, {y_bottom})', (x_center, y_bottom), cv2.FONT_HERSHEY_SIMPLEX, 0.5, (255, 0, 0), 2)
    contour_found = True


if contours1:

    contour1 = contours1[0]
    x_1, y_1, w_1, h_1 = cv2.boundingRect(largest_contour_1)
    cv2.rectangle(frame_usb, (x_1, y_1), (x_1 + w_1, y_1 + h_1), (0, 255, 0), 2)

    x1_center = x_1 + int(w_1 / 2)
    y1_bottom = y_1 + h_1
    cv2.putText(frame_usb, f'({x1_center}, {y1_bottom})', (x1_center, y1_bottom), cv2.FONT_HERSHEY_SIMPLEX, 0.5, (255, 0, 0), 2)
    contour_found_1 = True

    with open('coordinates_xz.txt', 'w') as f:
        f.write(f'{x1_center}\n')
```

Figure 7 Finding the color, putting a rectangle around it and getting its coordinates.

We've managed to send data to the Arduino by creating a python program that communicates through serial with our board.

```python
import time
import serial

serialPort = 'COM3'
baudRate = 115200
timesPerSecond = 1

ser = serial.Serial(serialPort, baudRate, timeout=0.050)

while True:
    coords = ''
    with open('coordinates.txt', 'r') as f:
        coords = f.read()
        f.close()

    ser.write(coords.encode())
    print(coords)
    time.sleep(1 / timesPerSecond)
```

Figure 8 Serial Communication with the Arduino

Figure 9 Cad representation of the case

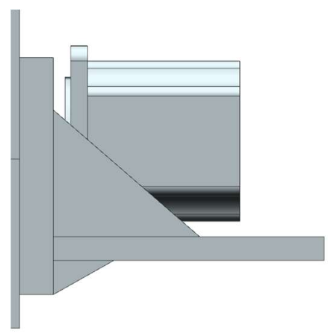

Figure 10 Y axis motor mount

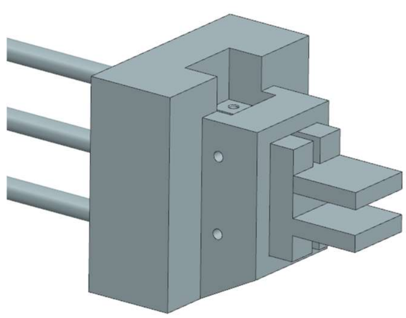

Figure 11 Gripper Case

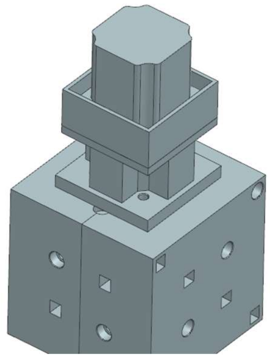

Figure 12 Z axis Motor Mount

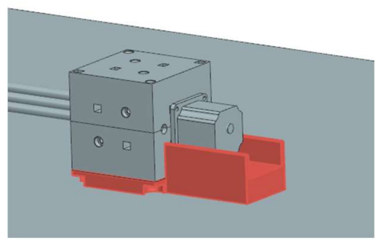

Figure 13 X axis Motor Mount

3. Conclusion

To conclue, we have learned a lot from this project and we are thrilled to finnish it and also be able to develop new and complex robots. We still need to complete the followings :

- Finishing the serial communication
- Programming the Arduino for data manipulation
- Finishing the design for the docking station
- Implementing wireless charging into the docking station
- Actuating the gripper using an electro-valve

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AUTONOMUS MICROCLIMATE FOR REGULATING THE VITAL PARAMETERS OF PLANTS

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SUMMARY:
Considering the rapid advancement of automation technology, it is evident that a time will come when every aspect of our lives will operate autonomously. With this project my aim was to embark on a personal journey towards the implementation of ecological automation, specifically by creating a microclimate system that effectively regulates crucial factors for plants such as irrigation, ventilation and lighting. In the practical demonstration, sorghum plants were carefully selected as the primary specimens, although it is worth noting that alternative plant species can be seamlessly incorporated. By combining the principles of automation and ecology, I endeavor to pave the way for sustainable and efficient solutions in the realm of environmental management, setting a precedent for fture endeavors in this domain.
KEY WORDS: automation, healthy ecosystem, botany, Arduino Mega, plants

1. Introduction

An autonomous microclimate for regulating the vital parameters of a plant refers to a system that creates and maintains optimal growth conditions for plants, independent of external climatic conditions. This system is designed to control and regulate key factors that affect the health and development of plants, such as temperature, humidity, light, air and water circulation, CO_2 levels and nutrients.

Such an autonomous microclimate can be established within a greenhouse or a growth chamber, utilizing various technologies and equipment. For instance, an automated control system can monitor and adjust temperature and humidity using sensors and climate control devices. Artificial lighting can be employed to provide optimal light levels, while an automated irrigation system can deliver water in appropriate quantities and frequencies.

By maintaining an autonomous microclimate, plants can grow in a stable and controlled environment, leading to accelerated growth, improved crop quality and reduced risks associated with external climatic fluctuations such as drought or extreme temperatures. Nowadays, this approach is used in modern agriculture and scientific research to achieve more consistent and efficient results in plant production.

2. Current stage

For the purpose of illustrating the use of a microclimate, the plant chosen was sorghum, for which the parameters were adjusted to provide optimal growth conditions within the microclimate. The optimal growth conditions were taken into account regarding the requirements for light, air and water, using sensors and special devices illustrated in the table below.

Table 1. Electronic components used in the project

Category	*Name*	*Number*	*Voltage (V)*	*Location*	*Activation parameters*	*Actions activated*
IRRIGATION	Soil moisture sensor [1]	5	3.3-5	inside the microclimate	>34%	Water pump on
	Waterproof NTC sensor [2]	2	5	1.in the soil 2.in the water basin	<5^{o}C or >50^{o}C	Water pump off
	Water lever sensor [3]	2	3.3-5	1.inside the microclimate 2.in the water basin	1. >1% 2. <10%	Water pump off
	Water valve [4]	1	12	irrigation carcass	-	Water pump safety
	Water pump [5]	1	12	irrigation carcass	-	Irrigation
VENTILATION	DHT22 [6]	2	5	1.inner carcass 2.outer carcass	<30% or >68%	Ventilators on
	MQ135 [7]	2	2.5-5	1.inner carcass 2.outer carcass	>27%	Ventilators on
	PM sensor [8]	1	5	inner carcass	>0.28mg/m^3	Ventilators on
	BMP280 [9]	1	1.8-3.6	inner carcass	>25^{o}C	Ventilators on
	DC12V ventilator [10]	2	12	lateral walls	-	Ventilation
LIGHTING	TEMP6000 [11]	1	3.3-5	inner carcass	<200mV	LED band on
	LED band [12]	1	5	around the walls	-	lighting
OTHERS	Relay [13]	4	5	voltage control carcass	-	
	Voltage lowering mode [14]	3	2.5-25	voltage control carcass	-	1. output 3.3V 2.output 5V 3. output 12V
	LCD 20x4 [15]	1	5	LCD support	-	text messages
	Arduino MEGA [16]	1	5	Arduino carcass	-	-

3. Assembly process

The comprehensive assembly process encompassing all components was of a complex nature, spanning several days, to ensure that the ultimate outcome is characterized by aesthetic appeal, structural integrity and functional efficacy.

3.1. Central box

From three 50x100 Plexiglas sheets, six panels measuring 50x50 were derived. Among these panels, five were utilized in constructing a cubic enclosure, while the sixth panel constituted an endpiece that was securely connected through the implementation of two metallic hinges and endowed with a convenient handle. The structural integrity of the box's edges was ensured by reinforcing them with L2.5x2.5 plastic profiles, while a wooden plank was affixed at the base of the container to facilitate its transportation. Moreover, a 50x10 Plexiglas sheet was employed as the supporting element for the external casings of the microclimate. The comprehensive assemblage process involved the utilization of metallic brackets, M4 screws and nuts, and adhesive for plastic elements.

3.2. Auxiliary casings

To enhance the aesthetic appeal, six casings were printed for each set of components: an irrigation casing including the valve and pump, an exterior sensor casing (for DHT22 and MQ135), en electric voltage control casing, an Arduino MEGA board casing, an interior sensor casting and a casing for the LCD module with a mounted LCD stand positioned above it. The casings were designed using Fusion software and printed using a Creality Ender-3 3D printer.

Fig.1. Side view of the microclimate, illustrating the shape and assembly of the casings and the box itself

3.3. Electrical connections

Commencing from the "brain" casing, which houses the Arduino Mega board, meticulous attention was given to establishing the intricate electrical connections that corresponded to each individual component. Prior to the voltage reaching its intended destination, a prudent measure was taken by routing it through a voltage step-down module. This precautionary step served the purpose of safeguarding the delicate electronic components from the perils of excessive voltage, thereby mitigating the risk of irreversible damage. By diligently implementing this crucial intermediary, the potential hazards of both excessively high and low voltages were effectively neutralized. Once these intricate electrical connections were impeccably established, the subsequent stages of coding and comprehensive testing ensued. This meticulous approach was paramount in ensuring a seamless integration between hardware and software components, ultimately culminating in a robust and reliable result.

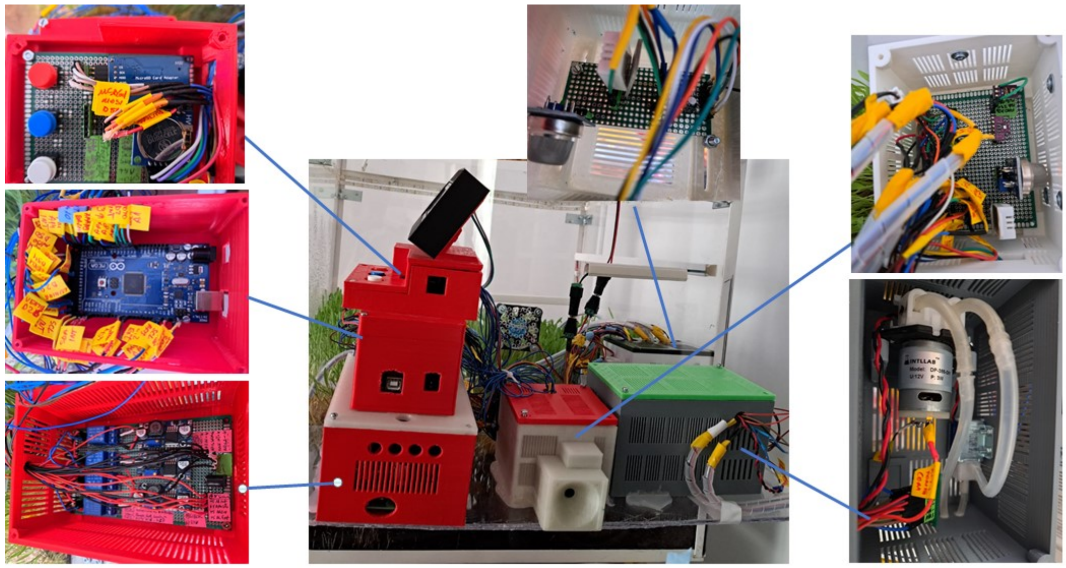

Fig.2. The electrical connections, delineated for each individual casing, were clearly delineated and organized, highlighting the orderly arrangement of each individual component.

4. Coding and results

The process of coding and testing the microclimate involved a systematic approach to programming and verifying the functionality of the created software. It began with the development of the code, where the desired behavior and operations are defined using the Arduino programming language in the Arduino IDE App. This entails writing functions, loops, conditional statements, and utilizing libraries as needed. After writing the code, it was uploaded to the Arduino board, where it is executed.

During the testing phase, various scenarios and inputs are simulated or provided to observe the behavior of the code and ensure its correctness. This includes checking sensor readings, verifying output signals, and testing the integration of different components.

Debugging techniques are employed to identify and fix any errors or unexpected behavior in the code. Through iterative testing and refining, the code is optimized and fine-tuned to meet the desired functionality, reliability, and efficiency. Rigorous testing is essential to ensure that the microclimate operates as intended, providing the desired results in a consistent and dependable manner.

The test results obtained could be observed both on the LCD screen attached to the microclimate system and in the Serial Monitor of the Arduino IDE application. Similarly, any errors or issues that arose during testing were identified and resolved using the same method. Upon final verification, a series of example text messages displayed in the Serial Monitor were extracted and compiled in the table below.

Table2. Examples of messages on Serial Monitor, the same as the text messages on the LCD

<table>
<tr><th>Observations</th><th>Text message</th></tr>
<tr><td>Reading the external sensors</td><td>DHT22 - EXTERIOR - Umiditate aer : 61.20 % | DHT22 Temperatura aer: 23.90 *C |
PM, Particule fine aer: 0.00 mg/m3 | | PM - Aer Curat !!! | Ventilatoare OFF
PM 2 - EXTERIOR, Particule fine aer: 0.00 mg/m3 |
NTC 1 | Temperatura Sol (in adancime): 22.44 *C | NTC 2 | Temperatura Apa Bazin: 20.33 *C |
Nivel Inundatie Sol : 6 % | Nivel Apa Bazin: 0 % | | NIVEL APA OK | Pompa - Vana OK | Bazin Apa GOL | Alimentare OPRITA!</td></tr>
<tr><td>Increased air humidity is observed inside so the fans are activated until the humidity level drops below 68%</td><td>DHT22 Umiditate aer: 75.80 % | DHT22 Temperatura aer: 23.90 *C | | Umiditate excesiva! | Ventilatoare ON
DHT22 Umiditate aer: 76.20 % | DHT22 Temperatura aer: 23.90 *C | | Umiditate excesiva! | Ventilatoare ON
DHT22 Umiditate aer: 76.20 % | DHT22 Temperatura aer: 23.90 *C | | Umiditate excesiva! | Ventilatoare ON
DHT22 Umiditate aer: 76.10 % | DHT22 Temperatura aer: 23.90 *C | | Umiditate excesiva! | Ventilatoare ON
DHT22 Umiditate aer: 76.00 % | DHT22 Temperatura aer: 23.90 *C | | Umiditate excesiva! | Ventilatoare ON
DHT22 Umiditate aer: 75.80 % | DHT22 Temperatura aer: 23.90 *C | | Umiditate excesiva! | Ventilatoare ON
DHT22 Umiditate aer: 75.60 % | DHT22 Temperatura aer: 23.90 *C | | Umiditate excesiva! | Ventilatoare ON
DHT22 Umiditate aer: 75.60 % | DHT22 Temperatura aer: 23.90 *C | | Umiditate excesiva! | Ventilatoare ON
DHT22 Umiditate aer: 75.20 % | DHT22 Temperatura aer: 23.90 *C | | Umiditate excesiva! | Ventilatoare ON
DHT22 Umiditate aer: 74.70 % | DHT22 Temperatura aer: 23.90 *C | | Umiditate excesiva! | Ventilatoare ON
DHT22 Umiditate aer: 74.20 % | DHT22 Temperatura aer: 23.90 *C | | Umiditate excesiva! | Ventilatoare ON
DHT22 Umiditate aer: 73.90 % | DHT22 Temperatura aer: 24.00 *C | | Umiditate excesiva! | Ventilatoare ON
DHT22 Umiditate aer: 73.60 % | DHT22 Temperatura aer: 23.90 *C | | Umiditate excesiva! | Ventilatoare ON
DHT22 Umiditate aer: 73.50 % | DHT22 Temperatura aer: 24.00 *C | | Umiditate excesiva! | Ventilatoare ON
Umiditate aer: 68.20 % | DHT22 Temperatura aer: 24.40 *C | | Umiditate excesiva! | Ventilatoare ON
/ 2009 -> DHT22 Umiditate aer: 67.90 % | DHT22 Temperatura aer: 24.40 *C | | Umiditate normala! | Ventilatoare OFF</td></tr>
<tr><td>Output from the light intensity sensor</td><td>Senzor foto Modul :   Bine luminat   ! :   Banda LED OFF   263 Volti</td></tr>
<tr><td>Reading the soil moisture sensors</td><td>Umiditate Sol Zona A: S1:   39.49% ;   S2:   30.21% ;   S3:   53.57% ;   S4:   51.91% ; Pompa OFF Umiditate Sol Zona A Buna. Pompa 1 este Oprita</td></tr>
<tr><td>Closing the loop and returning to reading the external sensors</td><td>MQ135 Calitate aer: 11% | | Aer curat! | Ventilatoare OFF
MQ135 Calitate aer - EXTERIOR: 6% |</td></tr>
</table>

.

6. Conclusions

In conclusion, it is evident that automation technology continues to advance rapidly, with the potential to revolutionize various aspects of our lives. Also, the integration of automation and ecology, as demonstrated through the microclimate project, showcases the potential for sustainable and efficient solutions in environmental management.

Based on the obtained results, we could envision a potential future version of the microclimate system that incorporates an interactive means of communication with the human operator, such as a simple keyboard, allowing for an easy monitoring and control. Additionally, the addition of a functionality of data storage could be implemented by creating a database that captures both sensor readings and their continuously interpreted actions. This would enable the human operator responsible for the microclimate system's operation to access this database in the event of an error occurrence, facilitating error identification and troubleshooting.

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[7].***https://www.waveshare.com/w/upload/2/24/MQ-135-Gas-Sensor-UserManual.pdf
[8].***https://www.sigmanortec.ro/Senzor-particule-praf-p136248725?gclid=Cj0KCQjwr82iBhCuARIsAO0EAZydy05RUWDGjf3KE8d3FtXb8mOEBxtDpOLW1a0o5VlY2nin1-7-bykaAjE6EALw_wcB
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ENGRAVING WITH LASER ON AN ARTICULATED SIX-AXIS KUKA ROBOT

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This paper has the objective to present the integration of a laser in an engraving operation on an articulated six axis robot KUKA KR 6 R 700-2. For this process we used this educational robot to improve from the cartesian structure which prove to be inaccurate. The laser that is used for this operation is a FB03, 4th class. It can engrave on different wooden materials by etching permanent, deep marks. Up to this point we were able to engrave the outline of some letters and geometrical shapes. After optimizing the current applications, we will move on to engraving on different planes other than XOY, XOZ, YOZ, also spherical and cylindrical surfaces.

Keywords: laser engraving, articulated robot, cartesian structure, 3D engraving

1. Introduction

The engraving with laser is used usually on a cartesian structure. We saw an opportunity, improving the application by moving the laser from the last structure to the six-axis robot. The laser used for this operation is FB03, 4th class, with 10 mm minimum focal distance. We've found out that the laser we use work on poplar wood without any unexpected difficulties.

Our six-axis robot used for this application is a KUKA KR 6 R 700-2. The improvement from the first structure reached an accuracy of a high precision, about ±0.02mm, and the facility to use 726 mm of workspace.

2. Overview

The image (fig. 1) contains the view of the first structure, where the laser was mounted on, however this structure proved to not be the best option for engraving, so the availability of a six-axis robot from KUKA was the best option to optimize the engraving process itself. The vibrations were significantly reduced. The interface of the robot, it's easier to understand and use, for us as students of Industrial Engineering and Robotics.

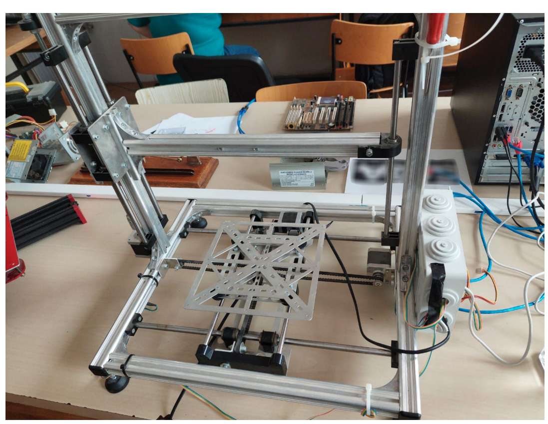

Fig. 1 The first structure

When we are talking about interface, we talk about the teach pendant, and the KUKA sim 4.0 software. The teach pendant interface looks like the Windows's interface, as a lot of us are used to it, it's simple to understand, to manipulate the robot and its workspace (fig. 2).

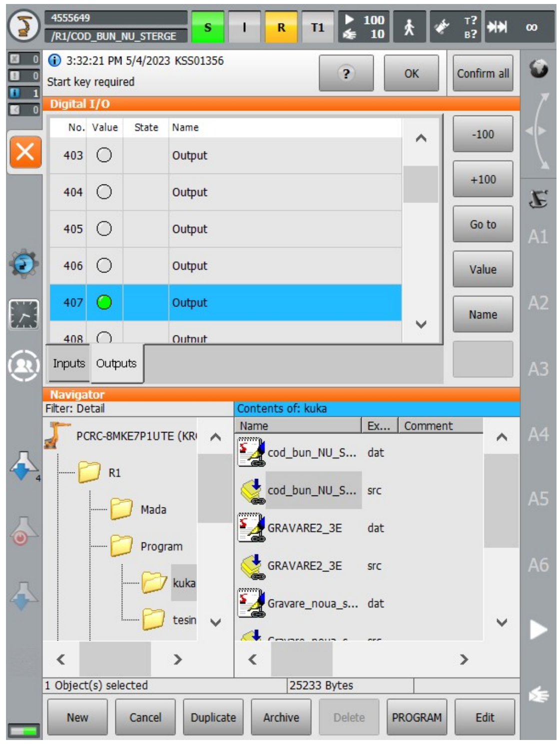

Fig. 2 Teach pendant interface.

KUKA Sim 4.0 was used to declare the points and the trajectory of the tool (laser), to realize the contour of the letters, or the geometrical shapes. In this software we created the codes, and applications of engraving process, by putting the right coordinates of the TCP, where we used a 3D CAD of the laser model with the focal distance. In the next image (fig. 3) we can see the KUKA Sim 4.0 interface, and the letter K. We have the tool path option on to preview the whole process. At that time, we didn't have a CAD added to the robot flange. However, in this image we can see the tool path from the home point to P1, and back.

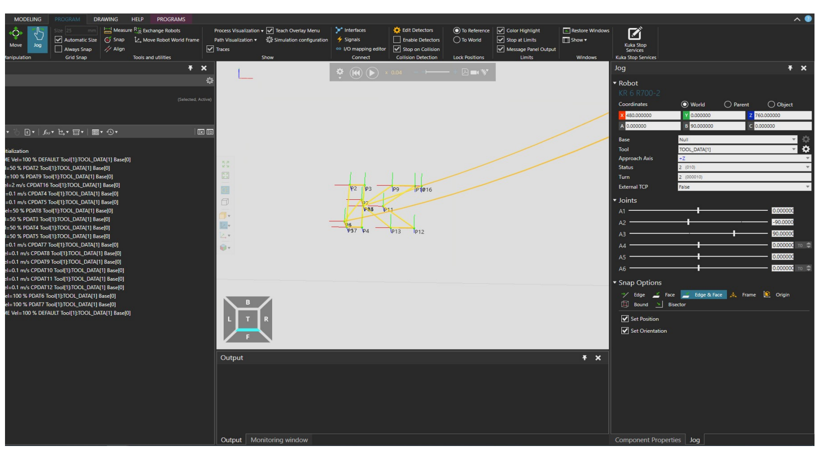

Fig. 3 Simulation on KUKA Sim 4.0

3. Rear electronics and laser connection

In the next image (fig. 4) we can see the laser we used for this application, a FB03, 4th class laser, as we mentioned earlier. To fix it to the robot flange, we made an adaptor using the 3D printing technology. The orange adaptor is used to expand the possibility of mounting different types of tools. The white adaptor is made to connect the laser to the robot. We chose this orientation in order to minimize the length of the end-effector. To further protect the connections between electrical components, a dressing was used (fig.6). Thus, we also tidied the cables and fixed them to some points on the robot so the accidental disconnection will not occur.

Fig. 4 FB03

A Zener diode (fig. 5) is a special type of diode that is designed to operate in the reverse breakdown region of its voltage-current characteristics. Zener diodes are commonly used in electronic circuits for various purposes, including voltage regulation, voltage clamping, surge protection, and voltage reference generation. They are often used in power supplies, voltage regulators, and in circuits that require stable and precise voltage levels. When a Zener diode is reverse biased and the applied voltage reaches its specified breakdown voltage (known as the Zener voltage or Zener knee voltage), it starts conducting current in the reverse direction. The Zener diode's breakdown region is highly stable, meaning that a small change in the reverse voltage does not cause a significant change in the current flowing through it. For our purpose, the diode was used to prevent a power surge in the laser. By regulating the voltage, we get a constant flow of light and the mark left on the plaque is consistent. The laser input is 5V and output from the robot is 27V, so the best option was to integrate the diode. In the (fig. 5) we can also see the electrical scheme of I/O signals with Zener diode.

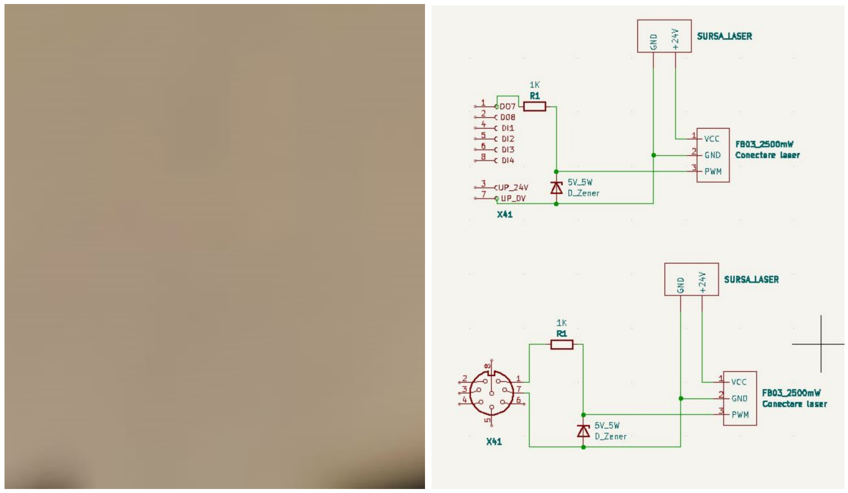

Fig. 5 Zener Diode and electronic scheme

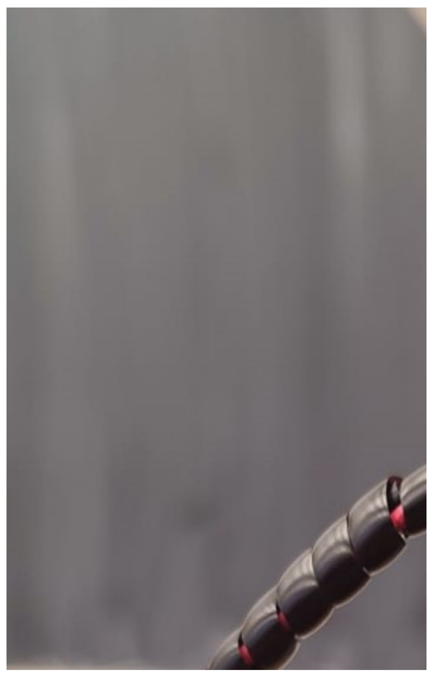

Fig. 6 The dressing

4. Engraving application

About the application, the laser must be first focused on the object that is engraved. Next, we select the program with the desired shape and the process can begin. The light emitted heats up on the focus point and leaves behind a deep mark on the object. The faster the laser is moving the shallower the mark is. For a good result, we must find the correct constant speed. What problem we encountered were any sharp angles. In that point, the laser stops briefly but long enough to leave a noticeable dot. The solution was creating a block spline, which realizes the optimal path between points declared in application. We also changed the time while the robot stays in a point from the block spline, engraving the shapes without additional dots. In the next image (fig. 7) we have the robot in the middle of execution of the new code, assisted by a human operator. This was also a test, the human operator, looking at the software, observing if the robot respects the code, or there are abnormalities.

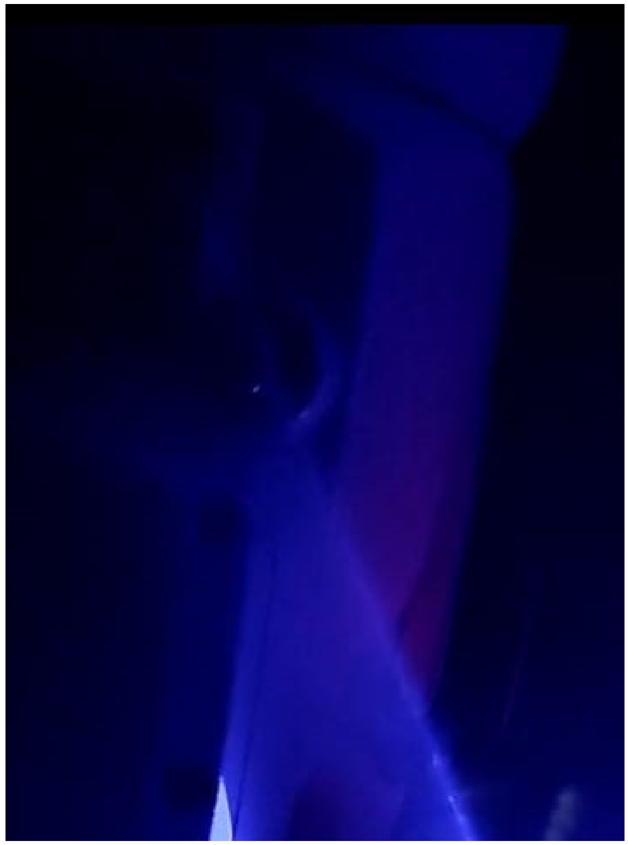

Fig. 7 The laser beam

To eliminate the need of human interaction, the port X41 from the A4 interface (fig. 8) was put in use. Because we did not need all the pins, a custom port was made just to command the laser through the teach pendant. Now the application does not require the human operator to get close to the workspace.

We can also see the signals in (fig. 2). There are implemented in the using code, before and after the block spline.

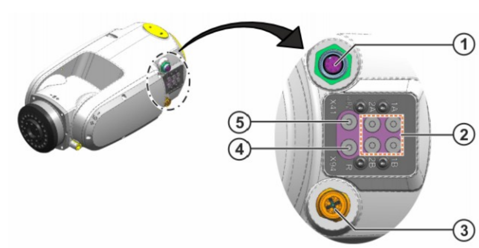

Fig. 6-11: Customer interfaces A4, example

1 Connection X41
2 Air connections, valve unit
3 Connection X94
4 Valve venting R
5 Air line AIR2

Fig. 8 I/O control

5. Conclusions and future work

In conclusion, integrating a laser into a wooden engraving application on a six-axis robot offers advantages such as precision, speed, versatility, customization, consistency, and automation. However, it is essential to consider safety measures and ensure compliance with regulations to maintain a safe working environment. For this reason, we would like to make use of a dedicated cell with blue light filter panels instead of safety goggles. In this way, we can make the process safe for everyone around it. After this cell, we can automate the process by adding a system for loading the next poplar plaque and a system to eject the final product. The next step for us is to research and develop a solution for 3D engraving. This technology fits perfectly with our articulated robot arm.

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NAVBOT THE AUTONOMOUS ROBOT

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ABSTRACT: This article presents to presents a robotic system developed for laboratory applications. The system employs computer vision techniques using OpenCv to detect and track objects based on color. The robot's capabilities include object detection, movement control, and obstacle avoidance using ultrasonic sensors.
KEY WORDS: 3D printing, computer vision, 3D design

1. Introduction

The rapid advancement of robotics technology has brought about significant changes in various industries, revolutionizing processes and pushing the boundaries of what is possible. From manufacturing and healthcare to agriculture and exploration, robots have found their way into numerous fields, streamlining operations and augmenting human capabilities. One area where robots have proven particularly valuable is in laboratory work.

Robots in the industrial and laboratory sectors share common characteristics. They are designed to perform tasks autonomously or with minimal human intervention, offering advantages such as increased precision, repeatability, and productivity. In industrial settings, robots have become integral components of manufacturing processes, carrying out assembly tasks, material handling, and quality control. They operate with high speed and accuracy, contributing to improved efficiency and cost-effectiveness.

In laboratory environments, robots play a pivotal role in scientific research, experimentation, and analysis. They are employed in diverse scientific disciplines, including chemistry, physics, biology, pharmaceuticals, and materials science. Lab robots offer several key advantages, including the ability to handle hazardous materials, execute repetitive tasks with consistency, and work in controlled and sterile conditions.

The robot at hand, named "NavBot," has been designed to serve as a versatile assistant in laboratories, catering to various disciplines, from chemistry and physics to small workshops. Its primary objective is to provide valuable support and streamline operations in these environments, offering ease of use and utility.

NavBot incorporates computer vision [1] to facilitate object recognition. Through an integrated graphical user interface (GUI), the robot can identify and track different objects, shapes, or even living organisms, based on predefined parameters. This capability enhances data collection and analysis, expediting research processes and increasing accuracy.

To ensure efficient navigation and obstacle avoidance, NavBot is equipped with an ultrasonic sensor. This sensor enables the robot to measure distances accurately and adapt its path to avoid potential collisions with objects or obstacles. By prioritizing safety, NavBot mitigates risks and minimizes disruptions during experiments and laboratory operations.

Beyond its application in laboratory environments,[2] NavBot has the potential to extend its impact to various fields of work. In pharmaceutical manufacturing, for example, the robot can contribute to tasks such as compound synthesis, high-throughput screening, and quality control. Its precision and consistency enhance productivity and reliability in the pharmaceutical development process.

NavBot's capabilities also find value in biomedical research, where it aids in automation for genomics, proteomics, and drug discovery. By handling large sample volumes and executing repetitive tasks, the robot accelerates research timelines and increases throughput, ultimately contributing to advancements in healthcare.

2. Robot design

In creating this prototype, we also considered environmental concerns by choosing materials carefully. Although we were somewhat limited, we wanted to use materials that were as environmentally friendly as possible. For this reason, the base of the robot is made from an old, reused toy.

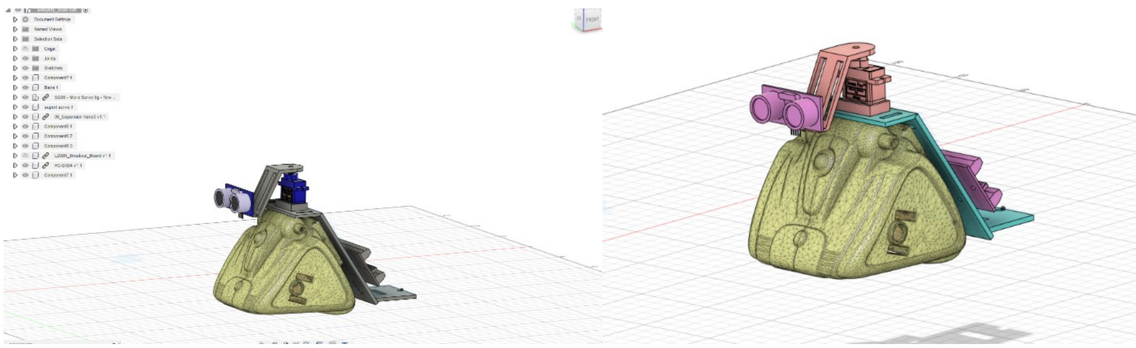


Fig.1 NavBot 3D model

Fig.2 Robot 3D scanning

2.1 3D printing of the robot components

For the realization of the robot components, we used 3D printing technology. This process allowed us to create a 3D model of the device, enabling us to analyze and make adjustments before the final manufacturing.

The component elements were printed using the ANYCUBIC MEGA 3D printer, [3] utilizing PLA (Polylactic Acid) filament. PLA is a popular biodegradable and environmentally friendly material derived from renewable resources such as cornstarch or sugarcane. It is known for its ease of use, low warping, and minimal odor during printing.

The ANYCUBIC MEGA printer has a spacious printing area measuring 300mm x 300mm x 305mm, providing ample space for large-sized components. PLA filament offers excellent print quality, allowing for precise and detailed designs.

To ensure optimal printing results, we set the extrusion temperature to around 200-220°C. Additionally, we adjusted the printing speed to a moderate level of 50 mm/s, striking a balance between print time and quality. These settings allowed us to achieve a smooth and consistent layer-by-layer construction of the components.

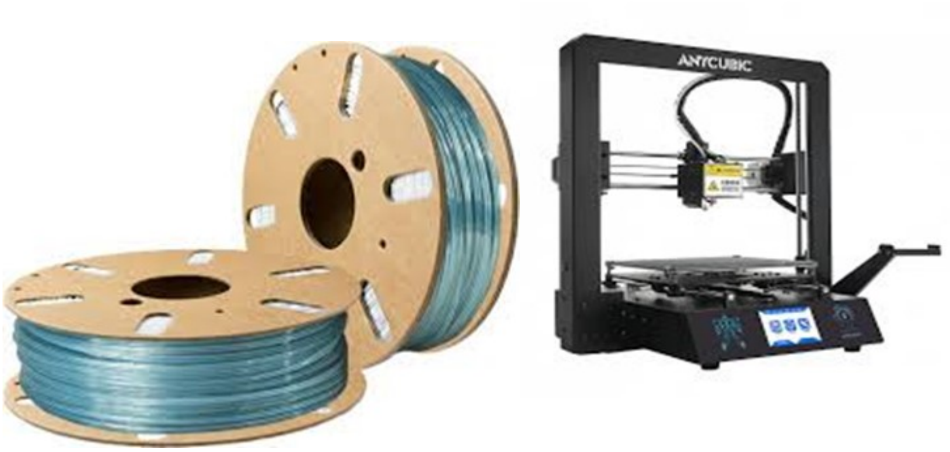


Fig.3 The 3D printer and filament used

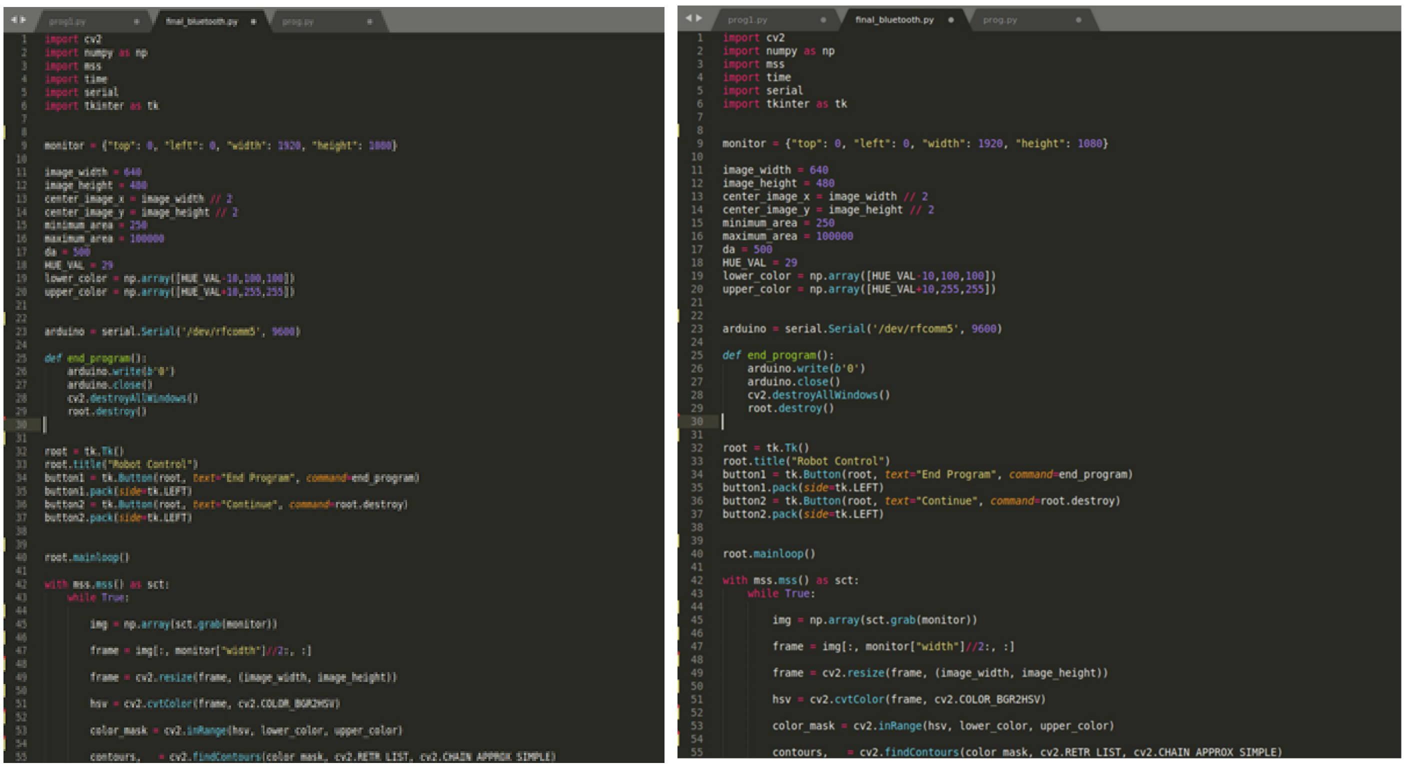
2.3 Electrical part of the robot

The robot operates through an Arduino Nano board, to which a servo motor is connected to move the ultrasonic sensor. It also has a Bluetooth module, HC-05, which receives processed images from the computer facilitate a faster operation. The movement is achieved with the help of two DC motors.

Fig.4 Electrical components used

3. The code

This code captures a region of the screen and processes the image received by the laptop from the wireless camera mounted on the robot to detect a certain color. It then identifies the largest object of that color and determines the robot's control action based on its position in the image. If the object is in the center of the image, the robot moves forward. If the object is off-center, the robot turns towards it. If the object is too small, the robot searches for it, and if it is not found, the robot keeps searching.
The code also has a graphical user interface (GUI) window with buttons to end the program or continue running it. It is written in Python uses the OpenCV library to process images, the mss library to capture the screen, the serial library to communicate with the robot, and the tkinter library to create the GUI window.



```python
import cv2
import numpy as np
import mss
import time
import serial
import tkinter as tk


monitor = {"top": 0, "left": 0, "width": 1920, "height": 1080}

image_width = 640
image_height = 480
center_image_x = image_width // 2
center_image_y = image_height // 2
minimum_area = 250
maximum_area = 100000
da = 500
HUE_VAL = 29
lower_color = np.array([HUE_VAL-10,100,100])
upper_color = np.array([HUE_VAL+10,255,255])


arduino = serial.Serial('/dev/rfcomm5', 9600)

def end_program():
    arduino.write(b'0')
    arduino.close()
    cv2.destroyAllWindows()
    root.destroy()


root = tk.Tk()
root.title("Robot Control")
button1 = tk.Button(root, text="End Program", command=end_program)
button1.pack(side=tk.LEFT)
button2 = tk.Button(root, text="Continue", command=root.destroy)
button2.pack(side=tk.LEFT)


root.mainloop()

with mss.mss() as sct:
    while True:

        img = np.array(sct.grab(monitor))

        frame = img[:, monitor["width"]//2:, :]

        frame = cv2.resize(frame, (image_width, image_height))

        hsv = cv2.cvtColor(frame, cv2.COLOR_BGR2HSV)

        color_mask = cv2.inRange(hsv, lower_color, upper_color)

        contours, _ = cv2.findContours(color_mask, cv2.RETR_LIST, cv2.CHAIN_APPROX_SIMPLE)
```

Fig.5 The code that runs on laptop

The Arduino code [4] is quite straightforward:
The code defines pin numbers for a robot's motors and a distance sensor. It sets the pins as inputs or outputs, and starts serial communication with the computer(laptop).
In the main loop, it waits for a command from the computer. If the command is 'f', 'b', 'l', or 'r', the robot moves in the corresponding direction: forward, backwards, left, right. If the command is '0', the robot enters an autonomous mode where it avoids obstacles using the distance sensor.
The distance function measures the distance to an object using the sensor, and the “autonom” function controls the robot's movements in autonomous mode based on the distance measured so that the obstacle could be avoided.

File Edit Sketch Tools Help

program_bluetooth_arduino

```
#include <SoftwareSerial.h>
SoftwareSerial bluetooth(12,11);
int leftMotorPin1 = A1;
int leftMotorPin2 = A0;
int rightMotorPin1 = 4;
int rightMotorPin2 = 5;

int trigPin = A3;
int echoPin = A2;

#define MAX_DISTANCE 20
void setup() {
  pinMode(leftMotorPin1, OUTPUT);
  pinMode(leftMotorPin2, OUTPUT);
  pinMode(rightMotorPin1, OUTPUT);
  pinMode(rightMotorPin2, OUTPUT);
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);

  Serial.begin(9600);
  bluetooth.begin(9600);
}

void loop() {
  //Serial.println(distanta());
  //delay(200);
  if (bluetooth.available()) {
    char command = bluetooth.read();
    if(command == '0'){Serial.println("haha intru in mod autonom");
    autonom();
    }
    if (command == 'f') {
      forward();
    } else if (command == 'b') {
      backward();
```

program_bluetooth_arduino

```
    }
    if (command == 'f') {
      forward();
    } else if (command == 'b') {
      backward();
    } else if (command == 'l') {
      left();
    } else if (command == 'r') {
      right();
    } /*else if (distanta() <= 15) {
      oprire();*/
    }
  }*/
}

void forward() {
  digitalWrite(leftMotorPin1, HIGH);
  digitalWrite(leftMotorPin2, LOW);
  digitalWrite(rightMotorPin1, HIGH);
  digitalWrite(rightMotorPin2, LOW);
}

void backward() {
  digitalWrite(leftMotorPin1, LOW);
  digitalWrite(leftMotorPin2, HIGH);
  digitalWrite(rightMotorPin1, LOW);
  digitalWrite(rightMotorPin2, HIGH);
}

void left() {
  digitalWrite(leftMotorPin1, LOW);
  digitalWrite(leftMotorPin2, HIGH);
  digitalWrite(rightMotorPin1, HIGH);
  digitalWrite(rightMotorPin2, LOW);
}
```

File Edit Sketch Tools Help

program_bluetooth_arduino

```
}

void left() {
  digitalWrite(leftMotorPin1, LOW);
  digitalWrite(leftMotorPin2, HIGH);
  digitalWrite(rightMotorPin1, HIGH);
  digitalWrite(rightMotorPin2, LOW);
}

void right() {
  digitalWrite(leftMotorPin1, HIGH);
  digitalWrite(leftMotorPin2, LOW);
  digitalWrite(rightMotorPin1, LOW);
  digitalWrite(rightMotorPin2, HIGH);
}

void oprire() {
  digitalWrite(leftMotorPin1, LOW);
  digitalWrite(leftMotorPin2, LOW);
  digitalWrite(rightMotorPin1, LOW);
  digitalWrite(rightMotorPin2, LOW);
}
int distanta(){
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(5);
  digitalWrite(trigPin, LOW);

  long duration = pulseIn(echoPin, HIGH);
  float distance = microsecondsToCentimeters(duration);

  if(distance<100){return distance;}
  }
long microsecondsToCentimeters(long microseconds){
```

File Edit Sketch Tools Help

program_bluetooth_arduino §

```
  delayMicroseconds(5);
  digitalWrite(trigPin, LOW);

  long duration = pulseIn(echoPin, HIGH);
  float distance = microsecondsToCentimeters(duration);

  if(distance<100){return distance;}
  }
long microsecondsToCentimeters(long microseconds){
  return microseconds / 29 / 2;}

  void autonom(){
  if (distanta() > 0 && distanta() <= MAX_DISTANCE) {
    Serial.println("oprire");
    oprire();
    delay(500);


    Serial.println("Left");
    left();
    delay(1000);


    Serial.println("forward");
    forward();
  } else {
    Serial.println("forward");


    forward();
  }


    }
```

Fig.6 The code that runs on Arduino

4. Conclusion

In conclusion, robots like NavBot have transformed laboratory environments by bringing automation and efficiency to scientific research and experiments. Their ability to recognize objects, navigate with precision, and perform tasks independently makes them valuable assets in multiple disciplines. As technology continues to advance, robots like NavBot will play an increasingly vital role in driving scientific discoveries, enhancing productivity, and shaping the future of laboratory work.

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MODELLING AND MANUFACTURING OF A MODULAR X-Y-THETA PLATFORM WITH WIRELESS CONTROL

MUREȘAN Ştefan-Claudiu[1], MOROȘAN Teodor, S.l. PhD. Eng. CRISTOIU Cozmin Adrian, S.l. PhD. Eng. IVAN Andrei Mario

The topic aims to present the benefits of developing and implementing a modular solution in industrial production and automation processes, as well as to present a prototype variant produced for the study and analysis of behavior and performance, complementary to virtual simulation. Additionally, various production processes have been studied and simulated to compare costs, quality, and duration of the production process between them.

Keywords: Prototyping, translation axes, modular, production, CNC

1. Introduction

Industrial robots/machines, although flexible in applications, are operationally limited due to their structural design. Therefore, a robot/machine capable of modifying its structural design would result in an increased number of possible applications compared to the traditional structure of an industrial robot/machine on the market. To achieve a wide variety of possible configurations, while considering the complexity, performance, and costs involved in this project, after analyzing possible options, it was concluded that a series of modular translation axes represent the preferred solution to be implemented. This is due to their relatively simplified organological structure (compared to a rotational axis) and significantly improved kinematics, in addition to the already mentioned criteria.

2. Actual status and axis design

The first aspect considered before designing the axes is the possibility of interconnecting them with other identical additional axes in a wide variety of ways, considering that this is the fundamental quality of these structures. Additionally, optimizing space and achieving a compact configuration of the components included in the assembly were also taken into account. A prototype of a modular X-Y-Theta platform was created for further researches and improvements in the domain of mechatronics modularity and also smart manufacturing solutions.

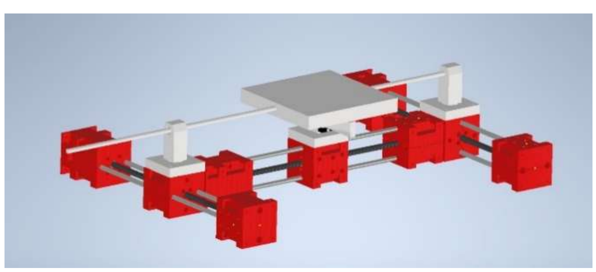

Fig. 1. Digital Twin of the X-Y-Theta modular platform

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3. Internal Organological Structure

For the internal organological structure, a screw-nut mechanism of the ball screw type was chosen (for the prototype, trapezoidal screws and bronze nuts were used for cost reasons), coupled with a stepper motor using an elastic coupling (to correct any coaxiality errors between the screw's rotation axis and the motor shaft) and supported at the end with a series of radial-axial ball bearings on a single row (due to the presence of both radial and axial loads during operation). For the guiding part, a system consisting of linear ball bushings and aluminum guide rods was chosen.

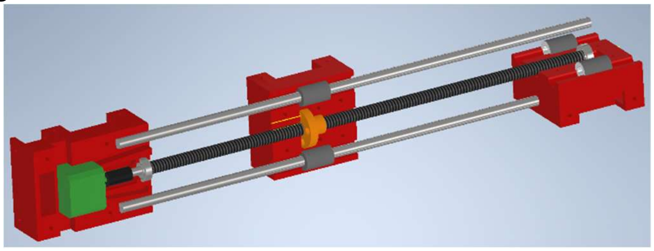

Fig. 2. Internal structure of a single axis

4. Production Process

Regarding the production of the respective casings, initially, their 3D modeling was performed using Autodesk's Inventor Professional software, as well as the 2D production drawings using Autodesk's AutoCAD software. The design process also included determining the tolerances of the parts.

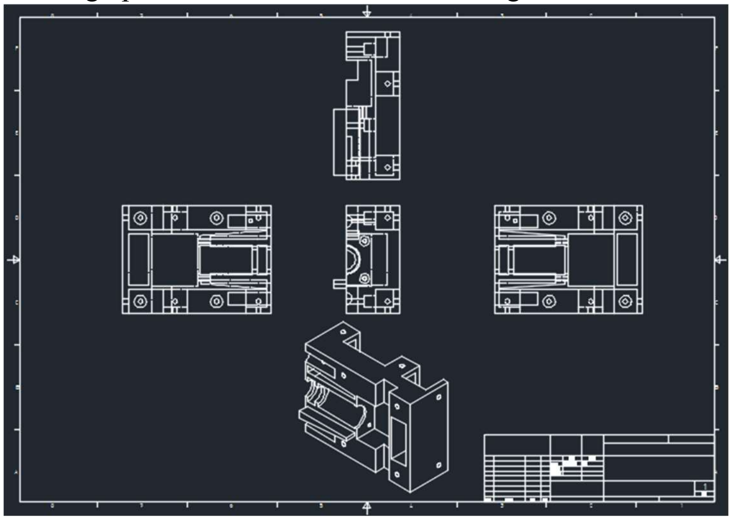

Fig. 3. Drafting views of the motor cover

In terms of the actual production process, additive manufacturing (3D printing) with PLA plastic filament was chosen for the physical prototype due to the low material and equipment costs involved. The 3D printing was carried out using the Creality CR-V 10S printer. The specific settings for this PLA filament printing process included selecting a nozzle temperature ranging from 190 to 220 degrees Celsius and a bed temperature between 40 and 50 degrees Celsius, according to the manufacturer's specifications. A 20% Gyroid infill option was chosen due to its excellent strength-quantity ratio.

For a potential series production of a structure for commercialization and integration into existing industrial processes, alternative production methods such as injection molding or CNC machining could be considered to ensure higher precision and durability of the components. These methods would require the use of suitable materials such as metal alloys or engineering-grade plastics.

A CAM (Computer Aided Manufacturing) simulation of casing production was performed using Fusion 360 software, developed by Autodesk, and a CNC machine with 3 degrees of freedom from OKUMA. In order to generate the G-code program to command the CNC equipment, it was necessary to parameterize it according to the type of material used (steel or aluminum), the chosen material's hardness, and temperature settings. An important stage in the production process is also the selection of the cutting tool, based on the size, shape, and complexity of the geometry, the required feed rate, and the speed determined by the already mentioned parameters (hardness and material type). Additionally, the presence of a forced cooling system is necessary to prevent deformation and premature wear of the cutting tool, as well as to prevent potential thermal deformations of the workpiece.

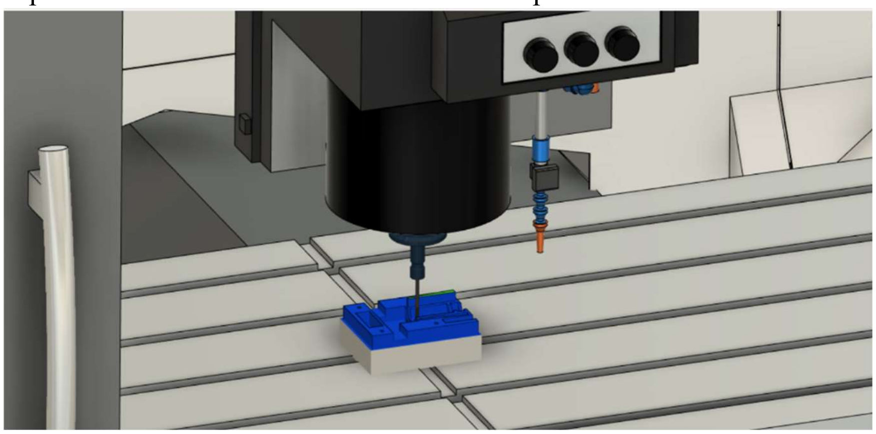

Fig. 4. Capture during the CAM simulation

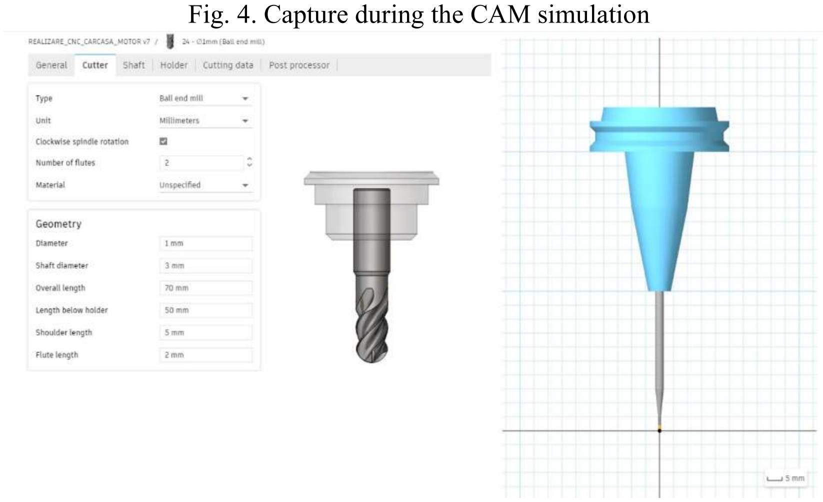

Fig.5. Tool parameters and specifications

Cutting data	Spindle speed	Surface speed	Cutting feedrate	Feed per tooth	Lead-in feedrate	Lead-out feedrate	Coolant
Default Preset	955 rpm	150.01105 m/...	460 mm/min	0.12042 mm	460 mm/min	460 mm/min	Flood

Fig. 1. Process parameters such as spindle speed and feed rate

5. GD&T Analysis

Following the manufacturing process, in order to guarantee the optimal selection of manufacturing processes and the correct selection of milling parameters a GD&T (gemetrical dimension and tolerances) quality control should be run using a high-precision machine. For this specific set o pieces it was created a simulation program for a CMM (Computer measuring machine) using a Renishaw tooling to inspect gemetrical characteristics such as parallelism, cylindricity, flatness and any specific tolerance market on the technical drawing that plays a crucial role in the well use of the system.

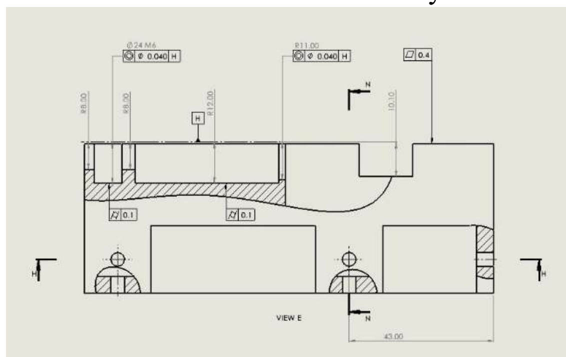

Fig. 7. GD&T prescriptions on the main drafting

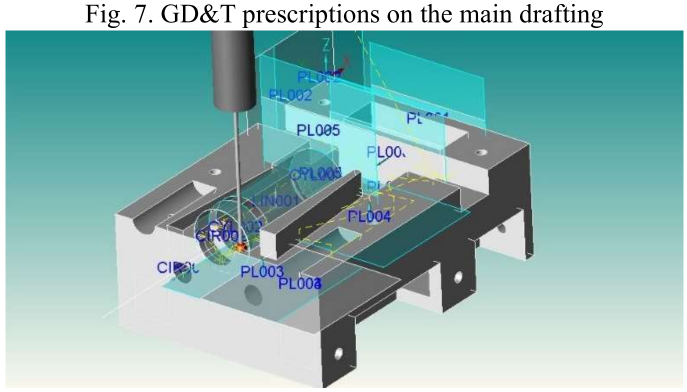

Fig. 2. Geometrical characteristics inspected on the CMM

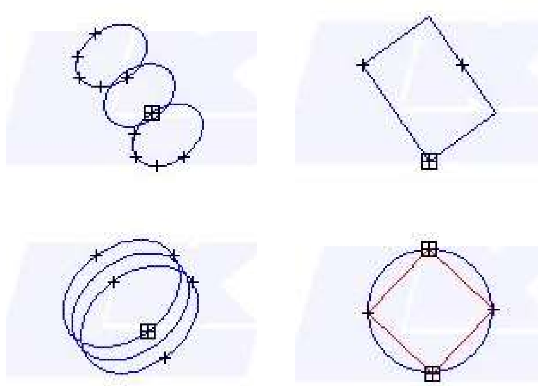

Fig. 3. A number of outputs resulted at the end of CMM inspection

6. Electronic control and command system

For the electronic control of the axes, an Arduino UNO R3 development board was used. The motors used were NEMA 17HS4401 stepper motors, which required coupling them with A4988 stepper motor drivers. These drivers are connected to a 12V power supply, which is sufficient for powering the motors. An electrical panel was built to serve as a command and control system for the axis, corresponding to the electrical schemes of the robot.

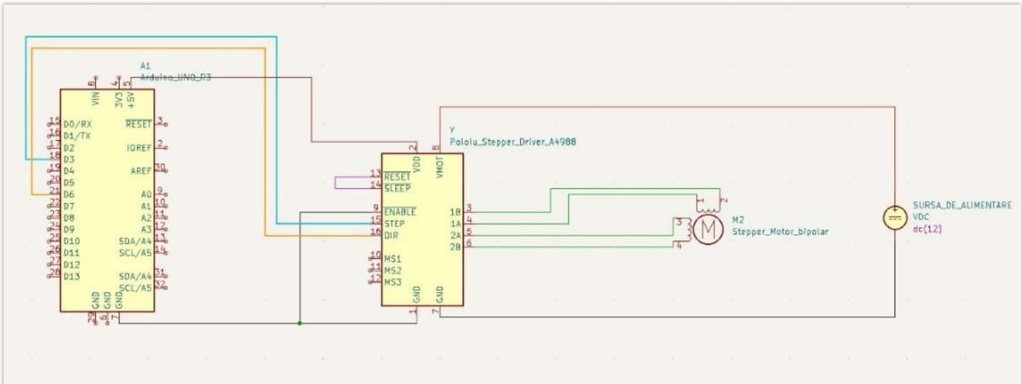

Fig. 4. Electrical diagram designed in Kicads

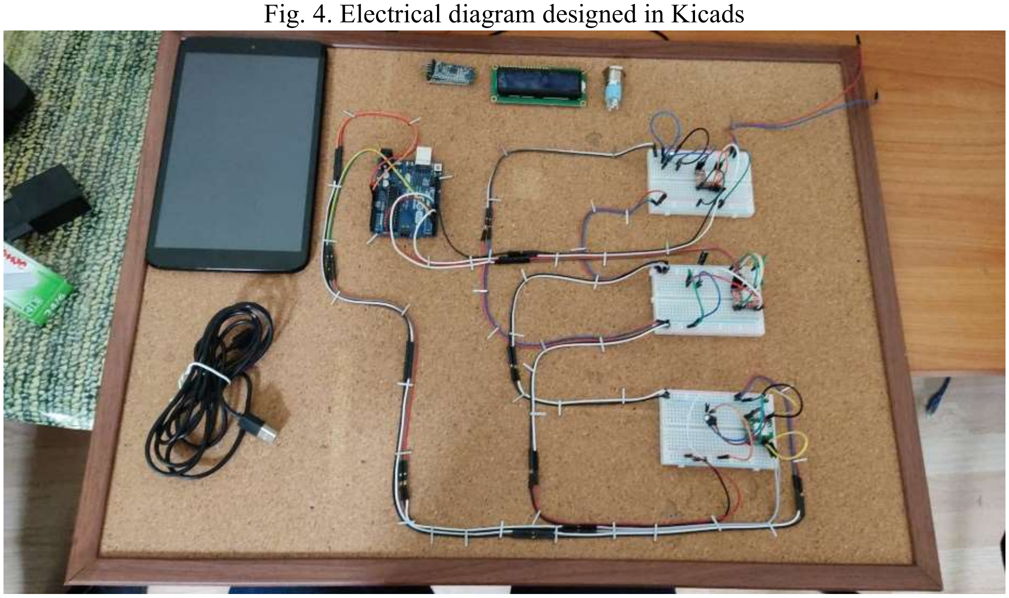

Fig. 5. Real life electrical pannel

In the case of configurations with 3 such axes, the GRBL firmware was used on the Arduino board. As a graphical user interface (GUI), Universal G-code Sender (UGS) was used for sending G-code commands from devices with Windows operating systems.

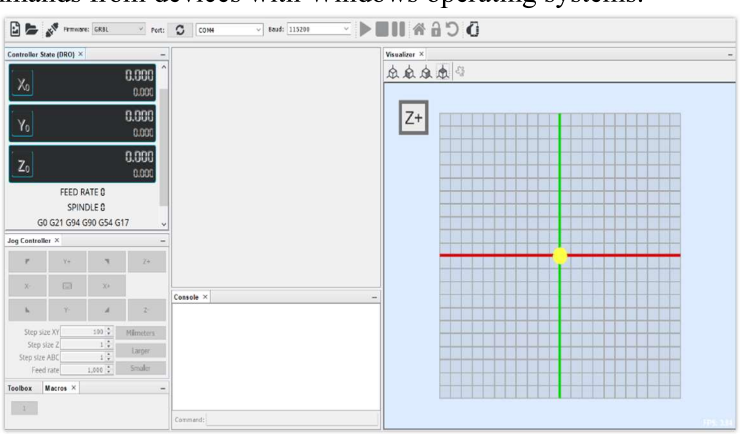

Fig. 6. Windows interface used for communication

Fig. 7. Android interface used for wireless communication

For Android operating systems, GRBL Controller was used, and in this case, the actual data transfer between the Arduino board and the touchscreen interface was done via Bluetooth. This aspect also necessitated a separate power supply for the Arduino board in the absence of a wired connection between it and the touchscreen interface, so the Arduino board is powered by the 12-volt power supply as well.

6. Results and Conclusion

The modular solution using translation axes showed promising benefits for industrial production and automation processes. The ability to reconfigure the structure according to specific application requirements offers increased flexibility and adaptability. The simplified organological structure, combined with improved kinematics, contributes to enhanced performance and efficiency.

The prototype variant produced for the study demonstrated the feasibility of the concept and provided valuable insights into the design and production processes. However, further refinement and optimization are necessary for commercialization and integration into existing industrial setups.

The simulation and analysis conducted on the modular solution confirmed its potential advantages, enabling better decision-making in terms of production process selection and optimization. The comparison of costs, quality, and duration among different production processes helps identify the most efficient and cost-effective approaches.

In conclusion, the development and implementation of a modular solution using translation axes offer significant benefits for industrial production and automation. The prototype variant and virtual simulation provide valuable tools for further research and development in this area, with the potential for enhancing productivity, versatility, and competitiveness in industrial settings.

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REFURBISHING AND MODERNIZING A ROBOTIC MANUFACTURING CELL

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Scientific Coordinator: Conf. PhD. Eng. **Florea Dorel ANANIA**

This scientific paper presents a laborious reverse engineering study aimed at elucidating the functionality of a more than 20-year-old Computer Integrated Manufacturing cell. The investigation focuses on understanding the intricacies of its constituent elements, which include a raw material storage system, an optical verification system, two Industrial Robots from Mitsubishi (RV-E3J and RV-E2) and conveyor belts. Through this endeavor, we aim to enhance our understanding of legacy CIM technology and provide valuable insights for future educational use.

KEYWORDS: CIM, Reverse Engineering, Manufacturing

1. Introduction

The faculty offered the opportunity to refurbish an old Computer Integrated Manufacturing (CIM) cell, initially used for training and research of technological manufacturing. The first steps were to identify the functionality of the systems and equipment as we did not have any inherited documentation. Additionally, we encountered the challenge of determining the compatibility of existing drive systems or, alternatively, exploring suitable alternatives.

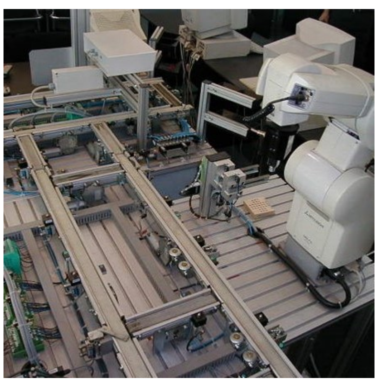

Fig. 1. Initial configuration of the CIM

Fig. 2. RV-E3 industrial robot

Fig. 3. RV-E2

2. General description of the IR

The manufacturing cell integrates two industrial robots of Mitsubishi make, model numbers Melfa RV-E2 and Melfa RV-E3J. They are part of the same family, with one having 6 degrees of freedom, the other only 5. Other similarities elements include repeatability, which is ±0.04mm, maximum composite speed (3500mm/s), and their same positioning system (architecture, operation ranges and dimensions).

The addition of the fourth, twist axis, allows the RV-E2 a higher degree of flexibility, allowing better positioning characteristics when compared to its 5-axis relative. This, however, reduces structural rigidity and therefore maximum operational radius (for the E3J, this is up to 630mm, while E2 can only reach 621mm). The original application utilized the pair in a cooperative manner, with one being used to load and unload a 3-Axis numerically controlled milling center, the other being used in pallet handling from adjacent conveyor belts. One of the goals of this project is to maintain the concept of cooperating IR's, while modernizing their functionality and better integrating them with modern hardware.

The robots' controllers were initially not in working order, predominantly due to passage of time and general wear. One of the first tasks undertaken was to clean the circuit boards using isopropyl alcohol, a thorough check of electrolytic capacitors (which are known points of failure) and cleanup of connectors, in order to avoid imperfect contacts. This brought one of the controllers back on-line but left the other still unresponsive. Through trial and errors (as controller manuals were not available), it was determined to be in a "configuration mode", accepting parameter modifications via the on-board buttons. By cycling between them, the proper combination was discovered, and the controller brough back to working order.

The teach pendants were still functional, as they represented very simple electronics, a far cry from what is considered current tech standard. They consist of an LCD screen, followed by a group of buttons, with multiplexed functionality: while in different menus, their functionality changes. The "dead man's trigger" mechanism is implemented by depressing the "step/move" key, after which motion of the robot is made available. Other functionality that has been explored when documenting the teach pendant was the ability to create new programs, delete and edit previous ones, as well as allow finer parameter entry and general maintenance. Homing of the robots is also achieved via a menu located on the teach-pendant, the reset procedure having been inferred from a recovered laboratory handout, which detailed the necessary steps.

After understanding the principles of the industrial robots, as well as the technical capabilities and limitations of the structures, the methods by which off-line programming could be achieved were studied. Utilizing the laboratory computers, it was able to access the robot's software, by means of the Cosimir integrated development environment. This allows for full off-line programmability, via graphical and textual means (the programming language is the easy to understand MoveMaster Command instruction set).

Since plenty of the CIM's functionality depends on timing of events and being able to react to external stimuli, the use of the controller's input-output (I/O) blocks was also studied. It was recognized that these I/O's are of the mechanical relay type, incapable of PWM or other functionality, but able to produce binary true-false conditions. This will prove useful in the future, as functions that would normally depend on the existence of a Programmable Logic Controller (PLC) can be offloaded into the robot's controllers, giving more flexibility to the designers and programmers of the cell. Interestingly, initially despite verifying that the commands would be issued from the robot controller, it was noted that no response would be obtained from the I/O boxes. It was theorized (a hypothesis which proved to be true) that the robot controller was acting as a current sink for the relays, requiring an external voltage to function correctly. After applying 24vDC to the I/O box's VCC pin, it was noted that the pins would act as programmed.

3. The pneumatic system

The Transfer/Transport System's is equipped with a pneumatic system that is electronically controlled. This system is composed of 5/2-way mono-stable electro valves, small pneumatic cylinders, and pressure regulators. The pneumatic cylinders, controlled via 5/2-way mono-stable electro valves, are positioned and have the role of stopping the pallet-carrier at the work station.

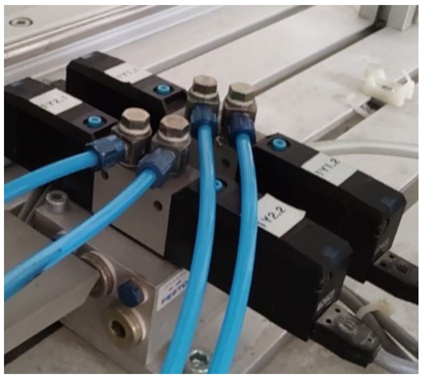

Fig. 4. 5/2-way mono-stable electro valves

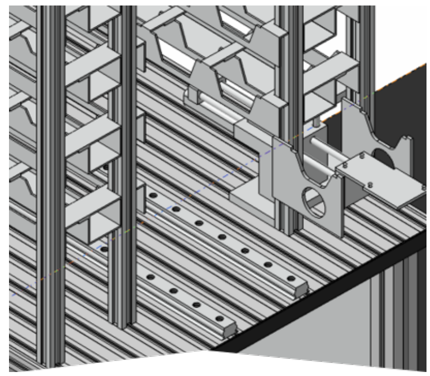

Fig. 5. Pallet loading and unloading system

Connected to the Transfer/Transport System is the automated rack. The pallet carrier is arrested at the fore of the rack, then elevated to the loading and unloading system. The pallet is then transferred into the rack by means of a pinion gear mechanism. The Load/Unload System for the pallets is composed of 2 pneumatic cylinders and two 5/2-way mono-stable electro valves and a pressure regulator. The small cylinder traverses the boom vertically, the long cylinder ensures axial movement, with the end goal being the transfer from the pallet carrier and into the pick-up area. Working pressure has been established to be 2.5bars, with electronic commands being issued by the rack's integrated PLC.

Reprogramming of this PLC has been determined to be an unfeasible endeavor, as the means to achieve it are lost to time: by studying the reference manual, it was found that the main means of programming is via a memory card, which is used to transfer programs into the internal battery backed-up RAM. Therefore, the decision was taken to consider the electronics of the rack a black box, with efforts going into understanding the means of commanding it.

The main interface to the other cell's components is a 4-bit electrical I/O port. By applying logic level high voltages to each of the bits, commands can be issued. Understanding the rack is still a work in progress, however initial tests have proven that both the electronics and mechanical parts are functional. A special program was developed in python, to automate sending of the 4-bit commands, which resulted in an initial indexing of positions within the stack. Further research is required on this topic, however time constraints restricted our ability to further delve into the subject.

Gaskets in the cylinders have worn down over time and become brittle. During our testing, while the pneumatic cylinders were observed to function, after a number of cycles failure was observed, as pressure was rapidly lost in the system. At the current time, efforts to replace the cylinders are underway, however the possibility of taking the pneumatics of the rack off-line and replacing their functionality with the 5-axis IR has been taken into account.

4. Electronic peripherals

The system incorporates specialized modules designed for the detection and identification of pallet carriers. This is done utilizing two sensors: an inductive proximity sensor, which detects the presence of a pallet carrier, and a capacitive identification sensor, which reads the unique identifier from a small built-in plastic tab. Both sensors are interfaced with special local-control modules, which aggregate signals, while transmitting information about their state over the RS-232 bus to the main PLCs. Reverse engineering of both these sensors and the local control centers proved to be a tedious process, which required connecting a logic analyzer to first identify what protocol was in used, then the structure of data sent over the bus.

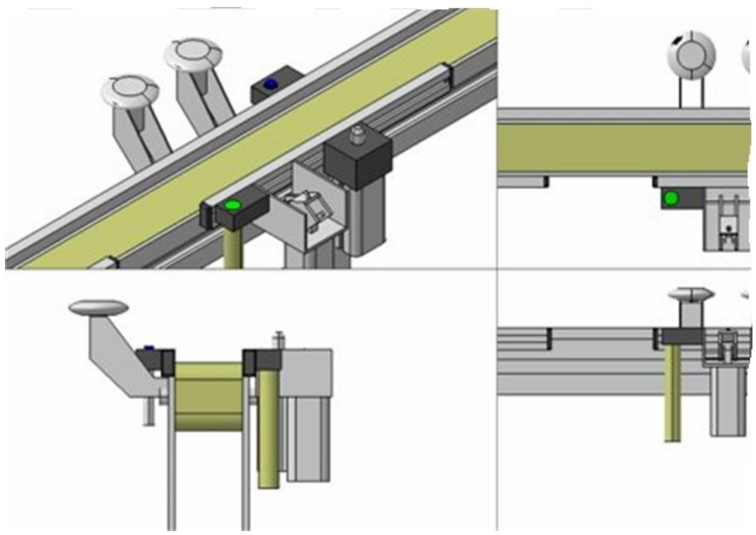

Fig. 6. CAD model of capacitive and inductive sensors

5. Conclusions

As was proceeded with the reverse engineering process, it was successfully discovered how to work with some of the available systems and components of the cell. At current time, the robots, the optical verification system and the pneumatic components are fully functional, with all that remains being to determine how to control the stack.

Further work concerns both documenting all that has been researched (recognizing that the CIM's purpose is first and foremost an educational one) and development of a new, flexible fabrication system. Building on the foundation of what has been achieved, we wish to create an application that both serves an industrial and an educational purpose, breathing life into an abandoned but still valuable piece of technology.

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EDUCATIONAL APPLICATION WITH EDUCATIONAL ROBOT WITH LEGO TYPE COMPONENTS, ULTRASONIC AND COLOR SENSORS THAT SOLVES THE RUBIK'S CUBE

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ABSTRACT: In this paper we present how we can use a programmable lego robot, the advantages that students can obtain if they use a construction like this and highlight the program involves the use of sensors works.

KEYWORDS: Robot, Arduino, Programing Robot, Assembly Robot.

1. Introduction

In training robot programming skills, it is important to work with models that can solve many general situations and that are programmable. One such example is the LEGO MINDSTORMS EV3 robot (see [1]). It can be programmed in several languages, for example in Python (see [2]).

The advantages of using lego robot for a highschool stundet are:

- understanding the notions of elementary applied mechanics;
- understanding how can programming different servomotors and sensors in Python, C++ or Scratch;
- the development of algorithmic knowledge in the movement problems of a robot.

The advantages of using lego robot for a university stundet are:

- understanding the operation of a gear much better;
- understanding the use of the Arduino board;
- can simulate various processes on a model much less expensive financially than an expensive robot (for example Kuka robot).

2. Kit components

1. Brick

It contains the Arduino board. It has 8 ports (A,B,C,D- for motors; 1,2,3,4- for sensors). It can be connected via Bluetooth or Wi-fi. It works with batteries or is charged with a special charger.

Fig. 1. Brick

2. Two servomotors

The large EV3 servo motor is a powerful motor that uses tacho feedback for precise control to a degree of precision. By using the built-in rotation sensor, the smart motor can be made to align with other motors on the robot so that it can travel in a straight line at the same speed. It can also be used to give an accurate reading for experiments. The design of the motor housing makes it easy to assemble the gear trains. (Figure 1 and Figure 2)

- Tacho feedback to a degree of accuracy
- 160-170 RPM • Torque of 20 N.cm (approx. 30 oz / in)
- Locking torque of 40 N.cm (approx. 60 oz / in)

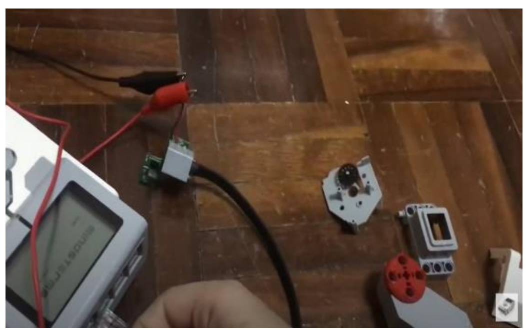

Fig. 2. Arduino servo motor

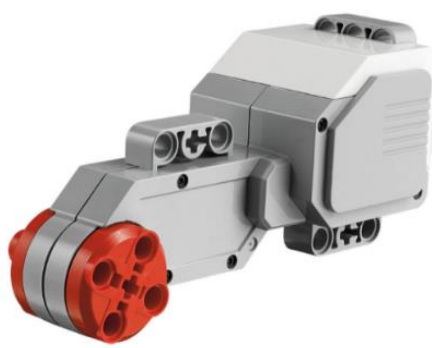

Fig. 3. Servo motor

3. A touch sensor

The EV3 Touch analog sensor is a simple but exceptionally accurate tool that detects when the front button is pressed or released and is capable of counting single and multiple presses. Students can build start/stop control systems, create maze-solving robots, and discover the use of technology in devices such as digital musical instruments, computer keyboards, and kitchen appliances.

- Hole of the transverse axis on the knob

Fig. 4. Touch sensor

4. Digital color sensor

The EV3 digital color sensor distinguishes between eight different colors. It also serves as a light sensor by detecting light intensities. Students can build color-sorting and line-following robots, experience the reflection of different colored light, and gain experience with a technology that is widely used in industries such as recycling, agriculture, and packaging.

- Measures reflect red light and ambient light from dark to very bright sunlight
- Capable of detecting eight colors. Can differentiate between color or black and white or between blue, green, yellow, red, white and brown
- 1 kHz sampling rate

Fig. 5. Color sensor

5. Medium servo motor

The medium device "EV3 Servo Motor" is great for lighter load, higher speed applications and when faster response time and a smaller profile are required in the robot design. The device uses mileage for precise control, having a built-in rotation sensor. Mileage to a certain degree of accuracy.

- 240-250 rpm.
- Operating torque of 8 N / cm (approx. 11 oz / in.).
- Stabilizing torque of 12 N / cm (approx. 17 oz / in.).

Fig. 6. Medium servo motor

6. Gyro sensor

The "EV3 Gyro" digital sensor measures the robot's rotational motion and orientation changes. Students can measure angles, create balancing robots, and explore the technology that powers a variety of real-world tools like Segways, navigation systems, and game controllers.

- "Angle" mode measures angles with an accuracy of +/- 3 degrees.
- "Gyro" mode has a maximum power of 440 degrees / second.
- The frequency rate is 1 kHz. • Auto-ID is built into the "EV3" software.

Fig. 7. Gyro sensor

7. Ultrasonic sensor

The "EV3" digital ultrasonic sensor generates sound waves, which read echoes to detect and measure the distance to objects. It can also send out single sound waves to work as a sonar or listen to a sound wave that triggers the start of a program. For example, students could design a traffic monitoring system and measure distances between vehicles. There is the opportunity to discover how technology is used in everyday items such as automatic doors, cars and manufacturing systems. It measures distances between 1 and 250 cm (one to 100 inches).

- Accuracy to +/- 1 cm (+/- 0.394 inches).
- Front lighting is steady while emitting and blinks while listening.
- The value "True" is returned if another ultrasonic sound is recognized.
- Auto-ID is built into the EV3 software.

Fig. 8. Ultrasonic senzor

3. Explanations on the action of the robot

The algorithm implemented in the robot solves the rubik's cube.

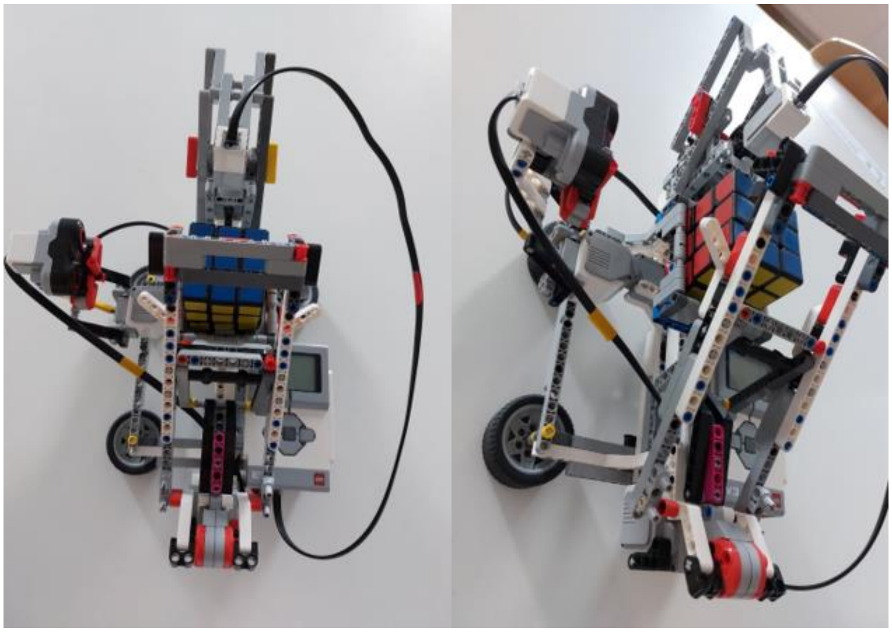

Fig. 10. LEGO robot

MindCub3r is a robot that can be built from a single LEGO MINDSTORMS EV3 home set to solve the well-known Rubik's Cube puzzle (see [3], [4]).

This robot uses a color sensor that reads the faces of the Rubik's cube, an ultra sensor that detects the cube placed on the turntable, two motors and a brick.

The first stage is to scan all the faces with a color sensor (it stores the position of each color on the faces in 3 x 3 matrix), then the cube positioning arms hold the cube and the rotating table at the base rotates, so the robot starts to solve rubik's cube.

The legs of the robot are made of wheels, which have a large diameter for good stability, without any vibrations in the structure.

4. Technical data about the program

The robot is based on the program of two sensors that transmit movement and color, but also two motors that are activated according to the code that is based on the order of actions.

The robot ultrasonically detects the cube as being placed on the rotary table at a certain distance, then the color sensor scans the surfaces and determines their colors and order (3x3 matrix is used). The colors are registered with a certain code but it must be a suitable brightness so that the wrong registration of colors does not occur.

After scanning each face, the robot has a moment of 3-4 s to think, after which it starts to grasp the cube with the robotic arm and twist the cube with the help of the rotary table. The duration of completing the Rubik's cube is counted. The program is made of 2 subprograms that call on each other, based on functions and calculated by mathematical algorithms transposed into blocks that establish steps for solving the rubik's cube.

5. Conclusions

The use of programmable LEGO robots represents a much cheaper way of simulation for many situations. The presented robot solves the rubik's cube. This mockup represents an alternative solution to highlight a classical algorithm that receives part of the input data from sensors and that trains sensors and motors.

6. References

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ANALYSIS OF THE BEHAVIOUR OF MODULAR WOODEN PANELS DURING A DROP TEST USING EXPLICIT DYNAMICS

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SUMMARY: The research comprises a modular wooden frame composed of planks, modeled and analyzed in ANSYS. The structure was subjected to a drop test from the height of 2m and an inclination angle of 15⁰. The simulation was performed employing the Finite Element Method in an Explicit dynamics approach, on a model with a highly controlled mesh and advanced computation settings.

KEYWORDS: modular frame, drop test, FEM, Explicit dynamics.

1. Introduction

The research is focused on the behavior of the prefabricated wooden frame manipulated by a robot, during a manufacturing process that takes place in a robotic cell.. It will be subjected to an accidental fall on the floor, from a height of 2m and an angle of 15⁰.

Fig. **Eroare! În document nu există text cu stilul precizat.**. The wooden frame placed on the table surface

2. State of art

The FEM simulation is based on an Explicit dynamics solver that includes advanced capabilities which allow depicting the dynamic behavior of the assembly on a detailed model, and to captures the physics for almost any field [1].

Model with 1D, 2D or 3D structures can be studied, considering contacts with severe nonlinearities, residual shape changes (loss of structural stability), cracks and cumulative effects. This method is used for transient phenomena with a short duration of time and extreme non-linearities [2]. The simulation project is illustrated in Fig. 2.

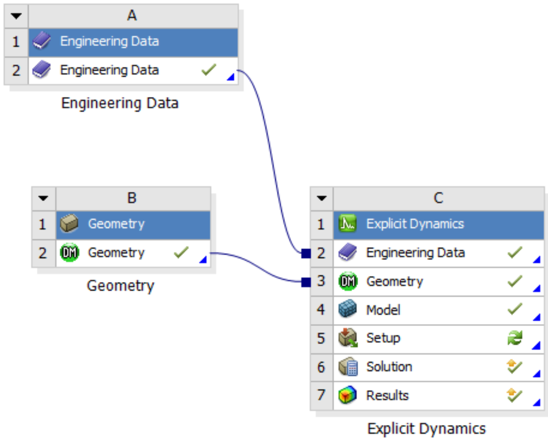


Fig. 2. Project structure in ANSYS

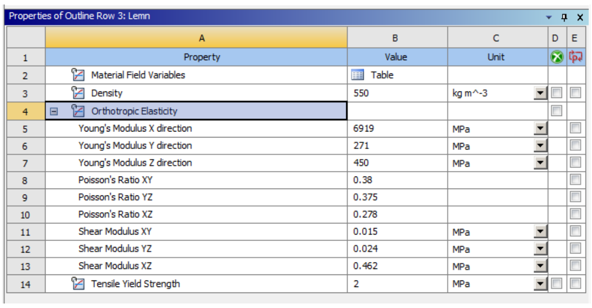
The material selected for the frame is pine wood. Because wood is a complex material with orthotropic properties based on its internal structure consisting of long and thin fibers arranged in concentric layers, it has different elastic properties on the 3 directions (longitudinal, radial, tangential). All the material properties were extracted from a recent scientific research article [3] in Table 1.

Table 1 [3]

Table 1. Off-diagonal terms and eigenvalues of the compliance matrix (2.3) for species of softwood

	data found in the literature				calculations in this paper			
	E_1	G_{12}	ν_{12}	ν_{21}	$-c_{12}$	$-c_{21}$	λ_1	λ_4
	E_2	G_{13}	ν_{13}	ν_{31}	$-c_{13}$	$-c_{31}$	λ_2	λ_5
	E_3	G_{23}	ν_{23}	ν_{32}	$-c_{23}$	$-c_{32}$	λ_3	λ_6
	[MPa]		[-]		[10^{-12}Pa^{-1}]		[10^{-6}Pa^{-1}]	
Pine [21]	6919	262	0.388	0.015	56	56	0.00014	0.00382
	271	354	0.375	0.024	54	54	0.00170	0.00423
	450	34	0.278	0.462	1027	1027	0.00282	0.02941

The allowable maximum stress σ_a was chosen as an average between several models of pine wood from the Matweb library (Fig. 3).


Properties of Outline Row 3: Lemn

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	550	kg m^-3		
4	Orthotropic Elasticity				
5	Young's Modulus X direction	6919	MPa		
6	Young's Modulus Y direction	271	MPa		
7	Young's Modulus Z direction	450	MPa		
8	Poisson's Ratio XY	0.38			
9	Poisson's Ratio YZ	0.375			
10	Poisson's Ratio XZ	0.278			
11	Shear Modulus XY	0.015	MPa		
12	Shear Modulus YZ	0.024	MPa		
13	Shear Modulus XZ	0.462	MPa		
14	Tensile Yield Strength	2	MPa		

Fig. 3 Material properties for pine wood

The CAD model was prepared in the DesignModeler module, and simplified by considering the entire frame as a single part, disregarding the nail joints that are present in the real model. All the modeling commands in model preparation stages are summarized in Fig. 4.

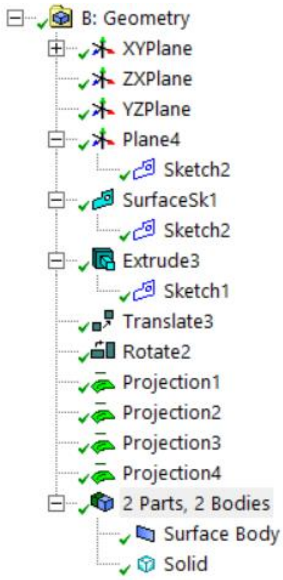
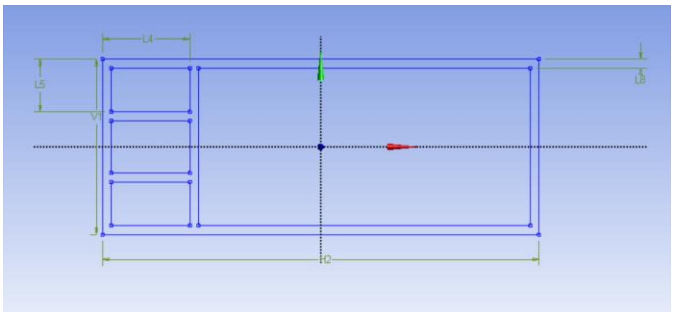


Fig. 4. Modeling stages in DesignModeler

The frame was designed based on the dimensions of the planks from the robotic cell, with the standard dimensions in the imperial system of 2x4 in. From the initial sketch, an extrusion was performed to materialize the 3D part. All the dimensions are summarized in Fig. 5.



Dimensions: 5	
H2	2500 mm
L4	500 mm
L5	300 mm
L8	50.8 mm
V1	1000 mm

Fig. 5 The 2D sketch that

The structure was placed at an initial height of 2m and tilted by 15º to represent an unfavorable position of the accidental fall (Fig. 6).

Details of Translate3	
Translate	Translate3
Preserve Bodies?	No
Bodies	1
Direction Definition	Selection
Direction Selection	Plane Normal
FD2, Distance	2000 mm

Details of Rotate2	
Rotate	Rotate2
Preserve Bodies?	No
Bodies	1
Axis Definition	Selection
Axis Selection	3D Edge
FD9, Angle	15 °

Fig. 1 Details of the initial conditions

All the edge points have been projected on the surfaces to enable the mesh generation. The maximum element size was set to 30 mm, to avoid the occurrence of the hourglass energy during the simulation (Fig. 7).

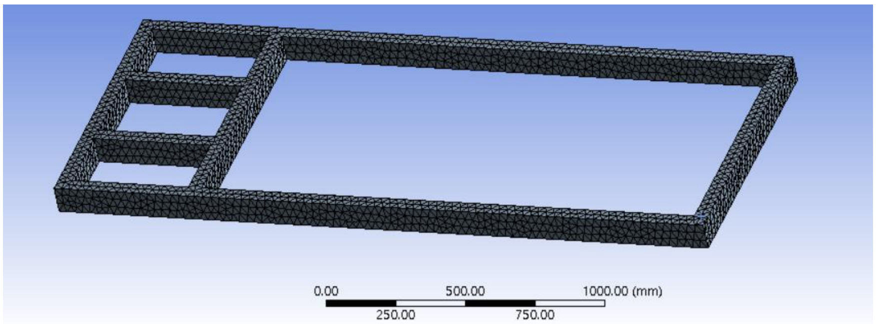


Fig. 7 The computational model of the wooden frame

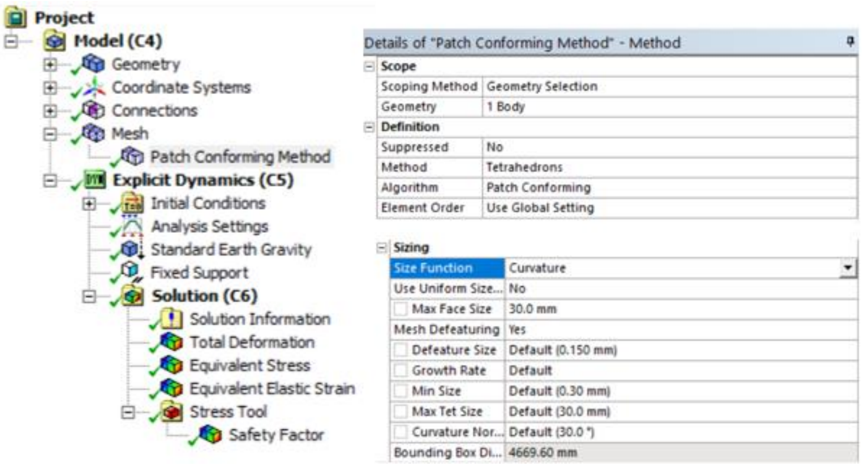


Fig. 2 Tree and discretization parameters

A standard earth gravity of 9.81m/s^2 was applied to the frame, and the floor was considered rigid. The total duration of the drop test was 1.5 seconds, and the tetrahedral elements integration was set at constant pressure (Fig. 9).

Solver Controls	
Solve Units	mm, mg, ms
Beam Solution Type	Bending
Beam Time Step Safety Factor	0.1
Hex Integration Type	1pt Gauss
Shell Sublayers	3
Shell Shear Correction Factor	0.8333
Shell BWC Warp Correction	Yes
Shell Thickness Update	Nodal
Tet Integration	Constant Pressure
Shell Inertia Update	Recompute
Density Update	Program Controlled

Fig. 3 Explicit dynamics settings

The most important results of the simulation are the equivalent stress according to the von Mises criterion, the equivalent elastic strain and the safety factor. The maximum displacements are not relevant because the frame is simulated during motion and the values correspond largely to the distance during in the fall [4] [5]. The maximum equivalent von Mises stress of 3.0337 MPa is significant and exceeds the yield strength of the pine wood at 2MPa (Fig. 10). The maximum values appear after the impact and start to decrease afterwards. The maximum value of the elastic strain is 0.11%, acting in an alternating pattern on the opposite side of the frame (Fig. 11).

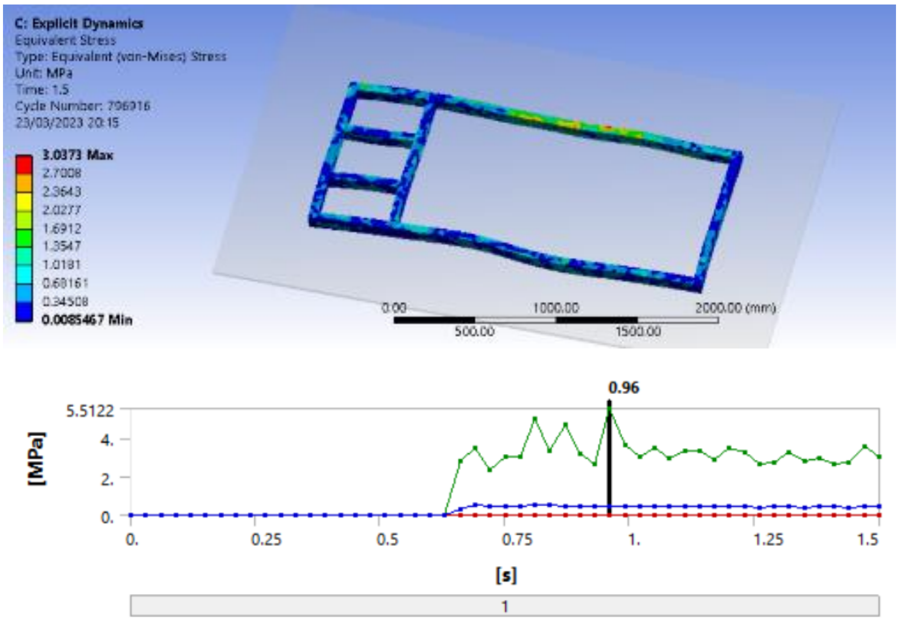


Fig. 10 Maximum equivalent von-Mises stress

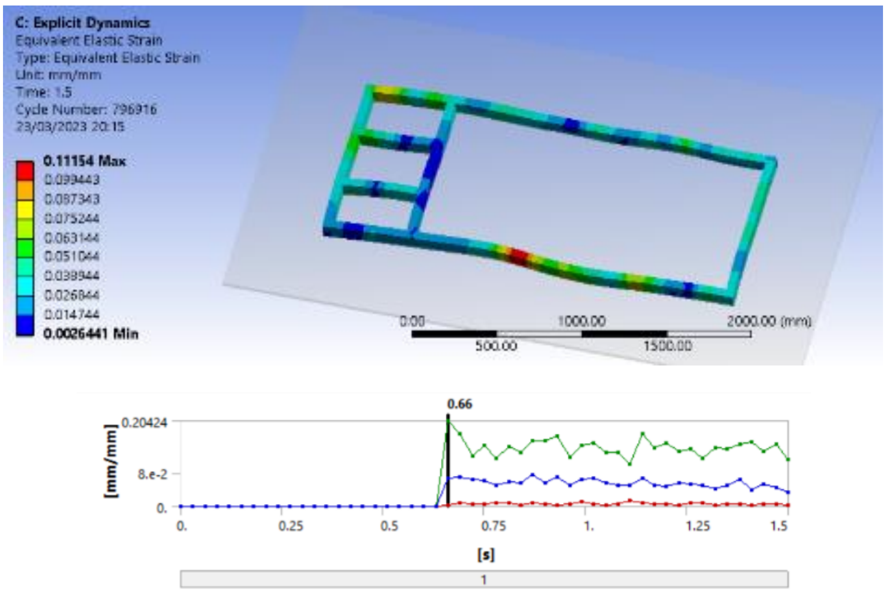


Fig. 11 Equivalent elastic strain

Throughout the simulation the safety factor is below the unit at several points of the model (Fig. 12). Thus, it may be assumed that the material does not withstand the impact loads, and this could lead to cracks occurring in the most peak points. To model the crack and breaking phenomena, additional material properties have to be introduced, most of the information can only be obtained experimentally.

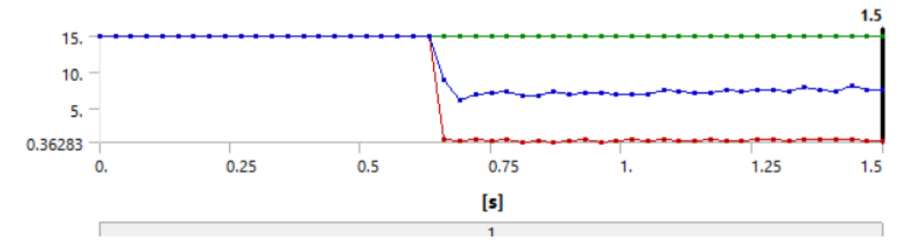


Fig. 12 Safety factor

3. Conclusion

The work has highlighted the pattern of deformation for the wooden frame during a fall and an accidentally impact from the height of 2m at a 15° angle. For the studied robotic cell, the trajectory of the robots handling these frames must be reconsidered, to avoid trajectories that are too high. From this perspective the design of the modular effectors could be improved to ensure sufficient grip of the frames, even in the event of a failure of the pneumatic system.

The novelty of the approach is based on the material model of the pine wood (wood, with orthotropic properties), the analysis be means of explicit dynamics, as well as entire robotic cell for assembling modular wooden panels.

Future work may focus on a different mesh pattern in respect to the hourglass energy to avoid wrong results. The simulation could also be performed in several what if scenarios, considering different heights and angles, to determine the point from which the wooden frame suffer permanent damage during the impact.

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STUDY AND 3D PRINTING OF AN ARTICULATED ARM ROBOT FOR SORTING PHARMACEUTICAL PRODUCTS

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Abstract: The research consists in developing a new system for an industrial robot manipulator with 5 degree of freedom that can sort color boxes using a color system sensor. The main goal of employing these systems is to sort products in the pharmaceutical field. The system can be developed by proposing various algorithms to achive the highest accuracy and precision. Examining, confirming, and naming colors are the typical stages of color perception. To detect a physical situation, sensors and microcontrollers play a crucial part in the automation system.
KEY WORDS: Design, 3D Printing, ANSYS, Witness

1. Introduction

The purpose of the research is to investigate, design, and manufacture a 3D-printed articulated arm automation system for classifying pharmaceutical products. The integration of robotics and 3D printing is an innovative method for improving the precision and efficacy of pharmaceutical classification processes. The approach will involve a comprehensive examination of the requirements and obstacles associated with the sorting of pharmaceutical products.

Using Ansys software one can observe the robot operation in a virtual environment, can determine the functional parameters (speeds, angles, accelerations) that can be further employed in programming and checking the operation of the kinematic joints, to assure a proper work of the robot.

2. State of art

The state of art in robot arms for color sorting incorporates advancements in several areas, as cameras and sensors with increased resolution and sensitivity enable precise color detection and sorting. In addition, sophisticated algorithms and Machine Learning techniques improve the capacity to recognize and distinguish subtle color variations. The end-effector of modern color-sorting robots can manipulate a wide variety of object sizes, dimensions, and materials [1]. They are designed to be adaptable and configurable to accommodate a variety of classification needs, making them suitable for industries such as food processing, recycling, and manufacturing [2].

The pharmaceutical industry handles a vast multitude of products that require precise classification based on specific criteria such as dosage, expiration dates, and packaging variations [3]. Manual classification processes are time-consuming and error-prone, resulting to potential production and distribution bottlenecks in the pharmaceutical industry. Implementing an automated sorting system can considerably boost productivity by decreasing sorting time and ensuring consistent, reliable results.

Based on conceptual design, the embodiment design of the product was perfromed using the following 5 systems (Fig. 1):

- Power supply - is responsible for supplying electrical energy
- Mechanical system - provides a strong and stable support structure.

- Sensor system - it provides the robot with the ability to make decisions based on that information
- Movement system - it is responsible for the robot's movement and manipulation of objects
- Task environment system - it defines the specific tasks and functions that the robot is designed to perform

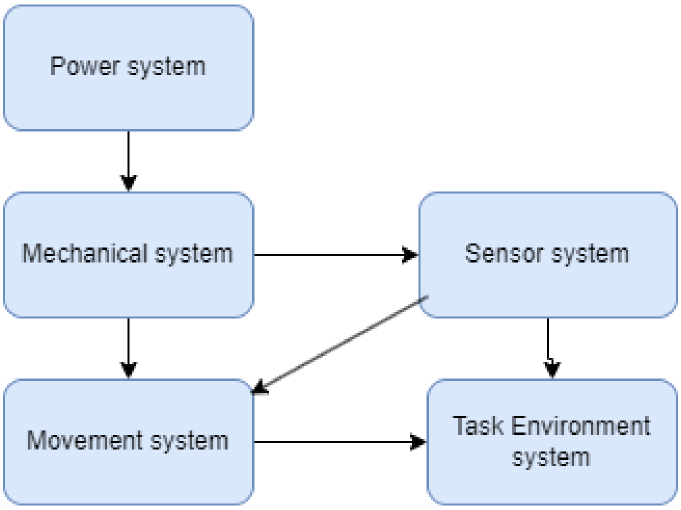


Fig. 1. Conceptual design

The parametric design was performed in Solidworks (Fig. 2). This software was chosen because it is highly efficient and can create a prototype by combining all the parts. It is a 5 degree of freedom Industrial Robot made by 6 parts: Base – has a significant role because provides stability; Waist – is essential because it maintains a balance and conduct specific actions; Arm1 - has the pliability to extend its working range by stretching and bending; Arm2 – because it has the ability to move in different directions and reach objects in different positions; Arm3 - is the connection between the arm and the gripper and is used for the pitch movement; Gripper support and End effector.

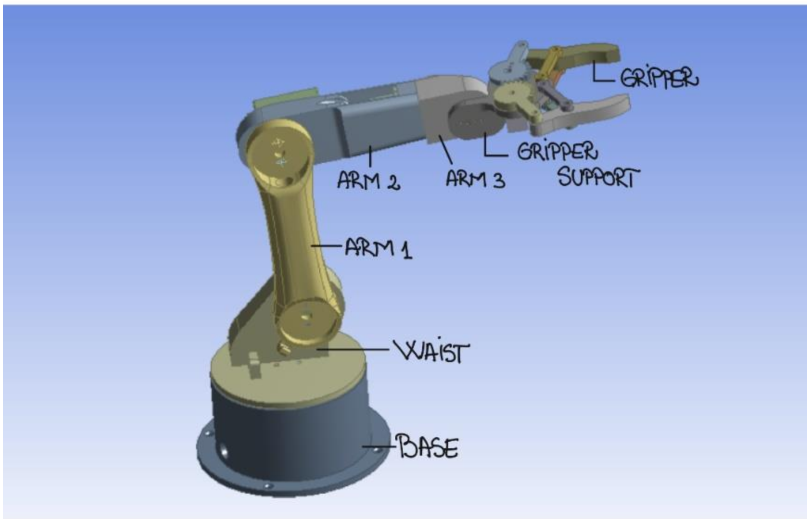


Fig. 2. Robot design in Solidworks

The material that has been employed both in the simulation and in the manufacturing stages of the product is PLA because it enables a high-quality printing, providing a good lamination and creates a clarity and gloss products. During the operations, one can check the behaviour of the materials through action. The characteristics of the material are illustrated in Table 1.

Tabel 1. Material properties

Density	1.28 g/cm3
Young's Modulus	2270 Mpa
Poisson's Modulus	0.35
Bulk Modulus	2.5222E+09 Pa
Shear Modulus	8.4074E+08 Pa
Specific heat	1.8 J/kg*K

Using Ansys simulation environment the constructive solutions were checked. For example stresses, strains and a comparison with robot performances like repeatability and optimization time were done.

The Transient Structural analysis (Fig. 3) proved that the safety factor is 2-2.5, often used in the mechanical field. The stresses are not high, therefore they can not cause problems in terms of structural stability and possible fatigue phenomena. If stability problems occur that means that it is a design problem that has to be solved. When running the simulation the „Stiffness Behavior" of the Arm1 component was set as flexible, to have a visible representation of the stress, strains and displacements during the simulation.

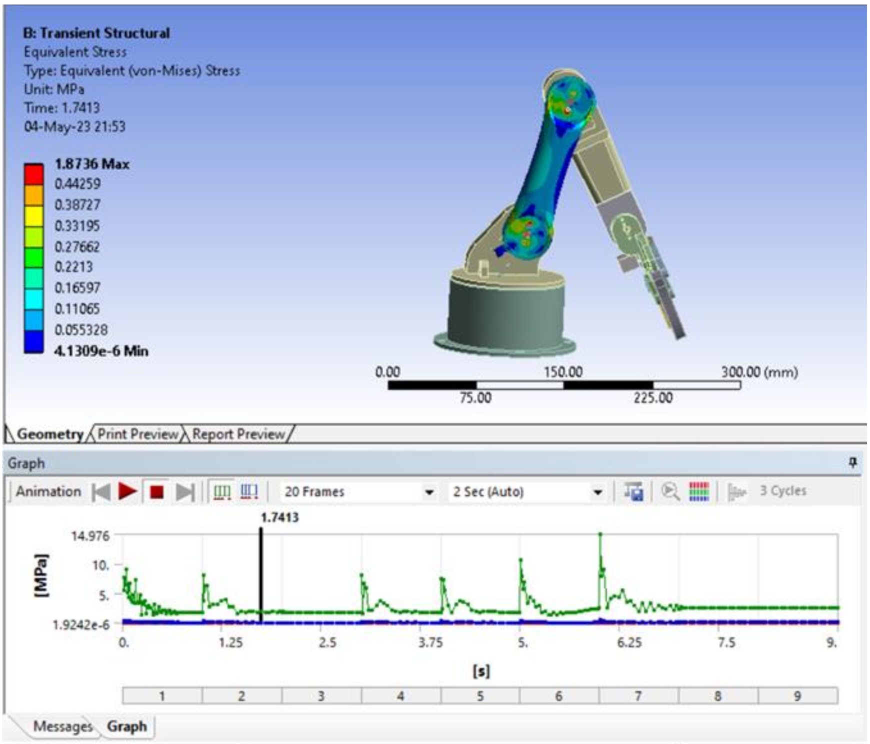


Fig. 3. Transient analysis of the robot

In order to determine the exact angles of action for the servomotors, the simulation environment was accessed (Fig. 4). The defined displacements and movements of the robot where simmilar to the real life behavior of the robot. Four rotational joints were defined, and with the simulation support, all the angles of the robot during operation were tuned with those employed in the programming stage of the robot.

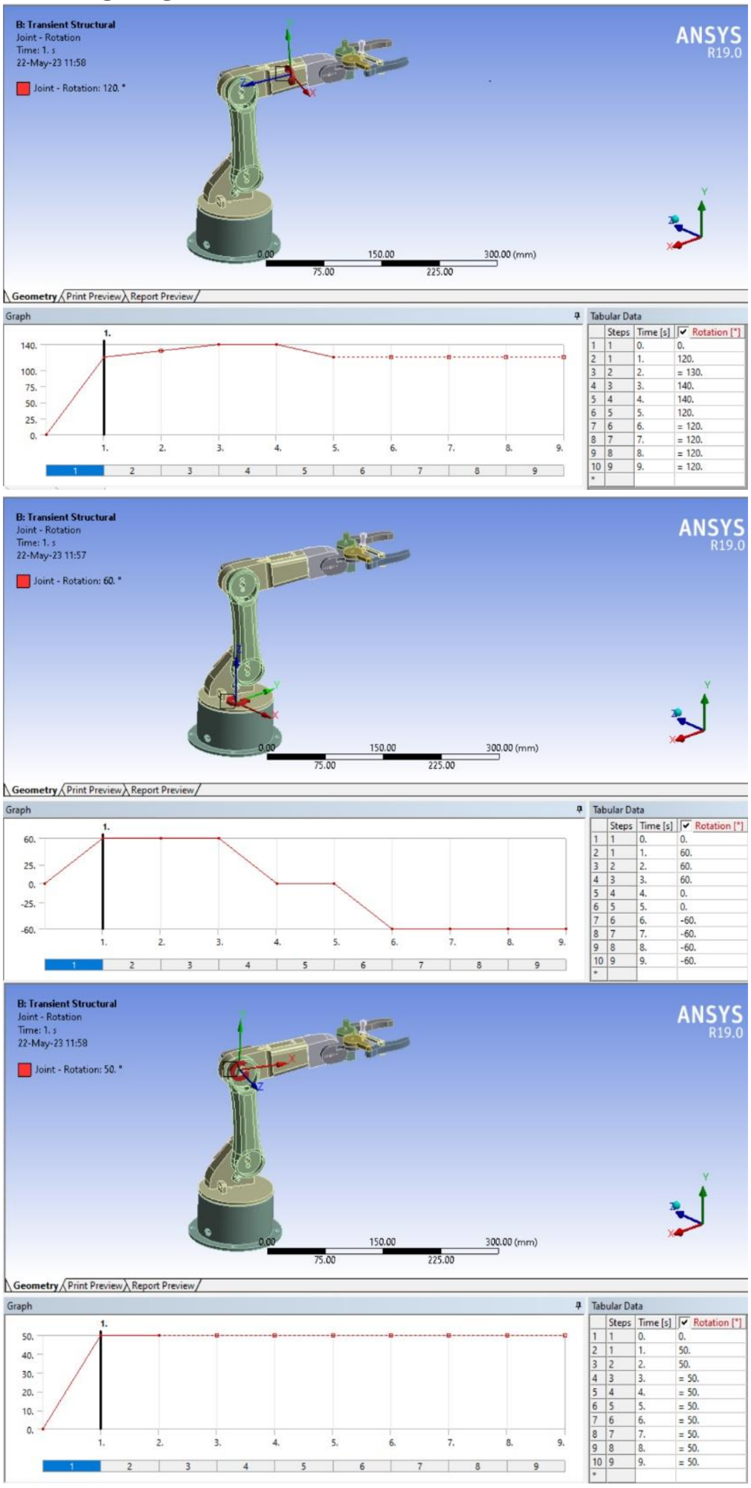


Fig. 4. Rigid Body analysis of the robot

Using Static Structural analysis (Fig. 5) the study proved that when the accelerations in the system are high and the acting forces are maximum, the structural deformability of the robot is small, the assembly is sufficiently rigid and does not affect the positioning accuracy and repeatability.

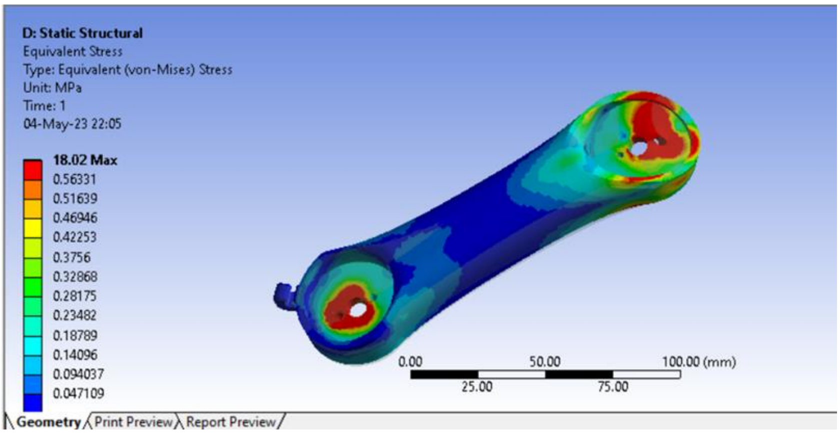


Fig. 5. Static analysis of the robot arm. The equivalent von Mises stress

For manufacturing the robot components Creality Ender 3 Pro printer was employed (Fig. 6), which is suitable for obtaining end product parts by directly importing them form the CAD system or software-created 3D design diagrams, figures and patterns [4]. The software employed to convert the 3D drawings in STP files for the 3D printed parts was CURA. One of the most important settings was to change the Infill Pattern from the Print settings [5]. The Gyroid pattern was chosen, because it provides a cubic symmetry, which in contrast to all other patterns is an almost isotropic structure. This means that it is equally resistant to forces acting from all directions [6]. Because all the pieces of the printed robot have largeg dimensions, this pattern is also useful to make the overall strongest structure.

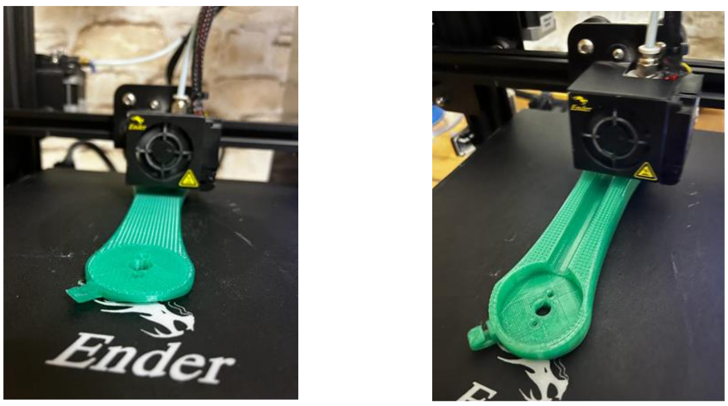


Fig. 6. 3D printed parts using Creality Ender 3 Pro printer

For programming the robot the Arduino UNO board was employed (Fig. 7), connected to five servo motors for the movements (3 are MG996 Servo Motors and 2 are SG90 Servo

Motors). A color sensor was also connected to the Arduino board and Python programming language was chosen to set the robot code.

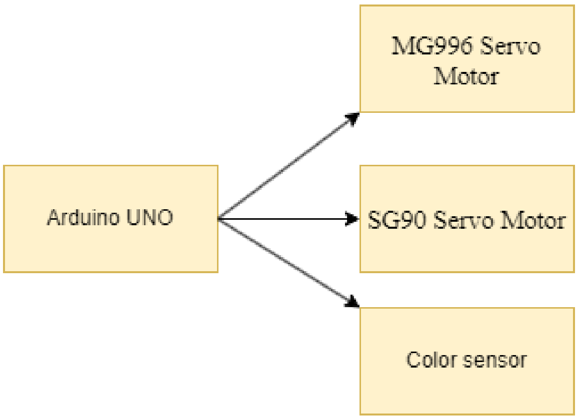
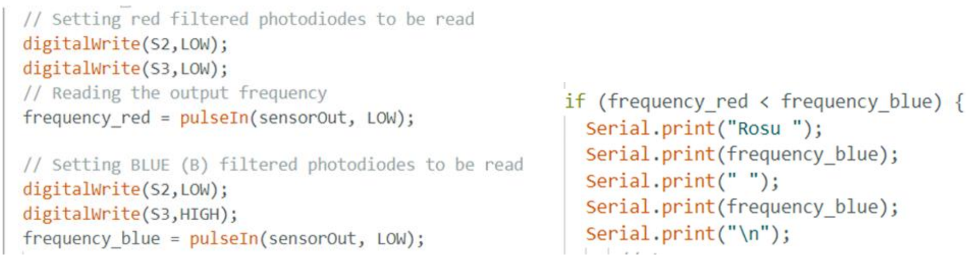


Fig. 7. Connection of the Arduino UNO system to the ServoMotors and the color sensor

An excerpt from the developed code is illustrated in Fig. 8.



```
// Setting red filtered photodiodes to be read
digitalWrite(S2,LOW);
digitalWrite(S3,LOW);
// Reading the output frequency
frequency_red = pulseIn(sensorOut, LOW);

// Setting BLUE (B) filtered photodiodes to be read
digitalWrite(S2,LOW);
digitalWrite(S3,HIGH);
frequency_blue = pulseIn(sensorOut, LOW);
```

```
if (frequency_red < frequency_blue) {
  Serial.print("Rosu ");
  Serial.print(frequency_blue);
  Serial.print(" ");
  Serial.print(frequency_blue);
  Serial.print("\n");
```

Fig. 8. Excerpt from the developed code

6. Conclusion

The research proved that the original robot produced by the 3D printing system provides low manufacturing costs and generates large revenues. It may meet the requirements for a high-quality prototype because of its good and accuracy and stability. Future work will focus on manufacturing additional parts on CNC machines to achive more stability and strength.

The CAE simulation provided the robot operability in a virtual environment and allowed the identification of the structural problems that were solved to increase the robot accuracy and scalability.

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SEISMIC BEHAVIOUR OF THE PALLET RACKS ASSEMBLY

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SUMMARY: The research consists in the simulation of a pallet rack assembly subjected to seismic loads. Since 2012 in Europe all the rules regarding the seismic checks have been updated and are much stricter. These norms are also mandatory even in countries that are not declared dangerous seismic areas. In this context, the shelves of a robotic application must be well dimensioned and made of durable materials.

KEYWORDS: pallet rack, seismic behavior, FEM.

1. Introduction

An assembly of pallet storage racks was employed to determine the seismic behavior, to calculate the maximum displacements during the earthquake, and to check the structural strength. The paper also illustrates how to process the earthquake spectrum for correct stress input. The difficulty of the problem was the lack of noteworthy earthquake spectra available in the studied seismic zone. Under these conditions several analyses were performed in the following variants:

a) Two rack loading arrangements: fully loaded and loaded only on the highest level at full load capacity

b) Three types of dynamic analysis: static, modal, frequency response

c) Processing of a major earthquake spectrum.

The combination of these variants resulted in different runs. The main results are presented and analyzed.

2. Preparation of the computational model

The industrial shelf model employed was first modeled in Catia V5 (Fig.1). Then this assembly was remodeled and simplified with beams in ANSYS - Design Modeler (Fig.2), to which a cross-section for each structural element was assigned (rectangular - crossbars, solid rectangular - "X" bars for stabilization, "C" profile - support posts). The reason for geometric defeaturing is that the discretization can be easily generated and the computation is much faster.

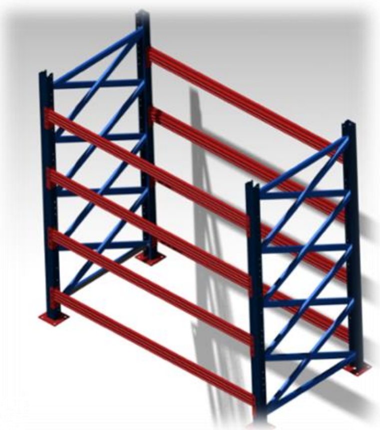


Fig.1

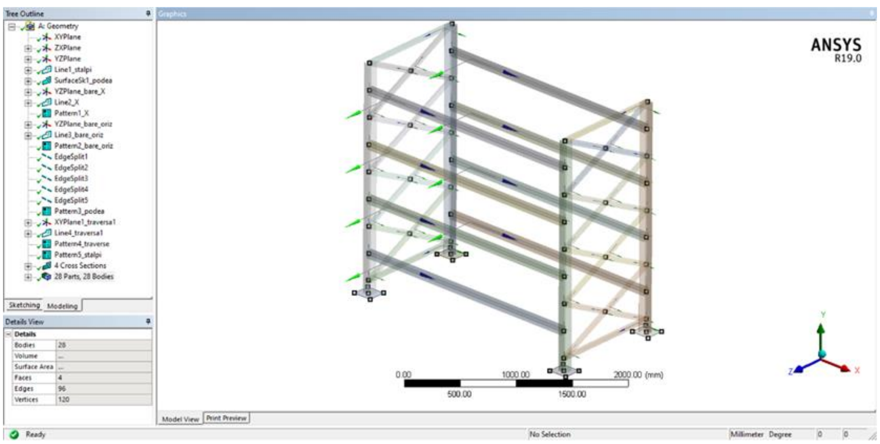


Fig.2

In order to perform a reliable simulation, it is essential to properly define the materials of the components. As such, the material employed was structural steel (Fig. 3):

Outline of Schematic B2, C2, D2: Engineering Data

	A	B	C	D	E
1	Contents of Engineering Data			Source	Description
2	Material				
3	Structural Steel			General_Materials.xml	Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1
*	Click here to add a new material				

Properties of Outline Row 3: Structural Steel

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	7850	kg m^-3
4	Isotropic Secant Coefficient of Thermal Expansion		
6	Isotropic Elasticity		
7	Derive from	Young's Modulus and Poisson's Ratio	
8	Young's Modulus	2E+05	MPa
9	Poisson's Ratio	0.3	
10	Bulk Modulus	1.6667E+11	Pa
11	Shear Modulus	7.6923E+10	Pa
12	Alternating Stress Mean Stress	Tabular	
16	Strain-Life Parameters		
24	Tensile Yield Strength	250	MPa
25	Compressive Yield Strength	250	MPa
26	Tensile Ultimate Strength	460	MPa
27	Compressive Ultimate Strength	0	Pa

Fig.3

3. Initial static structural analysis

A structural analysis was completed to check if the assembly can withstand the weight of 8 pallets, each weighing max. 1500 kg. On each of the 4 shelves there are 2 EUR3 pallets (LxW): 1000 x 1200 mm.

The structure is fixed to the floor by 4 "Fixed Support" surfaces. Forces are applied evenly along the length of the cross beam with "Line pressure" (6000 N/m).

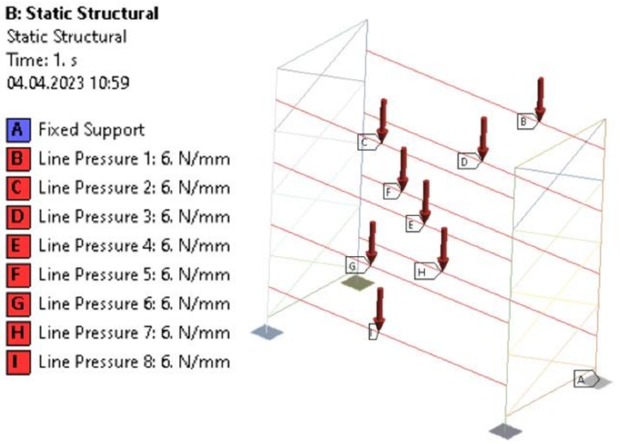


Fig.4

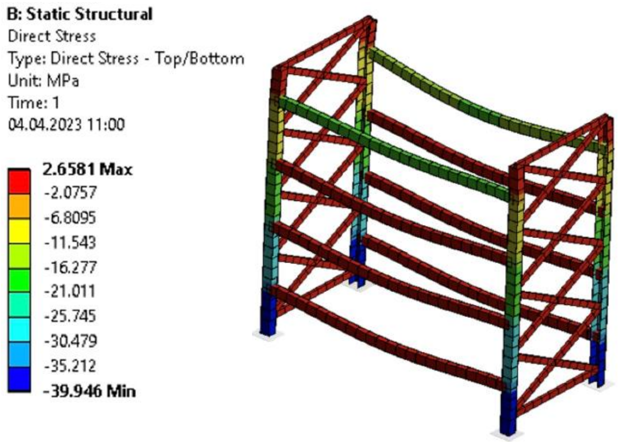


Fig.5

Static structural analysis results:

- Maximum direct stress is |-39.95| MPa = 40 MPa;
- Maximum displacements on the Y-axis (vertical) are 9.83 mm, on the X-axis are 1.91 mm and on the Z-axis are 7.65 mm. The displacements are significant even if the stresses are in the linear elastic range.

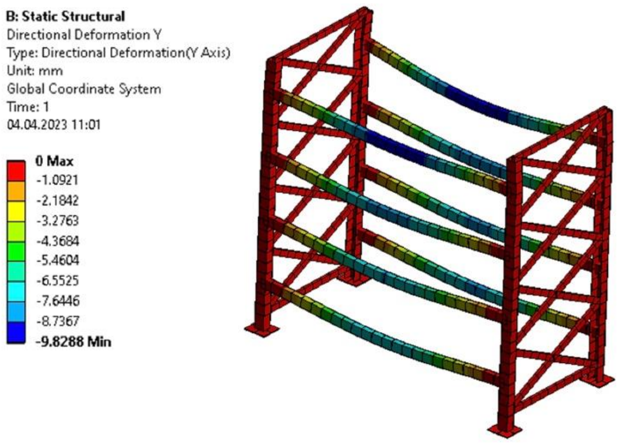


Fig.6

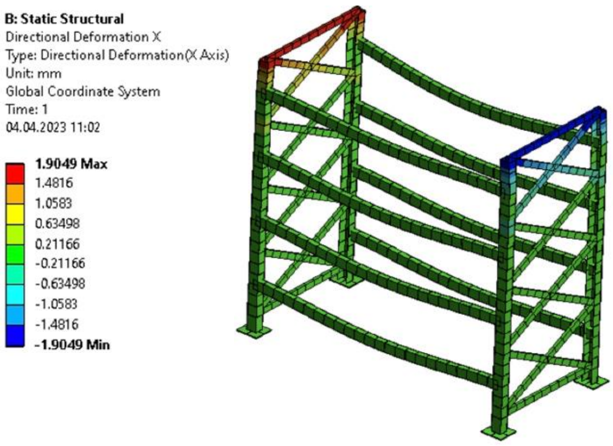


Fig.7

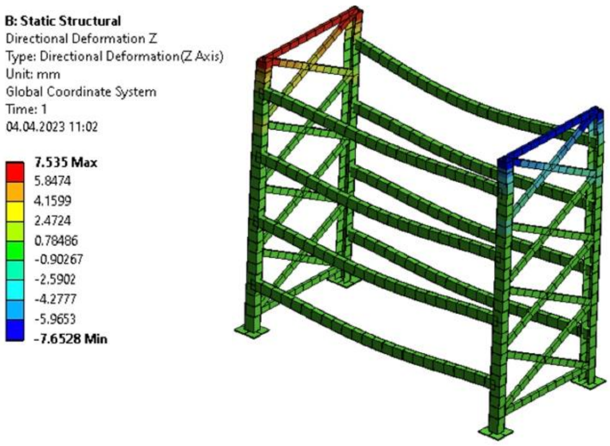


Fig.8

The system of equations solved during this computation:

$$\{F\} = [K] \cdot \{u\} \quad (1)$$

$$\{\varepsilon\} = [B] \cdot \{u\} \quad (2)$$

$$\{\sigma\} = [B] \cdot \{u\} \quad (3)$$

In ANSYS the solution of equation (1) is done by the Wavefront Method [1]. This means that the number of equations that are active at a given time.

$$F_k = \sum_{j=1}^{L} k_j \cdot u_j \quad (4)$$

Where k - is the equation number, j - the column, and L - the total number of equations.

The computation time depends on the square of the average value of the wavefront. Each resolving node is removed from the matrix by the Gauss elimination method. The stiffness matrix expands or contracts after the first or last occurrence of a node on an element. [2]

4. Modal analysis

Modal analysis was employed to determine the dynamic characteristics of structures, namely: natural frequencies and natural mode shapes. In the case of modal analysis, the mathematical formulation of the problem is:

$$[M]\{\ddot{u}\} + [C]\{\dot{u}\} + [K]\{u\} = \{0\} \quad (5)$$

Where [M] is the inertial matrix, [C] is the damping matrix [K] is the stiffness matrix. {F(t)} - the vector of external forces is {0}in this case. The matrices [C] and [M] are obtained by assembling the corresponding stiffness matrix of each finite element.

Modal analysis was done for 20 vibration modes to include a modal mass of 93% (Table 2), taking into account that a seismic computation wil be also performed. Five dominant mode shapes (1, 7, 14, 16, 20) were observed, in which the pallet rack swings in the X and Z directions (Fig.9 and 10), which may influence the response spectrum analysis.

The free vibration were checked for both cases. The frequencies between 10 - 73 Hz for case 2 (the shelf is loaded only on the highest level) are on a wider spectrum than case 1 with frequencies between 12 - 63 Hz (the shelf is fully loaded). The differences can be seen in Table 1. For this reason, the analysis was continued with the most unfavorable case 2.

Table .1

Modes	Case 1	Case 2
	Case 1(Hz)	Case 2(Hz)
1	12.374	10.573
2	20.883	18.082
3	27.581	28.206
4	28.844	29.342
5	30.968	30.703
6	32.256	31.815
7	34.593	32.721
8	36.96	36.749
9	39.056	38.335
10	40.225	38.788
11	42.112	42.143
12	44.574	44.103
13	46.219	45.388
14	46.371	46.381
15	52.38	52.422
16	56.899	61.68
17	57.096	65.093
18	57.367	65.978
19	57.6	66.571
20	62.871	72.803

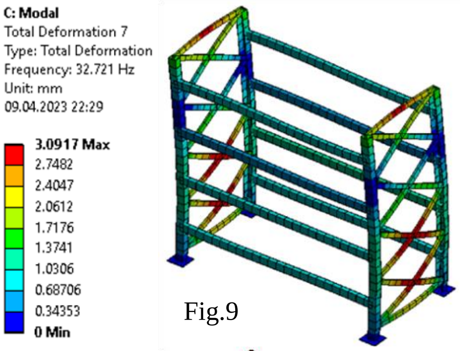
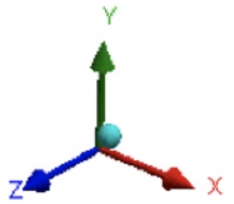


Fig.9



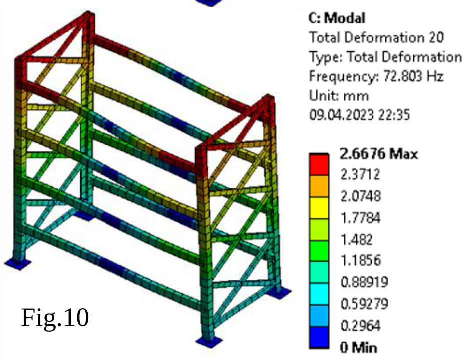


Fig.10

Table nr.2

***** PARTICIPATION FACTOR CALCULATION ***** X DIRECTION

MODE	FREQUENCY	PERIOD	PARTIC.FACTOR	RATIO	EFFECTIVE MASS	CUMULATIVE MASS FRACTION	RATIO EFF.MASS TO TOTAL MASS
1	10.5727	0.94584E-01	0.51371	1.000000	0.263900	0.798697	0.738633
2	18.0821	0.55303E-01	0.44111E-02	0.008587	0.194582E-04	0.798756	0.544617E-04
3	28.2064	0.35453E-01	0.0000	0.000000	0.00000	0.798756	0.00000
4	29.3422	0.34081E-01	0.0000	0.000000	0.00000	0.798756	0.00000
5	30.7035	0.32570E-01	0.0000	0.000000	0.00000	0.798756	0.00000
6	31.8153	0.31431E-01	0.0000	0.000000	0.00000	0.798756	0.00000
7	32.7208	0.30562E-01	0.23443	0.456344	0.549572E-01	0.965084	0.153820
8	36.7488	0.27212E-01	0.0000	0.000000	0.00000	0.965084	0.00000
9	38.3350	0.26086E-01	0.0000	0.000000	0.00000	0.965084	0.00000
10	38.7876	0.25781E-01	0.0000	0.000000	0.00000	0.965084	0.00000
11	42.1431	0.23729E-01	0.0000	0.000000	0.00000	0.965084	0.00000
12	44.1033	0.22674E-01	0.0000	0.000000	0.00000	0.965084	0.00000
13	45.3883	0.22032E-01	0.0000	0.000000	0.00000	0.965084	0.00000
14	46.3812	0.21560E-01	0.91526E-01	0.178165	0.837694E-02	0.990437	0.234463E-01
15	52.4217	0.19076E-01	0.0000	0.000000	0.00000	0.990437	0.00000
16	61.6801	0.16213E-01	-0.38316E-01	0.074587	0.146815E-02	0.994880	0.410922E-02
17	65.0925	0.15363E-01	0.39687E-03	0.000773	0.157502E-06	0.994881	0.440835E-06
18	65.9785	0.15156E-01	-0.41127E-01	0.080058	0.169140E-02	1.00000	0.473408E-02
19	66.5715	0.15021E-01	0.0000	0.000000	0.00000	1.00000	0.00000
20	72.8026	0.13736E-01	-0.39548E-04	0.000077	0.156406E-08	1.00000	0.437767E-08
sum					0.330413		0.924798

5. Characteristics of the earthquake employed as input data

The data used for the analyses was taken from records regarding a surface earthquake that occurred on September 20, 1999 in Taiwan. The magnitude of the earthquake was 7.7 with duration of 59 seconds. The acceleration spectrum in fig.11 includes the stresses on the X, Y, and Z axes, chosen according to the P and S wave directions of the earthquake, namely: V, N, and E. [4] [5].

The damping value was chosen 2% for all spectrums.

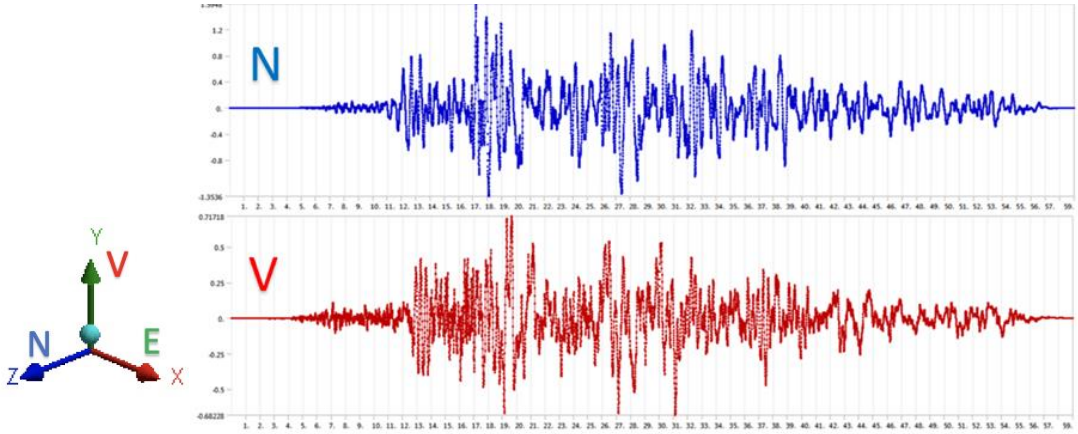


Fig.11 [5]

6. Response spectrum

The response spectrum evaluates the stress and displacements that occur in the assembly during the earthquake. It is useful in the design stage of the assembly due to its computational efficiency and "worst case" approach. An analysis of each vibration mode was performed to find the maximum, then the responses were combined to get the total result. This analysis employs the vibrational characteristics o the structure.

The following results were obtained:

- The cumulative maximum total deflections in case 1 do not exceed 3.1 mm (Fig. 12).

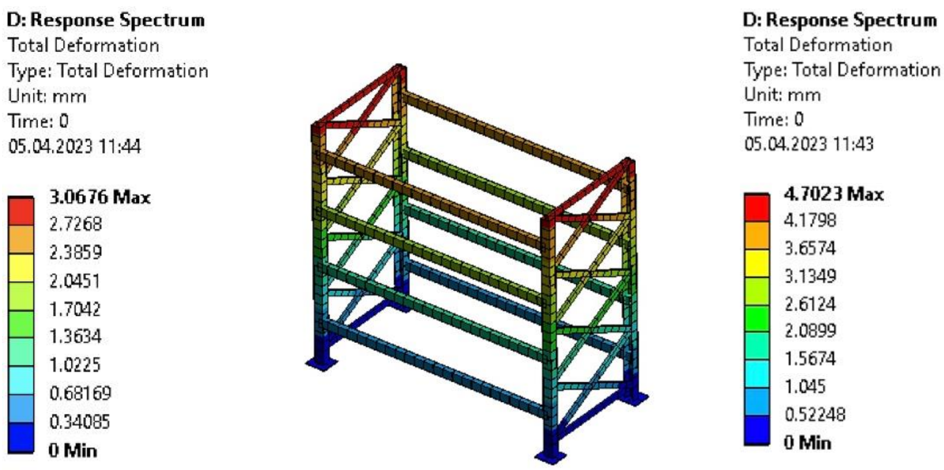


Fig. 12

➢ For the most severe test in case 2, this cumulative distance did not exceed 5 mm (Fig. 13).

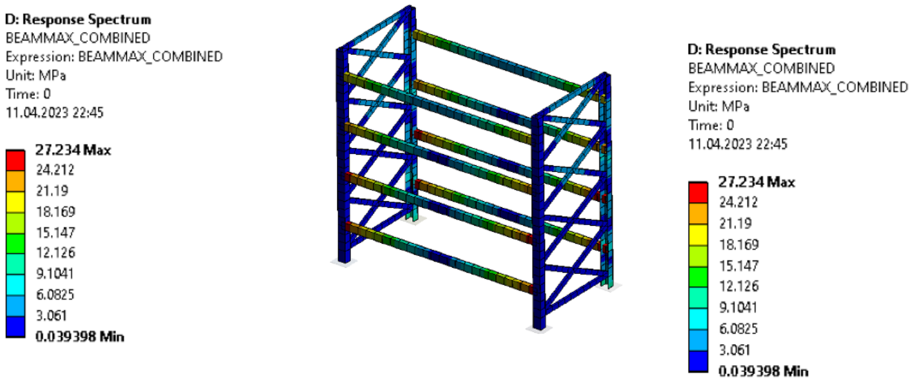
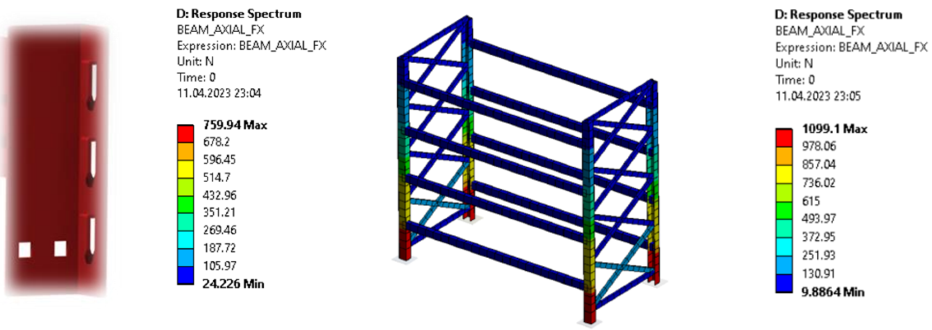


Fig. 13

➢ The axial forces of the beams were also processed to verify the assembly joints for case 1, 2 (Fig. 14).



(6)

Fig. 14

7. Conclusion

The results demonstrated that all the simulations carried out proved important displacements, but do not influence the structural integrity of the assembly. Also, the calculated maximum stress does not register unsafe levels. On the other hand, special attention was paid to the joints in order to check their shear resistance. No problems were found. This was clearly due to the appropriate X structural shape of the rack formed by the reinforcement bars. The assembly can be used both in the industrial field: in factories, warehouses, etc., but also in the public field: in shops, supermarkets.

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ON-CLOUD DATABASE AND 3D PRINTING TECHNOLOGIES FOR SMALL SCALE IFV HATCHES MONITORING SIMULATOR

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ABSTRACT: Nowadays, the industry has developed to such an extent that it is increasingly using automatization. This has forced all industries to scale up automatization processes, reaching military industry as well. This project describes a simulator of hatches operated using an Android application based on transmitting data via a cloud database. It allows portability and is accessible from most hand-held devices. The structure in which all the hardware components were assembled is an armored personnel carrier made by 3D printing that was designed in CAD specialized software.

KEYWORDS: 3D printing, wireless, Android, cloud database, simulation.

1. Introduction

Armored personnel carriers are military vehicles that ensure the transport and distribution of military personnel for the conduct of specific operations. Thus, the military industry has developed significantly, coming up with automated systems that give the personnel a much improved reaction time to possible dangers. Starting from this idea, in this work is presented the small-scale simulation of the operation of the hatches of an armored vehicle made with the help of 3D technology. The monitoring and operation of the access elements in the vehicle is carried out both from the distance and from inside the vehicle unit, this being facilitated by the application of Java, made for devices with Android operating system, which for the actuator it communicates with a mobile device that controls and controls the actuators associated with the hatches, and for the monitoring component it synchronizes with a cloud database.

The main component of automated systems is the microcontroller, an electronic structure designed to control a process or interaction with the outside environment. This is also the main component of the system for monitoring and operating the hatches of an armored vehicle presented as part of this work. The condition of portability of the system and of use both inside and outside involved the use of a remote data exchange technology such as Wi-Fi. The transmission of the drive commands and the visualization of the trap status at the user level are carried out through a Java graphics application, exploited in this work by a mobile device with Android. In order to achieve the kinematics necessary to open and close the hatches, servomotors have been used, often found in the automation applications of robotic vehicles (for example, when operating the control surfaces of aero models) and even of robots in general (for example, in the joints of robotic arms). Actuators turn out to be compatible and suitable for automation applications for several reasons, among them high efficiency, silent operation, high power developed in relation to their size, high torque and inertia ratio, as well as low acquisition costs.

In order to remotely control, mobile devices such as Personal Digital Assistant or mobile phones can connect to the Internet, which offers the possibility of monitoring and auditing all changes in the status of the hatches, changes that occur in the basic of data in the cloud, thus ensuring synchronization with low latency both at the level of the application and at the level of the module for transmitting the commands to the servomotors, called ESP32, also used in this paper.

In order to make the prototype, designed and assembled specialized three-dimensional modeling software (CAD – Computer-Aided Design), such as Onshape [5], 3D FDM (Fused Deposition Modeling) printing technology was used. For optimal printing, the standard printing program was used with small changes in the percentage of filling, the type of filling and the speed of printing. More details of the printing process can be found in Table 1. For 3D printing, PLA (Polylactic acid) material was chosen, having the color of the black filament. In order to fix the hatches and wheels on the frame of the vehicle, threaded rods of 3 mm and 4 mm diameter were used, respectively, provided with self-locking nuts for tightening. For fixing and operating the hatches, equipoises with steel rods coupled to the hatch using a cylindrical coupling were used.

Table 1. 3D printing parameters

Denuwell parameter	Parameter value
Layer height	0.2 mm
Walls	3
Filling	70%
Type of fill	liso
Support	only on the printing table
Type of support	matrix
The temperature of the printing bed	58°C
Filling speed	70 mm/s
Print head temperature	200°C

Thus, the realization of the project involved multidisciplinary, new, efficient technologies that demonstrate the usefulness in the testing and evaluation phases even of the systems on a real scale, by exploiting either the prototyped component (the vehicle and the small-scale hatches) or the software component (the Android monitoring and drive system), while also offering the possibility of distributing the results via the cloud.

2. State

Among the areas of use of microcontrollers, there is also the automated control of equipment. In order to ensure remote data exchange, the literature lists well-known low-energy solutions, such as Wi-Fi or Bluetooth. They can ensure optimal performance in transmitted from the mobile device and receiving command and control command commands at the level of the development module used in this work. The Android operating systems and the Java programming language for the front-end component represent optimal solutions in the early stages of product development, which require minimal computing resources and very short implementation times. Thus, such a system, based on an Android application, a cloud database and a microcontroller with Wi-Fi connection, provides all the premises for carrying out the proposed research work, which will simulate as faithfully as possible the real conditions.

The microcontroller is a compact integrated projection circuit and optimized to perform command and control functions for certain electronic devices. These components easily integrate into the automation project because they do not impose limitations in terms of memories and possibilities of interference; they integrate ideally in applications where the occupied space, the consumption of resources and the price per unit are critical aspects. The three main roles that define microcontrollers are: they receive input signals from sensors, they interconnect with components with Wi-Fi or Bluetooth communication, they store and process actions and instructions, as well as they apply the processed data to other activities/outputs.

The software component of the microcontrollers consists of a code made using the C++ language in the Arduino development environment and the specific libraries available in the language library. The structure of the code is based on embedded libraries that provide basic functionalities. In order to use the functionalities of the available Arduino terminals, each terminal is defined, associating with it the desired functionalities. The loop function is the most important software component, since it describes the main logical part of the circuit, following a series of instructions.

Development boards that offer compatibility with the Arduino compiler give flexibility in electronic applications, since the interaction with buttons, LEDs, motors, video cameras, GPS units is carried out at minimal cost, this fact is also given by the free application offered by the Arduino developers. These advantages led to the formation of a community of users who made contributions to the distribution of knowledge and the development of the Arduino project in general.

In the literature, programmable embedded components and remote communications with low energy resources are often mentioned in the development of robotic platforms. Thus, [1] a solution is presented to make a robot controlled from short distances by means of voice commands. Communication is provided for Bluetooth. The motors used are DC motors. A. M. Abdulazeez presents in [2] the use of robots in different environments, integrating a series of sensors, as well as a camera for understanding the environment. At the same time, the use of mobile devices in their control is brought up. In [3] the RoboCar robot is presented, which integrates a pe-ration fear sensor to transmit the collected data through a Wi-Fi communication. The control of the engines is carried out by tr-a L298n type H-axle. In the control of the robots, it must be taken into account its components of movement (displacement) that can be achieved in different configurations, such as a steering wheel chassis, a 4-wheel chassis of which two are turners or crawlers. Thus, [4] presents a solution to control the movement of long five-deck robots in order to avoid obstacles and move through narrow spaces.

3. Hatch operation and monitoring simulation

The development of the hatch actuation and monitoring simulator consists in the integration of commercially available computing and communication hardware components, as well as the bad realization through mechanical processing and at the 3D printer of structural components. For the command and control of hatches, code sequences implemented in the C++ language are used in the Arduino compiler compatible with the ESP32 development plate.

To ensure connectivity, the ESP32 must be connected to a Wi-Fi network with internet access, and the mobile device must have internet access. This configuration ensures reduced delay access to the cloud database, where trap states ("closed" or "open") are stored. On the mobile device, the developed Android application is installed, providing access to the control and control buttons of the hatches. The 2D graphics of the vehicle (top view) and the color symbolization of the buttons (red – light, green – dark) ensure that the position of the hatches in relation to the vehicle and their statuses are understood.

3.1 Hardware development

The development of the hardware component system of the vehicle's armored vehicle consists of the integration of 5 servomotors cocked in the ESP32 development module. To ensure the control of the system's on/off start/stop, an ON/OFF button was connected on the vehicle housing, which interrupts the power supply from a group of 3 18650 batteries (3.7V rated voltage) connected in series. At the same time, to signal the synchronization of the Android application and the embedded device with the cloud database, a led indicator was connected to one of the terminals of the development board.

Fig. 1 shows the block diagram of the vehicle hardware component from which the main components are distinguished. The ESP-32 development plate transmits the servo motor actuation controls in the form of transformed analog signals from the message received from the mobile application. This assembly is powered by an external current source with a voltage between 9 and 12V. The power supply used consists of 3 Li-Ion batteries of type 18650 of voltage 3.7V and capacity of 3000mAh. They are connected in series to ensure a vehicle supply voltage of 12V.

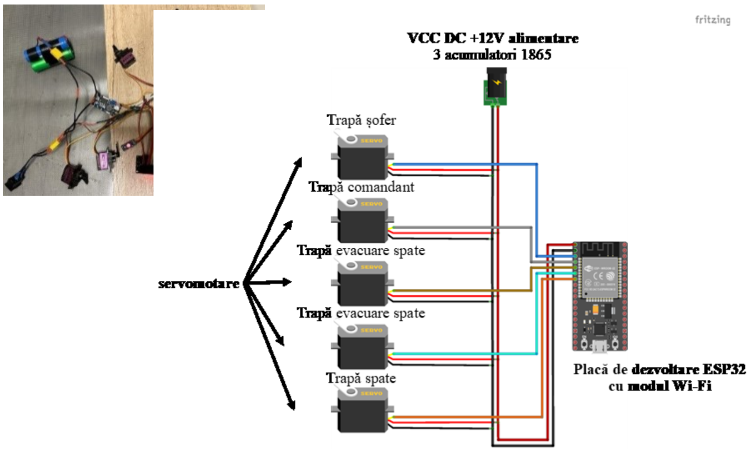


Fig. 1 Block scheme of the hardware component of the system (made using [6]).

The fastening of the components presented above is carried out with the help of 3M dual lock strips on the chassis l vehicle's 3D printed, so as to fit the level of fastening necessary to open/close the hatches. The connection of the hatches with the spin arm of the actuators is made by means of steel rods the length of which is determined in the triangle formed by the point of mounting the spinning arm (coincides with the axis of rotation of the gear wheel of the actuator), the point of attachment of the cylindrical coupling and the tip of the spinning arm, when it is in position "0" (approximately horizontal). For fixing the hatches (see Fig. 2) the threaded rods were used to lie previously by the bore practiced in their body, they also ensure a minimum play of the hatches, but also a rotation with minimal friction in order to avoid overloading the actuators.

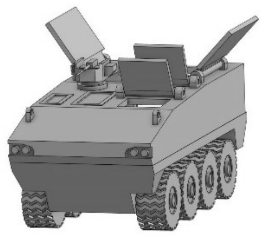
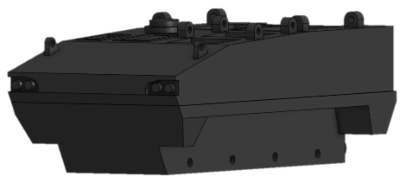
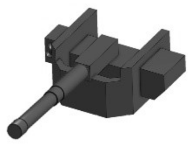
<table>
<tr><td></td><td></td><td colspan="2"></td></tr>
<tr><td>3D Assembly</td><td>Vehicle housing prepared for 3D printing (1x)</td><td colspan="2">Hatch driver and commander ready for 3D printing (2x)</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Rear hatch (1x)</td><td>Rear exhaust hatch (left and right) prepared for 3D printing (2x)</td><td>Turret prepared for 3D printing (1x)</td><td>Wheel prepared for 3D printing (8x)</td></tr>
</table>

Fig. 2 Parts designed 3D and made with the 3D printer.

Regarding the overall dimensions of the system, it was aimed at the realization at the 1:30 scale of an armored personnel carrier, responsible for the transport of people. Considering also the limitations of the cube (length x width x maximum print height) available for printing of the 3D printer, the resulting dimensions are those presented in Table 2, taking into account that the 8 wheels are 40 mm in diameter. The height of the hatches, as well as the minimum dimension of the case on the housing network, was not chosen to be 3 mm, but the choice was made taking into account the performance of the 3D printer, the desired quality of printing, the strength of the parts and the filling characteristics in the process of printer.

Table 2. Overall dimensions of 3D printed parts.

Benchmark	Length [mm]	Width [mm]	Height [mm]
Chassis (housing)	218	100	74.33
Hatch driver and commander	25	24	3
Rear escape hatch	62	34	3
Rear hatch	54.4	46	3
Turret	47.5	29.8	10

3.2 Development of the software component of the system

The software component of the system is made integrated and preloaded in the memory of the ESP32 development peace microcontroller. Fig. 3 shows the block diagram of the software component of the system from which the main 2 components of the source code are distinguished, as follows: the Java application component (Android) whose interface is shown in Fig. 4, the component with the stored and accessed database (SaaS – software as a service) in the cloud, the hatch command and control component (Arduino-based)). The logical flow is schematically represented by the loop marked in yellow, which suggests that between all 3 components there is a logical connection, thus starting from the command and to the actuation at the level of the f final effector, the hatches. In the Body block are defined the design elements of the interface represented by the drive buttons and their positioning. In the Script block, the functions of the triggering buttons are assigned. The *communication* function *has* the lotto ensure the data exchange between the application-database cloud-command and control module, transmitting without noise the communications in the execution area. *The function of actuation and monitoring of the hatches* is provided by the actuators and the controls given by the ESP32 module that initialize and transmit angular controls in order to ensure optimal kinematics. The latter ensures that the hatches are initialed, opened and closed without overloading the actuators, while respecting the construction limits of the housing. The hatches are operated exclusively after consulting the states in the cloud database. Thus, in the Android application loop, the database is interrogated so that the commands do not overlap and successively execute the commands given by pressing the button visually presented through the respective hatches.

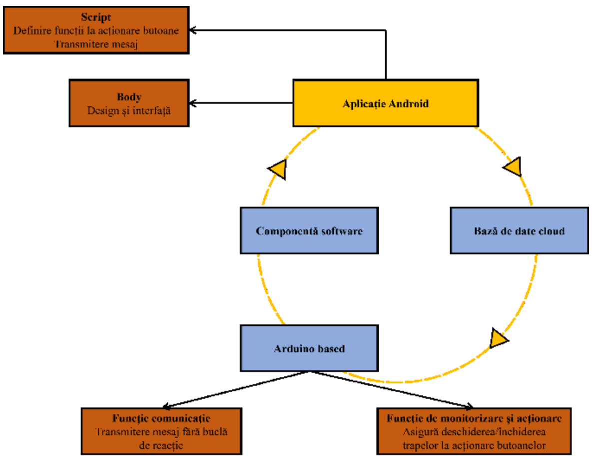


Fig. 3 Block scheme of the software component

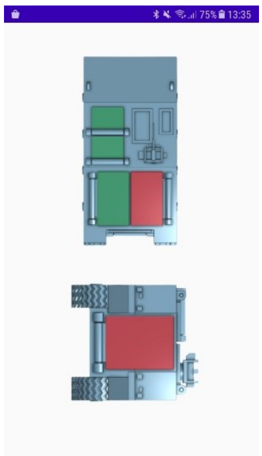


Fig. 4 Android hatch command and control app (close-green, open-red)

In Fig. 5 are presented the defined steps that the robot must follow to meet the requirements imposed by the user in the actual scenario. The steps that lead to the committing in normal parameters of the actuation of the hatches are stimulated by the triggers, which trigger the commands through which the complete execution route is made.

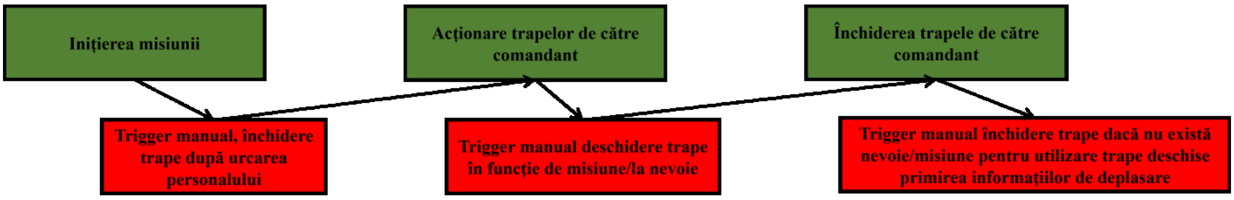


Fig. 5 Command flow and triggers (trigger elements).

4. Conclusions

According to the industrial evolution in which we find ourselves, in the future, projects based on process automation will find even greater applicability in both civilian and military fields, both of which know common elements in the production area. This work was aimed at highlighting the current possibilities of developing an action simulator and monitoring the small-scale hatches of an armored troop transport vehicle. At the same time, the use of the Android application and a cloud database highlights the ease of data distribution and the possibilities of interconnecting the components via Wi-Fi. It is necessary to mention the versatility of the 3D design application, Onshape, and the quality of 3D printing. This multidisciplinary project also involved programming components in the C++ and Java language (Android application). Regarding the project perspectives, it will be carried out to identify prototyping possibilities and other automation system for the initial testing and evaluation of the equipment on a real scale, extending the functionalities of the application already made and the methodology for creating three-dimensional models with low costs, thus improving the production process and the quality and the times in the phase of testing and evaluation.

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PROGRAMMING A COLOR-BASED SORTING SYSTEM AND ITS UTILITY IN THE INDUSTRY

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ABSTRACT: We live in a time covered by technology, and it is not news that it is spreading day by day, from simple objects that we use in everyday life in our homes, to devices that save lives, ships space, and many other revolutionary inventions. The technology we use nowadays is also widespread in the field of machine tools. They are becoming more and more independent through automation and artificial intelligence, evolving so quickly that there is a great possibility that they will replace the human job itself. The equipment used in the machine tool industry provides evidence of reduced productivity costs, optimized processes, and increased efficiency. All in all, automated systems and artificial intelligence bring a great advantage to companies, even if they require greater investment.

KEYWORDS: industrial engineering, technology, robots, efficiency, productivity

1. Introduction

Software and hardware developments in machine tools aim at the principles of Industry 4.0. They continuously enhance their intelligence and communication capabilities, establishing connections with other devices or production lines. In the world of Industry 4.0, this equipment brings significant results, leading to smooth production and processes.

Intelligent manufacturing technology increases efficiency and eliminates weak points within the system. It is characterized by highly interconnected industrial enterprises with advanced knowledge, where all organizations and operating systems are connected. As a result, productivity, sustainability, and economic performance are improved.

2. Project presentation

This research paper presents color sorting equipment used in various industries such as machine tools, food industry, and textile industry. This particular configuration is primarily dedicated to the machine tool industry, specifically in the field of 3D printers. The equipment works with different materials, such as resin, plastic with varying hardness, metal infusion, conductive material, magnetic material, etc. The system described in this paper is designed for sorting filaments with specific hardness but different colors.

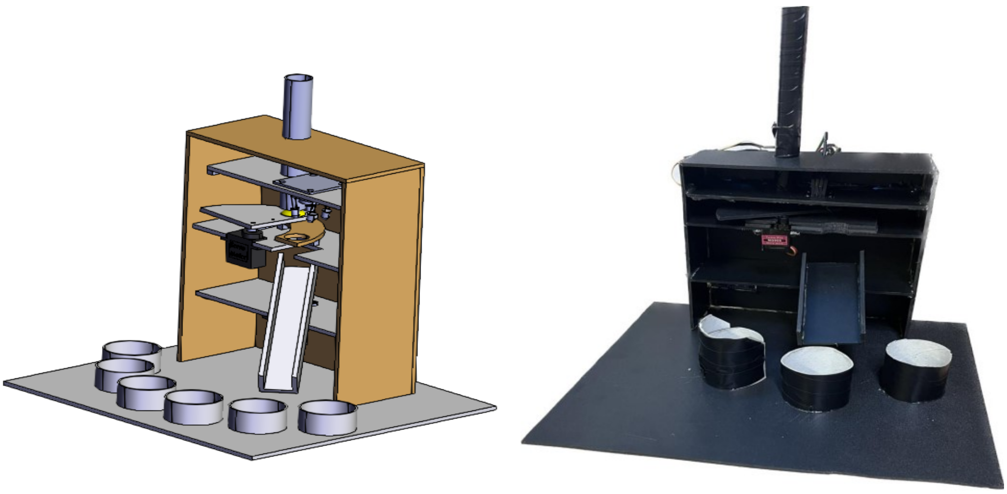

Fig. 1 3D Model and Physical Prototype

With the help of a conveyor, the filament roll reaches the storage container, and the servo takes them one by one, passing them in front of the color sensor. When the sensor detects a different color, the second servo moves the ramp towards the specific color container [1, 3].

3. Design and Connectivity

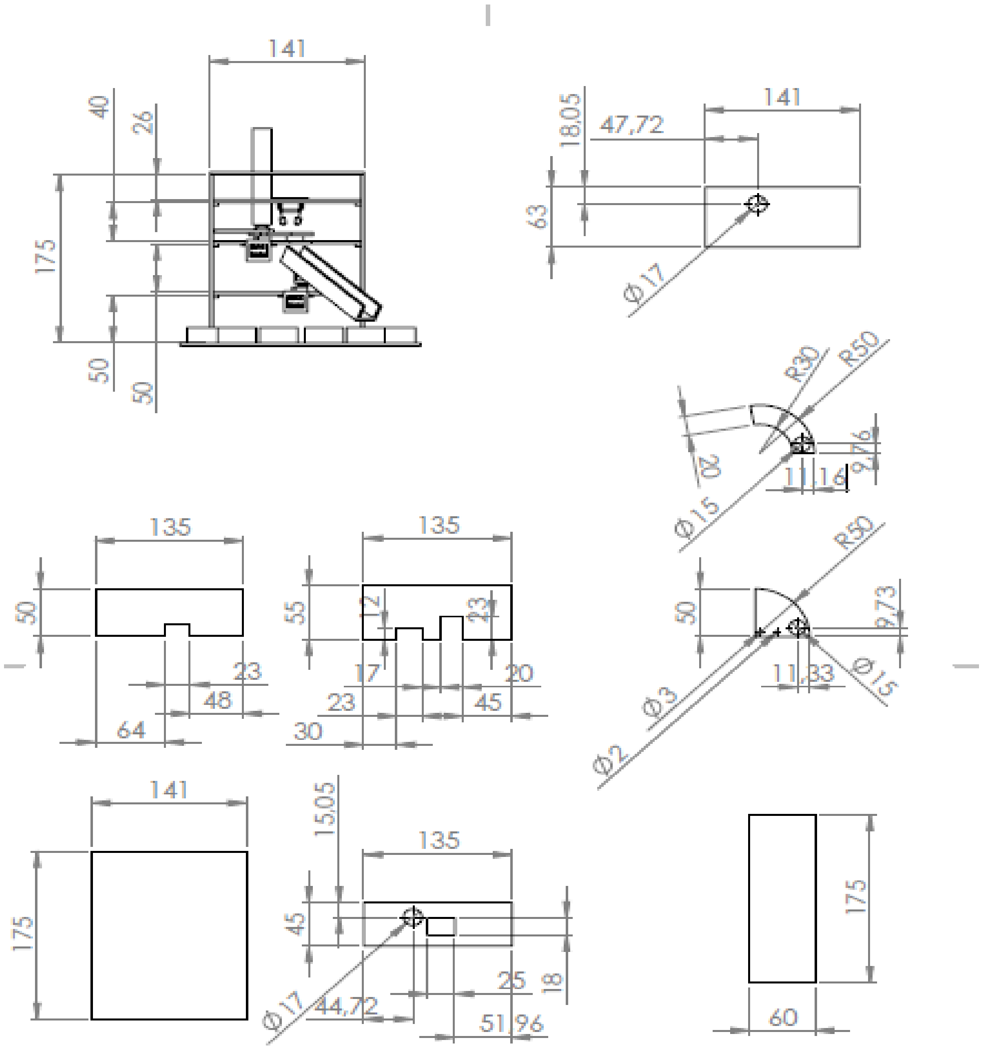

Fig. 1 Technical Drawing of the Parts

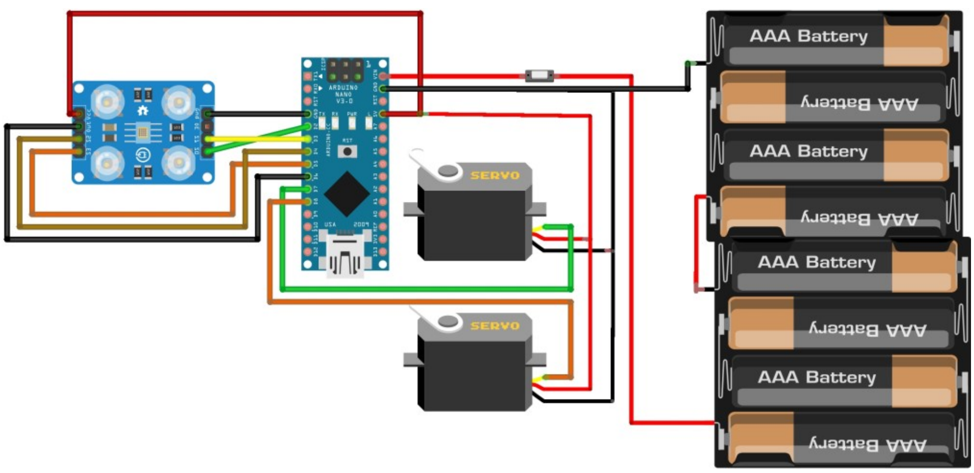

Fig. 2 Connection diagram

4. Advantages

• High Quality: Digitizing processes reduce the risk of human error and failure. This enables process monitoring and performance tracking, leading to increased efficiency and more effective resource utilization.

• Reduced Operational Costs and Predictive Maintenance: Smart factories can anticipate and resolve maintenance issues more rapidly, resulting in reduced equipment repair costs and minimized production disruptions.

• Enhanced Customer Satisfaction: Intelligent manufacturing provides managers with more accurate data and better measurement of key performance indicators, enabling them to serve customers more effectively and meet their requirements in real-time.

• Significant Cost Reductions: Improved access to supply chain and production data and analytics increases forecasting accuracy and reduces losses, contributing to cost reduction through proper demand management.

• Increased Productivity: Autonomous machines communicate with each other, generating vast amounts of data and enabling new analysis scenarios. Real-time insights into production processes help managers adjust efficiency planning and improve productivity.

• Higher Employee Satisfaction: Access to cutting-edge technology can attract and retain new talent. Additionally, modern technology reduces human errors, resulting in employees facing fewer issues related to dissatisfied customers.

• Energy Efficiency: All manufacturers can reduce their carbon footprint by minimizing waste. However, energy-intensive industries stand to gain the most in terms of energy savings, resulting not only in reduced energy waste but also increased product accessibility.

5. Programming/Code

```
int getRosuPW() {
  digitalWrite(S2,LOW);
  digitalWrite(S3,LOW);
  int PW;
  PW = pulseIn(sensorOut, LOW);
  return PW;
}


int getVerdePW() {
  digitalWrite(S2,HIGH);
  digitalWrite(S3,HIGH);
  int PW;
  PW = pulseIn(sensorOut, LOW);
  return PW;
}

int getAlbastruPW() {
  digitalWrite(S2,LOW);
  digitalWrite(S3,HIGH);
  int PW;
  PW = pulseIn(sensorOut, LOW);
return PW;
}
```

Fig. 3 Setting the Sensor for Color Frequencies

```
// Intervalele pentru fiecare culoare

int rosuMin = 14;
int rosuMax = 132;
int verdeMin = 17;
int verdeMax = 169;
int albastruMin = 15;
int albastruMax = 144;


int rosuPW = 0;
int verdePW = 0;
int albastruPW = 0;

int RV;
int GV;
int BV;
int rosuValue;
int verdeValue;
int albastruValue;
int color=0;
```

Fig. 4 Calibration of the Color Sensor

From the entire code, I have attached the most important parts of the program. In Figure 3, we have a set of instructions for each color that sets the frequency. The most crucial element in this equipment is the TCS230 color sensor [2]. It consists of 4 white LEDs directed towards the scanned element and a photodiode that captures the color reflection sent by the light. In Figure 4, we have the intervals for each color. To find the correct minimum and maximum values, we used a white sheet, which allowed the sensor to display the maximum value, and for the minimum value, we used the black color of the casing.

In addition to sorting, we also have two servos that are very useful. The first servo, which takes the elements and passes them in front of the sensor, has two possibilities programmed. When the color of the element is recognized, it sends it to the sorting ramp. The second possibility is when the color is not found, the servo repeats the movement and passes in front of the scanner again. The second servo is responsible for moving the ramp towards the respective color container.

```
  Serial.print("Rosu = ");
  Serial.print(rosuValue);
  Serial.print(" - Verde = ");
  Serial.print(verdeValue);
  Serial.print(" - Albastru = ");
  Serial.println(albastruValue);
delay(500);


  color = readColor();
  delay(10);
  switch (color) {
    case 1:
    bottomServo.write(85);
    break;
    case 2:
    bottomServo.write(105);
    break;
    case 3:
    bottomServo.write(125);
    break;

    case 0:
    break;
  }
  delay(300);
```

Fig. 5 Positions for the Sorting Ramp

6. Conclusions

Industry 4.0 is an industrial paradigm that refers to the digital transformation of production processes and the integration of digital technologies in factories and other industrial units. The term was first used in 2011 in a research project funded by the German government [4]. Since then, the term has been adopted by the international community and is used to describe a new era of smart factories, automated production, and the integration of advanced digital technologies into the manufacturing process. In recent years, the concept of Industry 4.0 has evolved and expanded to include technologies such as the Internet of Things (IoT), artificial intelligence (AI), collaborative robots, augmented reality (AR), and others.

Since the introduction of this industry, productivity has increased by 20%, the production cycle time has been reduced by 45%, documentation volume has decreased by 50%, manufacturing defects have decreased by 18%, and order preparation time has been reduced by 27% [5]. Additionally, it enhances competition among companies, pushing them to raise their quality standards. There are numerous factors that position our country in a very favorable position for transitioning to Industry 4.0. Although there are voices claiming that we cannot make the leap from 2.0 to 4.0, Romania will benefit significantly and attract numerous investments. Automated systems are among the few innovative elements that Industry 4.0 brings.

In conclusion, improving equipment with automated systems is optimal even if their cost is higher. In the future, companies will recover these costs in a very short time.

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- Data acquisition

Regarding data acquisition, Artificial Intelligence allows the collection and organization of information from various sources, such as measurement sensors for temperature, humidity, pressure, vibrations or dimensions. Data sets are stored in the Cloud, facilitating rapid and permanent access to them, both by systems and human resources.

- Data analysis

After data acquisition, analysis takes place, which leads to the efficient operation of systems. Their performance can be studied and corrected whenever necessary, in a timely manner. Thus, data sets can be deepened through analysis and comparison, informing even the human resources in case of need for optimization.

- Intelligent factory automation

After following the first two steps of data collection and interpretation, intelligent factory automation takes place, with reference to parameter control. Thus, through Artificial Intelligence, together with IIoT (Industrial Internet of Things), priority processes can be modified. For example, in the case of a significant increase in demand for a product, robots and digital production systems can be set to modify their manufacturing process, leading to timely market needs satisfaction with minimum effort.

3. Advantages of a smart factory

Fig. 2. The advantages of a smart factory

The implementation of a smart factory leads to high-level connectivity and operational efficiency, bringing with it a series of benefits (see Figure 2), such as:

- Increased productivity

Thanks to advanced technologies, autonomous machines can communicate with each other, making it possible to generate real-time data about production processes, which, once analyzed, contributes to a productivity improvement.

- High quality

By intelligently automating factories, the risk of potential errors is reduced. By monitoring processes and their performance, output is increased and resources are streamlined, ensuring high-quality production. [4]

- Flexibility

Considering that we live in a dynamic era, where changes can occur at any time, smart factories have the ability to adapt to any real-time demands by effectively measuring key production performance indicators. [3]

- Workplace safety

Intelligent factory automation allows human resources to be free from potential risks that can cause accidents. Thus, operators have the ability to focus on value-added tasks, and combine their creativity with the accuracy and speed offered by modern techniques.

- Reduced energy consumption

The efficiency of new production systems ensures reduced energy waste, carbon footprint and waste, thus optimizing energy management and increasing product accessibility. [4]

- Significant cost reductions

Smart factories have the capacity to prevent and quickly resolve potential maintenance issues, leading to reduced equipment repair costs and avoidance of interruptions, maintaining a balance between production and investment. Additionally, 3D simulation programs can mirror the physical world in a virtual world that can include robots, products, and people, all within specific industrial engineering processes. [6]

4. Disadvantages of smart factories

Smart factories can have certain disadvantages, such as:

- High costs

Implementing advanced technologies in the manufacturing process requires a significant investment in intelligent machinery, sensors, and the systems involved, many small and medium-sized enterprises not having the capacity to afford such an investment.

- Dependence on technology

Given that factories are intelligently automated, any small error or lack of synchronization can drastically affect the production system if preventive measures are not taken in this case.

- Security and confidentiality risks

Factories are becoming increasingly dependent on their relationship with the Internet, exposing them to cyberattacks that can lead to the loss or leakage of data that threatens the security of production processes. The data collected may be used to monitor employees or information related to the processes used within the factory.

- Job automation

The role of smart factories is to solve existing and future problems through intelligent automation, which involves an increase in productivity, sustainability, and economic performance, with minimal human assistance. For this reason, there may be a decrease in the workforce, leading to social disruptions.

5. Conclusions

Following the above, we can acknowledge the significant influence of smart factories on industrial engineering due to the latest technologies of Engineering 4.0, such as Artificial Intelligence, IIoT (Industrial Internet of Things), Cloud computing, or HMI (Human Machine Interface). Evolving from the automation stage, implemented about five decades ago, smart factories bring a new vision to the

THE DESIGN OF DIGITAL PRODUCTION SYSTEMS IN THE CONTEXT OF INDUSTRY 4.0

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SUMMARY: The Industry 4.0, also known as the fourth industrial revolution, involves the integration of cyber-physical systems such as IoT, computing, data analytics, robotics, and AI. Digital production systems help companies collect and analyze production data, make better decisions, optimize production processes, reduce downtime, and minimize production errors. The paper aims to present the crucial role of digital production systems in Industry 4.0, examining their benefits and challenges, as well as current trends in this continuously evolving field. The technologies used in Industry 4.0 include IoT, data analytics, smart factories, virtual and augmented reality, and blockchain. While these technologies offer advantages such as increased efficiency, reduced costs, and better user experience, they also come with challenges such as high implementation and maintenance costs, data security concerns, and lack of common standards.

KEYWORDS: Internet of Things, Artificial Intelligence, Blockchain, Smart Factories.

1. Introduction

The term "Industry 4.0" was coined in 2011 by a German project led in collaboration with universities and businesses by the federal government. Specifically, the development of sophisticated production techniques to increase productivity and efficiency in domestic industries was a strategic initiative. [5]

Industry 4.0 represents the fourth industrial revolution, characterized by cyber-physical systems, the Internet of Things (IoT), cloud computing, and artificial intelligence (AI). When it comes to manufacturing companies, Industry 4.0 entails a major transformation of the entire production process by integrating digital technologies and the Internet with conventional industry. [4]

The aim of this paper is to present the crucial role of digital production systems in the context of Industry 4.0, analyzing both their benefits and challenges, as well as current trends in this continuously evolving field.

2. The classification of technologies used in Industry 4.0

The Internet of Things (IoT) is a network of interconnected devices that can collect and share data in real-time without human intervention. These devices are equipped with sensors and communication modules that allow them to communicate with each other and with other internet-connected systems. IoT is used in a variety of fields, from smart homes and transportation to agriculture and manufacturing industries. [7]

Data analysis collected through IoT is the process of extracting and analyzing data collected through IoT devices to gain valuable insights and make informed decisions. This analysis may involve data analysis technologies such as machine learning to identify patterns and trends in the collected data. [7]

The smart factory is a concept that involves the use of digital technologies, such as IoT, data analysis, and automation, to create an efficient and adaptive production environment. The smart factory utilizes data collected from IoT devices to optimize processes and make real-time informed decisions. [6]

Virtual reality and augmented reality are technologies that allow users to interact with the virtual or real environment through digital devices. Virtual reality creates a completely virtual environment, while augmented reality adds digital elements to the real environment. [8]

Blockchain in Industry 4.0 is a technology that enables secure and decentralized storage and sharing of information without the need for an intermediary. Blockchain can be used in Industry 4.0 to create a trusted network among different parties involved in the production process. [9]

3. The advantages and disadvantages of using technologies in Industry 4.0

IoT can improve efficiency by connecting and automating devices, thereby reducing costs and the time required to complete tasks. The real-time monitoring and control offered by IoT can optimize activities and prevent issues, while the enhanced experience and comfort it brings can be beneficial for users. In the business environment, IoT can increase productivity by optimizing processes, but implementing and maintaining IoT technologies can be costly. Additionally, data collected through IoT can be vulnerable to cyber-attacks, so security and data protection are essential. The lack of common standards for IoT implementation can lead to fragmentation and difficulties in interoperability between devices and systems. [7]

Fig. 1 The connection between devices and ”things” (Internet of Things)

The data collected through IoT can improve business decisions and help identify trends and patterns, enabling a better understanding of the market and consumers. Data analysis can assist in eliminating unnecessary or redundant activities, which can increase efficiency. However, implementing and maintaining data analytics systems can be costly. Additionally, managing a large volume of data available through IoT can be challenging, and the use of appropriate analytics technologies is important to effectively manage and utilize the data. [7]

A smart factory can provide increased efficiency through the connection and communication between devices, enabling process automation and reducing time and costs. Furthermore, a smart factory can offer flexibility by quickly adjusting processes and workflows to market changes or customized customer requirements. Improving product quality is possible through real-time quality control, data monitoring, and analysis. The smart factory can reduce delivery time by eliminating unnecessary or redundant activities, optimizing processes, and improving efficiency. Additionally, the smart factory can enhance safety and security by monitoring and controlling critical processes and alerting users in case of issues. However, implementing and maintaining systems in the smart factory can be costly, and the need for specialized workforce training can be challenging. Additionally, smart factories can be vulnerable to cyber-attacks and hacking, so ensuring data security and protection is important. [6]

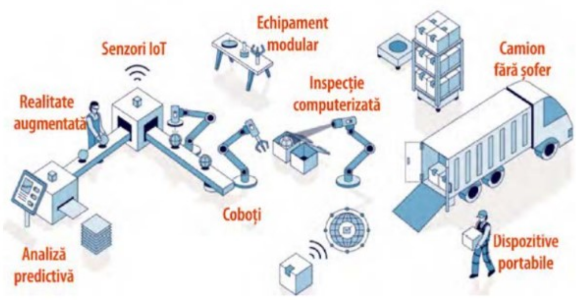

Fig. 2 Smart Factory

Virtual and augmented reality can enhance the user experience and reduce training costs, thereby increasing process efficiency and productivity. However, the implementation and maintenance of these systems can be expensive and require specialized resources. Excessive use of virtual and augmented reality technology can lead to dependency and negatively impact mental and physical health. Additionally, there are technical limitations such as battery capacity and device size that can affect the functioning of these systems. [8]

Fig. 3 Augmented and Virtual Reality

Blockchain is one of the emerging digital technologies that will play a role in the discoveries of the fourth industrial revolution. The use of blockchain technology has the potential to greatly benefit businesses of all sizes by increasing integrity, confidentiality, and openness for the reuse or redistribution of their data. [10]

Customizing products and services for each customer is possible using blockchain technology. However, the scalability issue may arise with many users or transactions, and implementing and maintaining a blockchain system can be complex and costly. Furthermore, the regulation of blockchain technology is still under development, which can lead to uncertainty or confusion in certain jurisdictions. [9]

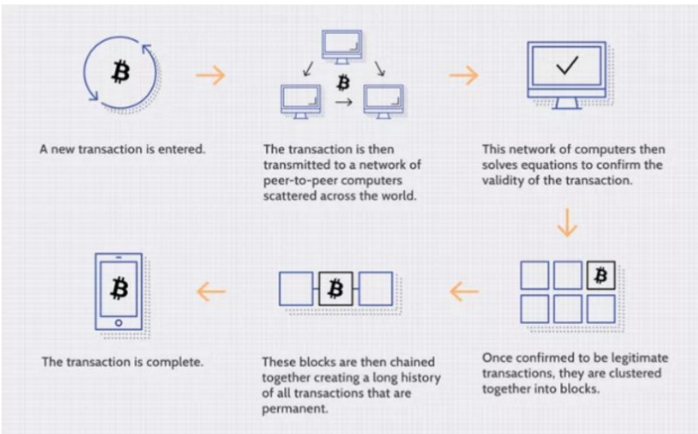

Fig. 4 The process of Blockchain technology

4. Integration of IoT technology in the CNC machining environment

CNC machines are numerically controlled devices that utilize computer programming to control the machining motion and achieve automated production of parts. These machines are used in a wide range of industries and enable the efficient and repeatable production of complex and precise parts. By connecting to the Internet of Things (IoT), CNC machines can be monitored and controlled in real time, thereby enhancing efficiency and productivity. The data collected from CNC machines can be used to optimize production processes and perform maintenance and troubleshooting activities more efficiently.

The Haas VF-2SS is a CNC milling machine manufactured by the American company Haas Automation. This vertical milling machine offers fast and precise milling capability for parts. The VF-2SS is equipped with an advanced control system, a through-spindle coolant system, and an automatic tool changer to ensure efficient and precise production. The machine is used in a wide range of applications, including the production of components for the aerospace industry, automotive industry, and many others. [2]

Fig. 5 Milling machine Haas VF-2SS

Another example of a CNC machine is the "TruLaser 3030," a laser cutting machine produced by the German company TRUMPF. This laser cutting machine offers a cutting capacity of up to 25 mm for a wide range of materials such as stainless steel, aluminum, copper, and many others. The machine is equipped with state-of-the-art technology, including high-precision sensors and advanced control software to ensure precise and fast cutting. The CNC laser cutting machine consists of a powerful laser light source, a system of mirrors and lenses that direct and focus the laser beam, a motion system that controls the position and speed of the machine, and a worktable that supports the material to be cut. Modern CNC laser cutting machines are also equipped with sensors and advanced control software, which enable them to work with high precision and perform complex cuts. [3]

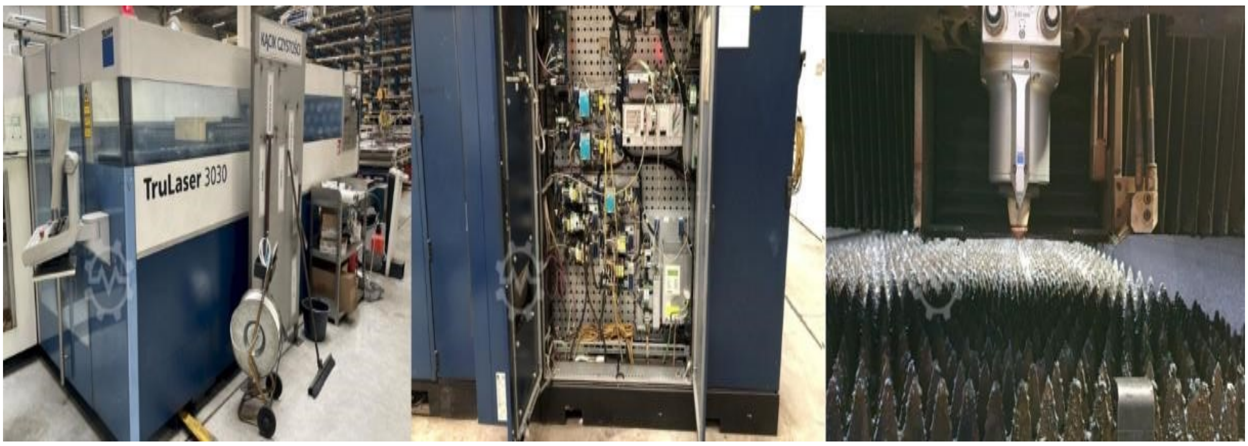

Fig. 6 Laser cutting machine TruLaser 3030

5. Case study

Employees in standard production are supported and assisted by artificial intelligence (AI). With the help of this fast, efficient, and reliable technology, employees are no longer required to manually check model inscriptions against order data, for example, during the final inspection. This task is now handled by AI, which alerts the employee if an inscription is incorrect. This, along with other AI applications, provides significant added value to the BMW Group production system. [1]

Fig. 7 Control panel using Artificial Intelligence

Virtual reality is used to simulate an interactive 3D environment in real time. Technology provides both players and companies with real added value. The international team at the BMW Group Virtual Reality Lab creates virtual spaces and scenarios that can be used to optimize processes and safety, for example, in the logistics sector. [1]

Fig. 8 Control panel that utilizes Artificial Intelligence

Intelligent transport robots are capable of independently transporting components weighing up to 0.5 tons from point A to point B. Once wireless transmitters have determined their location, they can calculate the best route to their destination on their own. Powered by recycled BMW i3 batteries, they have a battery life of approximately eight hours. [1]

Fig. 9 Transport robot

Currently, it is possible for people to work directly with conventional industrial robots on a large scale. Of course, safety is also paramount here: if a person approaches a robot dangerously, the latest safety technology intervenes to stop the movement of the robot's arm. [1]

Fig. 10 Industrial Robot

6. Conclusions

The purpose of this paper is to present the crucial role of digital production systems in the context of Industry 4.0, analyzing both their benefits and challenges, as well as the current trends in this continuously developing field.

This process of automation and interconnection of processes relies on an integrated system of equipment, machines, employees, mobile devices, and IT systems, which can communicate with each other both within and outside the factory.

By utilizing digital production systems, companies can collect and analyze production data, enabling them to make better decisions and optimize production processes. These systems can also help reduce downtime and minimize production errors through continuous monitoring of production processes and quick issue identification.

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THE INFLUENCE OF IMPROVING THE ASSEMBLY PROCESS ON THE ORGANIZATION AND OPERATION OF A PRODUCTION LINE

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ABSTRACT: In this study, I described a first step in the process of improving a manufacturing line. In order to be able to improve an assembly process, it is necessary to analyze it from the point of view of layout, location, but also from the point of view of line times. The main goal is to synchronize jobs to increase productivity

KEY WORDS*: technological system, assembly line, line indicators,evaporator,layout.*

1. Introduction

Usualy, for an Automotive Company, policy is conducted mainly along the following lines: increase the quality of staff, steady decrease in non-quality costs, react better to meet customers requirements and to solve problems, regulatory compliance for the environment, optimizing natural resource consumption, better waste management, prevent any type of pollution, chronic or accidental.

The theme aims to improve the production process of evaporators, by applying specific improvement methods in order to synchronize jobs and increase productivity.

During the study, i have followed:

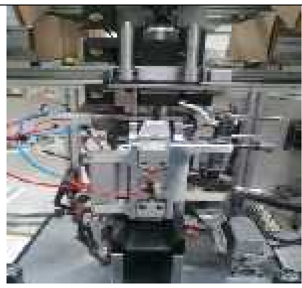
- description of the technological process of assembling the vaporizer;
- presentation of the initial situation of the assembly line;
- presenting the problems identified on the assembly line;

In order to be able to improve the process, it was necessary that the entire assembly line of the evaporator be analyzed. I performed the analysis of the activities and especially their durations in order to highlight the blocking positions.[1]

2. The actual stage

The production process in the case of the evaporator is a technological assembly process that consists of a series of operations that refer to the placement and fixing of component by component in order to obtain evaporators.). The detailed representation of the production process will refer to its structural elements, thus the operations, the time on each operation, the assembled components and the technological system will be specified. This detailing will be done in the form of a centralizing table 1 .[2]

Tabelul 1. Detailing the assembly process

Nr. Operation	*Name of operations / duration [sec]*	*Detailing operations / components to be assembled*	*Photo technological system*
Operation 1	Grease the body inlet-outlet holes 13’’	- automatic grease of holes made with the help of the ‘Glue Depozit’ technological system,	
Operation 2	Crimping inlet-outlet pipes 13’’	- manual assembly of rings, pipes on the lubricated body, - automatic crimping of pipes on the body by pushing using the ‘Pusher’ technological system, - subassembly 1 is obtained	
Operation 3	Assembling the grommet on pipes 14’’	- manual assembly of the grommet on the pipes of subassembly 1 performed with the help of the technological system ‘Grommet Station’ - subassembly 2 is obtained	
Operation 4	Flange, gasket and TXV assembly 17’’	- manual assembly of components: clamp, gaskets and TXV on subassembly 2 made with the help of the technological system ‘TXV Station’ - subassembly 3 is obtained	
Operation 5	Helium test 12’’	- automatic testing of possible liquid leaks from the evaporator performed using the ‘Helium machine’ technological system	

The form of production organization in this case is the organization in flow, on the assembly line, having specialized jobs in order to perform certain assembly operations, the final goal being to obtain evaporators.[3]

1.Evaporator assembly line

The characteristics of this assembly line are:

- the division of the assembly process into 6 approximately equal operations in terms of time, respectively the volume of work;
- the operations are carried out on 6 workstations;
- the grouping of operations on workstations was carried out according to the rhythm of the line;
- job specialization;
- performing two operations on each workplace;
- placement of workplaces in the order imposed by the execution of assembly operations, ensuring one-way movement for the evaporator: greasing, crimping, grommet mounting, clamp, gaskets, TXV, helium testing, final control;
- performing operations continuously, with a free rhythm;
- moving the object of work from one workplace to another is done manually, by the operator.

These types of lines are made up of workplaces where several operators work, performing several operations at several workstations (machines) on a single type of product.

The 'U' shape of the line gives operators the possibility to simultaneously service several machines that represent distinct operations, but this system requires the operator to support the part, space being limited.

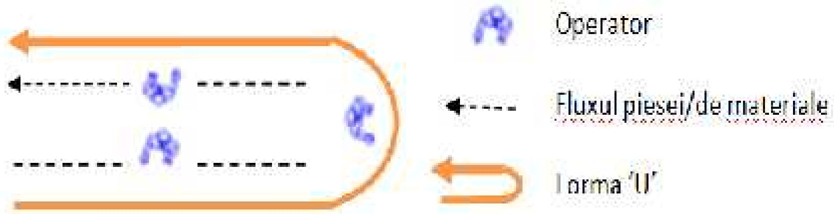


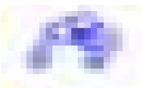
Fig. 2 The shape of the evaporator assembly line

One of the big disadvantages of this type of line is the impossibility of maintaining the continuity of the production process, when certain machines break down or certain materials are missing.

The number of machines on the evaporator assembly line is 6, these being served by only 3 operators in a cycle time of 1.55 min. The basic element of the line is the workstation. The line is delimited by 6 workstations. The correlation between all these elements of the evaporative assembly line is according to the table 2.

Tabelul 2. Work stations

Nr. Operation	***Workstation***	***Job***	***Nr. operators***	***Description of the activities of the work stations***

Operation 1	PL1	LM1		- Grease the body inlet-outlet holes - Crimping inlet-outlet pipes
Operation 2	PL2			
Operation 3	PL3	LM2		- Assembling the grommet on pipes - Flange, gasket and TXV assembly
Operation 4	PL4			
Operation 5	PL5	LM3		- Helium test - Final control
Operation 6	PL6			

The spatial arrangement of the evaporative assembly line is carried out according to figure 5.6, having a total area of 7m*7m, being surrounded by access ways and storage places of the line.

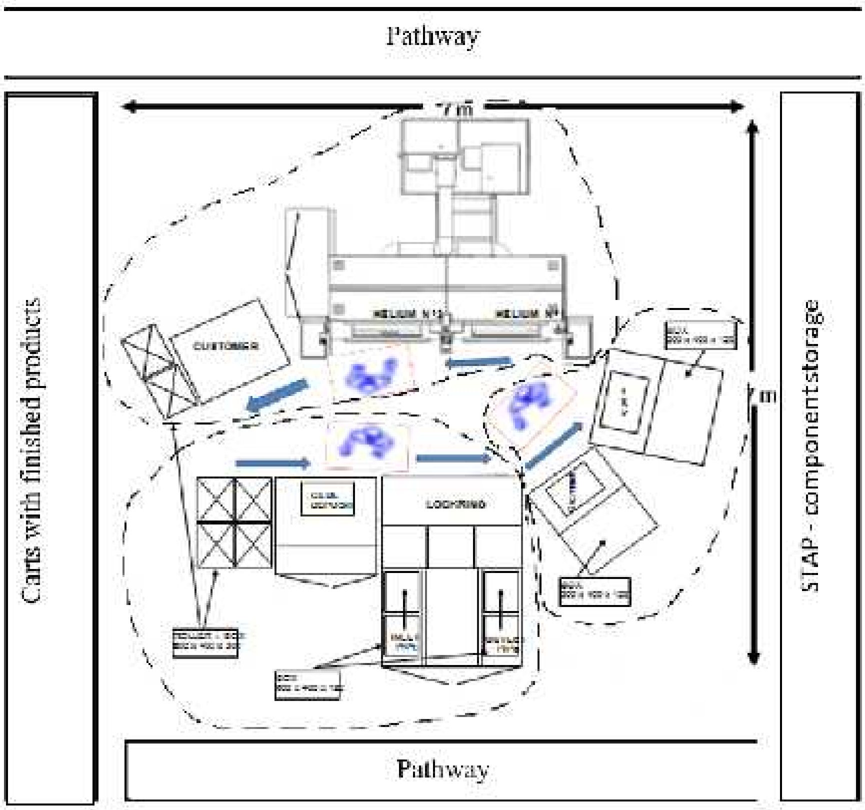


Fig.3 Evaporative assembly line layout

On this assembly line, 4 different types of evaporators can be produced (the difference being given by the way the pipes and TXV are assembled) but the process remains the same.[4]
As can be seen from the layout, the line has 2 storage areas:
- the supply area - represents the area where the necessary components for the supply of the line are stored, figure 5.7 a);

- the finished products storage area - represents the area where the finished products are stored in plastic boxes, figure 5.7 b);


Fig.4 Supply area


Fig 5. Finished products storage area

The supply on the line is done by one of the operators on the line, having its own supply unlike the other lines in the factory where the supply is done by an employee specialized for this activity.

The initial indicators of the evaporative assembly line

The general characterization of the line can be expressed most easily by determining its indicators. These indicators create an overview of the line from a functional point of view, as well as from the point of view of its performance, according to table 3.[5]

Tabelul 3. Line indicators

Functional line indicators										
Nr. of operators	***Td***	***Reg. stops***	***Q***	***T***	***R***	***KOSU***	***CP***	***L***	G_{il}	N_{lml}
[pers.]	***[min/sch]***	***[min]***	***[piece/sch]***	***[min/piece]***	***[piece/min]***	***[min/piece]***	***[piece/an]***	***[m]***	***%***	***[piece/line]***
3	**450**	**30**	**868**	**0.52**	**1.93**	**1.55**	**347400**	**10,5**	**85**	**3**

The determination of these indicators was carried out by applying calculation formulas, taking into account the following aspects:

- number of operators: 3

- available time/sch: 450 min (7.5 h)

- quantity produced/sch: 868

- line rate (Ci) or production rate

$$T = \frac{Tf}{Q} \quad (1)$$

$$T = \frac{450}{868} = 0{,}52\ [min/piece]$$

- the rhythm of the line

$$R = \frac{1}{T} \quad (2)$$

$$R = \frac{1}{0.52} = 1.93\ [buc/piece]$$

-the number of total jobs on the line

$$N_{lml} = \sum N_{lmi} = 3 \quad (3)$$

- line capacity

$$CP = Td*Q = 347400\ [piece/year] \quad (4)$$

$$Td = 200\ working\ days\ \left(\frac{5days}{week} * 2\ work\ shitfs * 4\ weeks * 10\ months\right)$$

- the length of the line

$$L = (N_{lml} \times d)/2 \quad (5)$$

$$L = (N_{lml} \times d)/2 = 3*7/2 = 10{,}5\ [m]$$

-KOSU

$$KOSU = (Nr_{op}*td)/Q \quad (6)$$

$$KOSU = (3*450)/868 = 1{,}55\ [min/piece]$$

As a general conclusion, a maximum of 868 evaporators are assembled per shift, in an effective working time of 450 minutes (7.5 hours). The 6 operations are performed at 3 workstations, each operated by one operator (3 operators in total). The time interval at which a piece/initial cycle of the line is completed is 31 seconds (0.52 minutes).
The annual capacity has been calculated taking into account the time reserved for maintenance and the factory's annual shutdowns (holidays, etc.).

Problems identified on the assembly line

The time on each job can be represented with the help of the diagram:

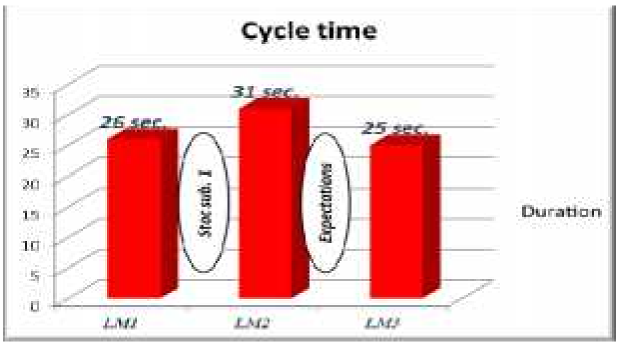


Fig.6 Job-time representation

The following problems were identified with the help of the diagram:
-a storage space needs to be created between workstation 1 and workstation 2, as the cycle time of LM1 (the greasing and crimping operation - 26 seconds) is smaller than that of LM2 (the grommet and TXV installation operation - 31 seconds).
-there is an intermediate storage space created between the two workstations with a maximum capacity of 200 products, as shown in figure 5.9. The maximum stock of pieces that can appear between the two workstations is 170 pieces, which is calculated as the difference between the total number of sub-assemblies that can be produced at LM2 (1038 sub-assemblies) and the total number of pieces that can be assembled at LM1 (868 sub-assemblies).

Fig.7 Intermediate subassembly storage space

-this intermediate storage space is considered an obstacle for operators when they need to move within the assembly line;
-as indicated in the diagram, there is a waiting period between workstations 2 and 3 during which the operator supplies components to the other stations, completes logistics forms, etc.;
-there are periods when the daily capacity of the evaporator assembly line is not sufficient compared to the firm order given by the customer, considering the maximum number of pieces per day (868 pieces).

3. Conclusion

As a general conclusion, following the analysis of the diagram, it was observed that an improvement of the assembly line is necessary from the point of view of the time lost between the workstations and the operations performed. In order to be able to improve an assembly process, it is necessary to analyze it from the point of view of layout, location, but also from the point of view of line times. The main goal is to synchronize jobs to increase productivity. Automated processes are expected to increase productivity and reduce error rates within the production line. Workers in such production lines have to adapt quickly to rapidly changing working conditions and at the same time, training and learning time should be minimized[2].

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IMPROVING A PLASTICS INJECTION PROCESS BY USING AN EFFICIENT PRODUCTION MANAGEMENT SYSTEM

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ABSTRACT: In the actual automotive industry context, in order to remain competitive on the market, all companies are constantly looking for solutions and tools to help increase productivity and improve the production process. The operational optimization through continuous improvement is the solution of this need. The paper describes how an injection process can be improved by implementing an MES- Manufacturing Execution System. This system provides visibility on process indicators, key data that reflect the operational performance. Through continuous monitoring and measurement of indicators, directions for continuous improvement can be addressed. MES Systems offer also a number of short and long-term benefits including reduced time, higher production volumes, improved yields, lower operating costs, increased compliance.

Keywords: Improvement; injection process; indicators; MES.

1. Introduction:

Optimizing the production process is an essential aspect in all the companies. The processes are becoming more complex, the requirements are more varied and in order to fulfill them, it is necessary to improve each step in the process.

Automatic control and permanent monitoring of the process allow access to essential data that must be analyzed in order to obtain favorable results and to improve production efficiency. Analysis of process data leads to a clear image of the aspects that need to be improved.

The profitability of companies is built more and more starting from the reduction of losses. Currently, most production processes are automatically controlled and monitored, which contributes to the identification of inefficient or repetitive processes, the correct analysis of process components and the search for optimization solutions.

Production management involves planning, coordinating, monitoring, administration, and judgment about the inputs and outcomes of a production process.

An extremely important foundation for process optimization is data analysis, perhaps even in real time that allows managers to understand changing conditions, system flow and how the system, process or line can be used to increase productivity. Companies must use this information to improve the production process or system.

MES (Manufacturing Execution System) is a software system intended for factories, which manages and controls the entire production process, from placing the order to obtaining the finished product, with the aim of optimizing all activities and resources in the production process.

The system provides real-time information on the status of each order, on which machine it is, at which stage in the production process, on machine parameters or on availability, performance, productivity and quality indicators. This solution helps to collect, measure and analyze the most important production performance indicators in a factory, to generate reports for efficiency analysis, anytime during the production process.

Such software has direct electronic connections to the planning system and control systems, collects and provides information and direction within the production activities thus proving an innovative industrial solution in the field.

2. The actual stage

There are many definitions for MES but they are all focused on the same direction: production improvement through the efficient management of all stages and the collection and analysis of real data from the process: "Manufacturing execution systems (MES) are computerized systems used in manufacturing to track and document the transformation of raw materials to finished goods. MES provides information that helps manufacturing decision-makers understand how current conditions on the plant floor can be optimized to improve production output."[1]

"A Manufacturing Execution System (MES) is a dynamic information system that drives effective execution of manufacturing operations. Using current and accurate data, MES guides, triggers and reports on plant activities as events occur. The MES set of functions manages production operations from the point of order release into manufacturing to the point of product delivery into finished goods. MES provides mission critical information about production activities to others across the organization and supply chain via bi-directional communication." [2]

With the help of this solution, managers can: permanently access the current situation of the machines in the entire factory; create an optimal production plan taking into account the situation of the machines and the tact; track in real time all machine stops, cycle times, speeds, production capacity utilization; calculate the OEE indicator based on data collected in real time from each machine.

The key factor of informed decisions, at the executive level, are the quality/performance indicators. Knowing and improving indicators can lead to increases in productivity by improving the use of equipment and increasing discipline in production. "An industry contains numerous types of equipment and processes that are a challenge to control and maintain in order to achieve highest performance and profit for the plant. Key performance indicators (KPIs) are fundamental in measuring the performance and its progress. KPIs can provide information about the performance in different areas such as energy, raw-material, control & operation, maintenance, planning & scheduling, product quality, inventory, safety, etc." [3]

The indicators provide specific information measured at a precise moment; they provide the image of the evolution and anticipation of the performance of an organization. Performance indicators allow performance measurement for each action taken, in order to achieve a proposed objective. They are therefore quantitative data, which measure the efficiency or effectiveness of a precise action. "Today, only modern Manufacturing Execution Systems (MES) offer real-time applications. They generate current as well as historic mappings of production facilities and thus they can be used as basis for optimizations." [4]

An organization can only effectively improve what it can measure and compare. By implementing and using a Manufacturing Execution System the most important indicators can be available anytime and for any period. "Manufacturing Execution Systems (MES) play a key role in the factory of the future" [5].

For the plastic injection process analyzed, the most important indicators are: availability, performance, quality and OEE. Others important indicators for this process are: down-time rate, scrap rate, cycle time deviation.

Further, I described the main indicators of the injection process together with the calculation method for each indicator and, in order to exemplify the way in which the MES system calculate the indicators and offers visibility on production data, I extracted and presented the main indicators results obtained in the first 3 months of 2023 year, for 8 injection machines.

3. Injection process indicators

3.1. AVAILABILITY (uptime)

Machine Availability in the context of the manufacturing industry- also referred to as uptime- is the first of the three key performance indicators that are taken into account for the calculation of the OEE. It takes into consideration all of the events that could have interrupted planned production time, whenever it has been stopped for a significant period of time.

The availability refers to the production time and indicates the percentage of time of actual production during the loading time. This performance indicator is therefore based on the time duration of the production.

Losses in effectiveness due to non-production during the loading time are called availability losses.

The formula for calculating this indicator is:

$$Availability\ (in\ \%) = \frac{production\ time}{loading\ time} \times 100 \qquad (1)$$

Machine Availability is presented in a percentage form and is measured by analyzing all of the equipment on the factory floor's uptime, which refers to the amount of time it takes machines to conduct their work (run time), and dividing it by the maximum time it would be available if there were no downtime for repair or unplanned maintenance. And in order to capture the actual availability, it's important to highlight each instance of downtime, whether planned or unplanned.

Loading time (operation time during the period under observation) = calendar time minus generally production -free times (weekends, plant holidays) minus scheduled availability gaps (shift changeovers etc.) minus order-independent scheduled down-times (maintenance etc.)

Production time = scheduled loading time minus order-contingent non-production times (machine set-up, calibration etc.) minus unscheduled down-times (malfunction, equipment breakdown, no staff, no material etc.)

3.2. PERFORMANCE (productivity, process rate)

The performance- also referred to as productivity or process rate- is the second of the three key performance indicators that are taken into account for the calculation of the OEE.

The performance refers to the production quantity and indicates the percentage of quantity produced, based on the quantity that theoretically could have been produced during the production time. This performance indicator is therefore based on the speed of the production, measured as a percentage of its designed speed, during the actual production time. In contrast, losses in effectiveness from unscheduled down-times (that is, from a reduced production time, as opposed to a reduced production speed) are taken into account in the availability.

Losses in effectiveness due to reduced production speed are called performance losses or speed losses.

$$Performance\ (in\ \%) = \frac{produced\ quantity}{target\ quantity} \times 100 \qquad (2)$$

Produced quantity = total produced quantity (yield + scrap)

Target quantity (order) = Target yield for the order

3.3. QUALITY (first pass yield)

The quality- also referred to as first pass yield- is the third of the three performance indicators that are taken into account for the calculation of the OEE.

The quality refers to the production quantity and indicates the percentage of yield in the total quantity produced. This performance indicator is therefore based on the quality of the production. Losses in effectiveness due to poor quality are called quality losses.

$$Quality\ (in\ \%) = \frac{yield\ quantity}{produced\ quantity} \times 100 \qquad (3)$$

$$= \frac{yield\ quantity}{yield + scrap} \times 100 \qquad (4)$$

3.4. Overall Equipment Effectiveness (OEE)

Fig 1. OEE indicator components.

OEE (Overall Equipment Effectiveness) is the gold standard for measuring manufacturing productivity. Simply put it identifies the percentage of manufacturing time that is truly productive. An OEE score of 100% means that the factory produces only good parts, as fast as possible, with no stop time. In the language of OEE that means 100% Quality (only Good Parts), 100% Performance (as fast as possible), and 100% Availability (no Stop Time).

Measuring OEE is a manufacturing best practice. By measuring OEE and the underlying losses, management obtains important insights on how to systematically improve the manufacturing process. OEE is the single best metric for identifying losses, benchmarking progress, and improving the productivity of manufacturing equipment.

The OEE is a measure for the effectiveness of single machines or whole plants; it measures the relation of produced yield to the theoretically possible yield during the loading time. The OEE incorporates effectiveness losses due to (insufficient) duration, speed and quality of the manufacturing process.

$$OEE\ (in\ \%) = \frac{availability}{100} \times \frac{performance}{100} \times \frac{quality}{100} \times 100 \qquad (5)$$

The 3 major indicators that are taken into account when calculating the OEE and described above, are briefly presented in the figures below:

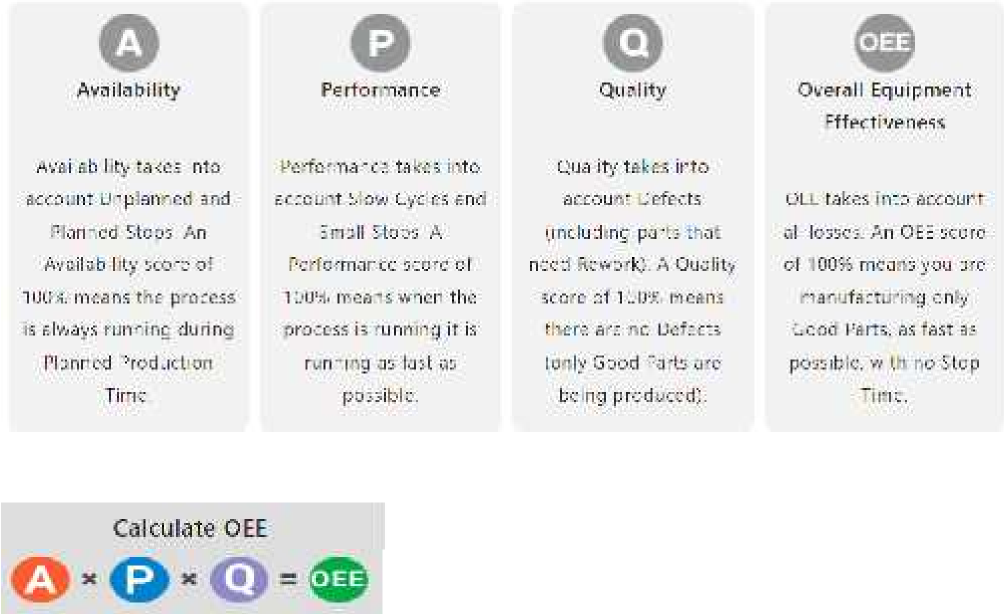

Fig. 2. OEE calculation formula

For the chosen period and machines, the results are presented below:

OEE machines

Timespan	from 01/01/2023 until 03/31/2023 (Shift Timespan from 01/01/2023 00.00.00 until 03/31/2023 08.00.00)
Machines	M1; M2; M3; M4; M5; M6; M7; M8;
Shift types	Eary shift-not in use; Productie pe weekend : Late shift-not in use; Night shift-not in use; L-V ora 08h00-16h00; L-V ora 16h00-00h00; L-V ora 00h00-08h00; Extra shift-not in use;
Downtime reason	According to masterdata

Device	Availability	Performance rate	Quality rate	OEE
M1	70 %	97 %	98 %	67 %
M2	85 %	100 %	99 %	85 %
M3	85 %	99 %	99 %	84 %
M4	91 %	98 %	98 %	88 %
M5	88 %	100 %	99 %	87 %
M6	84 %	100 %	99 %	84 %
M7	89 %	100 %	100 %	90 %
M8	87 %	81 %	99 %	70 %

Fig 3. Values for 3 months- 8 injection machines

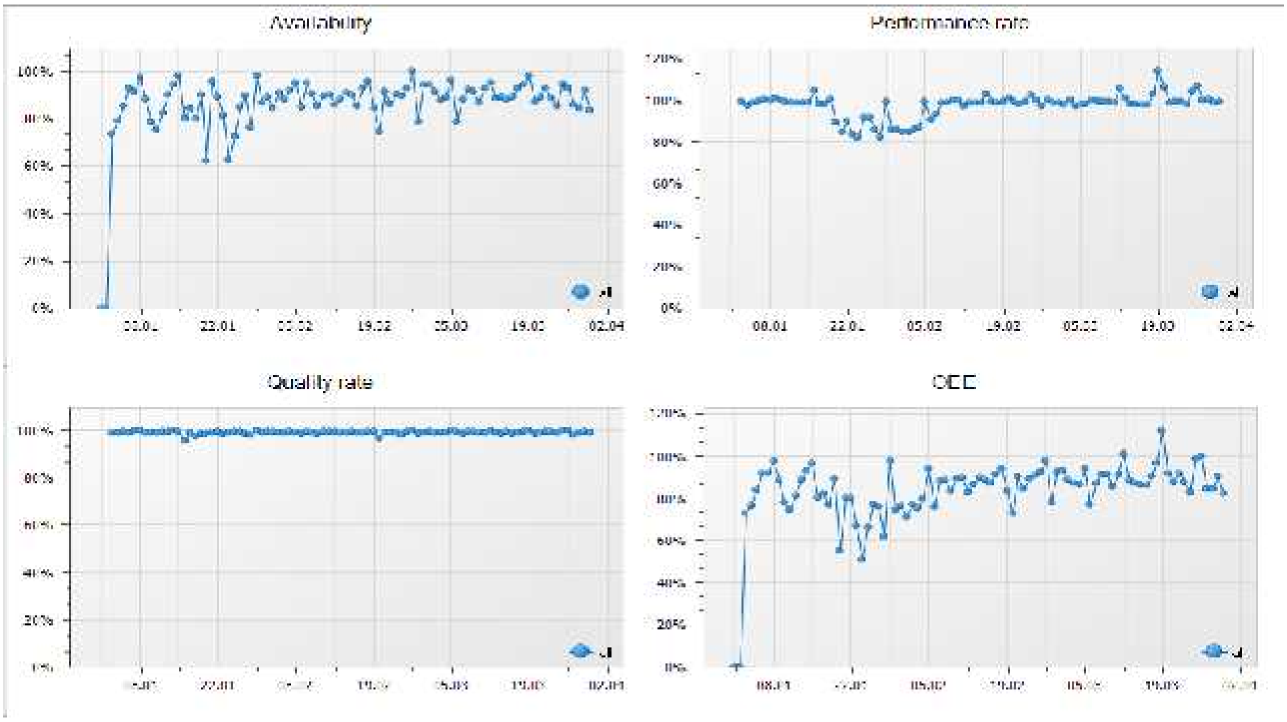

Fig 4. Values/each day

These indicators are automatically calculated by the MES system and can be available for one machine, for several machines or for the entire chain of injection machines at any time and for any period.

An ideal process, equipment, or system would operate at: 100% uptime, 100% capacity, and 100% proper parts quality. However, in real life, this situation is rarely encountered. The difference between the ideal situation and the current one is due to losses. If there is a gap between the daily production process and the ideal situation, the analysis must focus on this gap and find ways to overcome it. Losses can be classified into 3 main categories: non-functioning losses, speed losses and quality losses.

3.5. DOWN-TIME RATE

The down-time rate refers to the loading time and indicates the percentage of unscheduled down-times during the scheduled production time.
The down-time rate measures the availability losses.

$$Down - time\ rate\ (in\ \%) = \frac{non - production\ time}{loading\ time} \times 100 = 100 - availability \quad (6)$$

Non-production time= order-contigent non-production times + unscheduled down-times= loading time- production time.

If the various down-time reasons are assigned a resource type, the down-time rates can be calculated for each resource type individually.

3.6. SCRAP RATE (reject rate, defect production rate)

The scrap rate refers to the total production quantity and indicates the percentage of bad or defect products in the total quantity produced. The scrap rate measures the quality losses.

$$Scrap\,rate\ (in\,\%) = \frac{scrap\ quantity}{produced\ quantity} \times 100 = 100 - quality \qquad (7)$$

3.7. CYCLE TIME DEVIATION

The cycle time deviation refers to the target cycle time; it could reach a maximum of plus 100 percent (in the theoretical case the actual cycle time was zero) and can take any negative value.

$$Cycle\ time\ deviation\ (in\,\%) = \left(1 - \frac{actual\ cycle\ time}{target\ cycle\ time}\right) \times 100 \qquad (8)$$

If the actual cycle time is shorter than the target value (that means the production is running faster than planned) the deviation value is positive. If the actual cycle time exceeds the target cycle time (that means that the production is running slower than designed), the deviation value turns negative. An actual cycle time that is 50 percent longer than the target cycle time means that the cycle time deviation is minus 50 percent. An actual cycle time of twice the target cycle time results in a deviation value of minus 100 percent.

4. Conclusions

Machine monitoring was adopted in this era of smart technology to rise above competitors with optimal control. With real-time monitoring, the management can instantly detect when the machines or equipment are running, when they are abruptly stopped due to issues, and in which way they are exactly used. Reducing errors saves money, access to data keeps the team in the know, and complete transparency of the operations increase team morale. Real-time Machine Monitoring empowers manufacturers by gathering relevant data that helps them perfect overall production and ensure a fully productive time.

Manufacturing optimization is the result of a deep analysis of the entire process, analysis that can only be achieved using clear and real, quantifiable data. These data can be collected with the help of production control and management systems like MES.

This interactive tool helps management to act promptly and efficiently in case of any situation encountered in production. Thus, resources are used at maximum capacity, processes are accelerated, elimination of dead times or production stoppages is favored. Monitoring is easily and permanently carried out over the entire process, from sourcing to product delivery. Process optimization thus leads to cost optimization and increased process performance.

Reducing costs by optimizing resources is a requirement that modern manufacturing companies must face today in order to better survive in a world in continuous digitalization.

Production execution systems as MES thus play a key role in the factory of the future.

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INVENTORY OPTIMIZATION IN THE AUTOMOTIVE INDUSTRY

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Abstract: The "Inventory optimization in the automotive industry", theme wants to prove that an efficient inventory management is a strategic segment that is not limited to individual actions and does not refer to a single level of management. Demand forecasting, storage policies and replenishment activities are the basic techniques for stock optimization. Every aspect is crucial to ensure that the right stock is in the right places at the right time for all the companies.

***KEY WORDS**: stock, automotive, optimization, distance from suppliers, automatic synchronization, management, flow, efficient ordering, stock tracking*

Introduction

The main objective is to implement a new method of synchronous supply of workstations in order to reduce buffer stocks and therefore manufacturing costs.

The project itself consisted of continuous process improvement and took place in several stages within a well-defined timeframe.

To achieve this objective, the following steps were taken:

- ✓ assessment of the current way of supplying parts;
- ✓ understanding how the labelling, ground storage, manufacturing sequence reconstruction and trolley loading process works;
- ✓ management and tracking of indicators: cycle time, part change time, total of diversities, productivity, etc.;
- ✓ defining the maximum number of days of existing stock

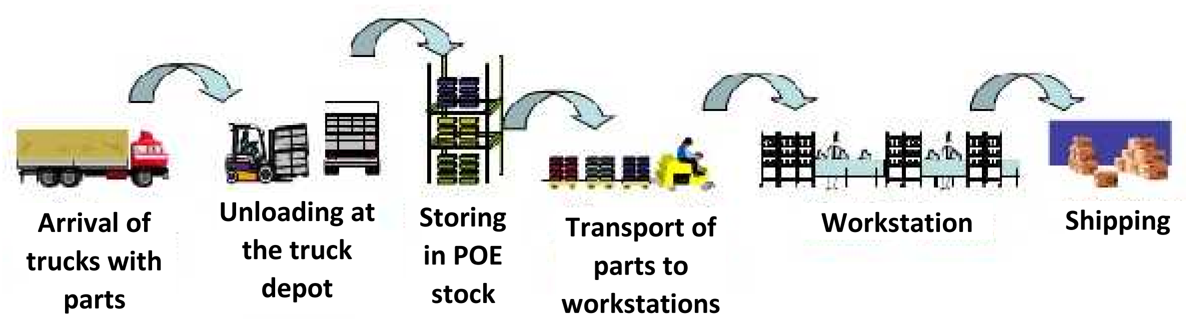

Fig.1.1 General flow of materials

The Logistics Service ensures all tasks related to the supply of parts at the head of the line in sufficient quantity.

The workshop covers all the internal activities of the assembly process, i.e., all the activities that add value to the product. The transfer of parts within the line is the responsibility of manufacturing.

* POE-parts of external origin.

2. The actual stage

This study describes the detailed functioning of the supply, storage and distribution process in the workstations for the seating collections.

Throughout the entire process, the vehicle assembly line is supplied in optimum time. The process contains several operations as shown in the layout diagram, these being:

1. the scanning operation
2. the labelling operation
3. the intermediate storage operation
4. the loading onto rolling bases operation.

In the scanning operation, the logistics operator checks all the parts that have newly entered the flow and, using a special gun, reads the bar codes on each individual package.

In the labelling operation, the same logistics operator prints and affixes the factory labels for the previously scanned parts. This operation is carried out in the same cell performed by one operator.

In the intermediate storage operation, the parts are stored according to the manufacturing sequence in order to send the appropriate parts for assembly to the assembly line.

Another logistics operator, with the help of a forklift, picks up the parts from the storage area and places them in the vicinity of the loading line on a rolling base for transport to the workstation.

Fig.2.1 Packaging with label

Another logistics operator, with the help of a forklift, picks up the parts from the storage area and places them in the vicinity of the loading line on a rolling base for transport to the workstation.

The packages must be arranged in a line so that operators can load them ergonomically and have a clear view of the labels.

During the loading operation onto the rolling bases, the parts are taken from the supplier's packaging and placed according to the manufacturing sequence and therefore to the customer's order on special trolleys for outdoor transportation to the workstation in another building (figure 3.5).

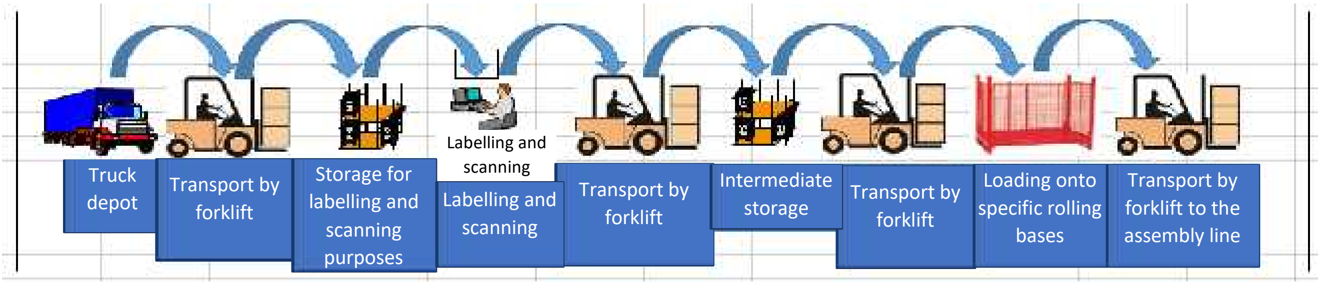

Fig.2.2 Flow chart for seat collections, initial situation

3. Improved method

The trucks dedicated to this flow are an integral part of the plant's fleet of vehicles, they will depart from the parking lot, to the M.O. from where they will pick up a maximum of 16 rear seats, then from the J.C. 24 collections of seats will be loaded, then the driver will transport the loaded packages to the customer plant.

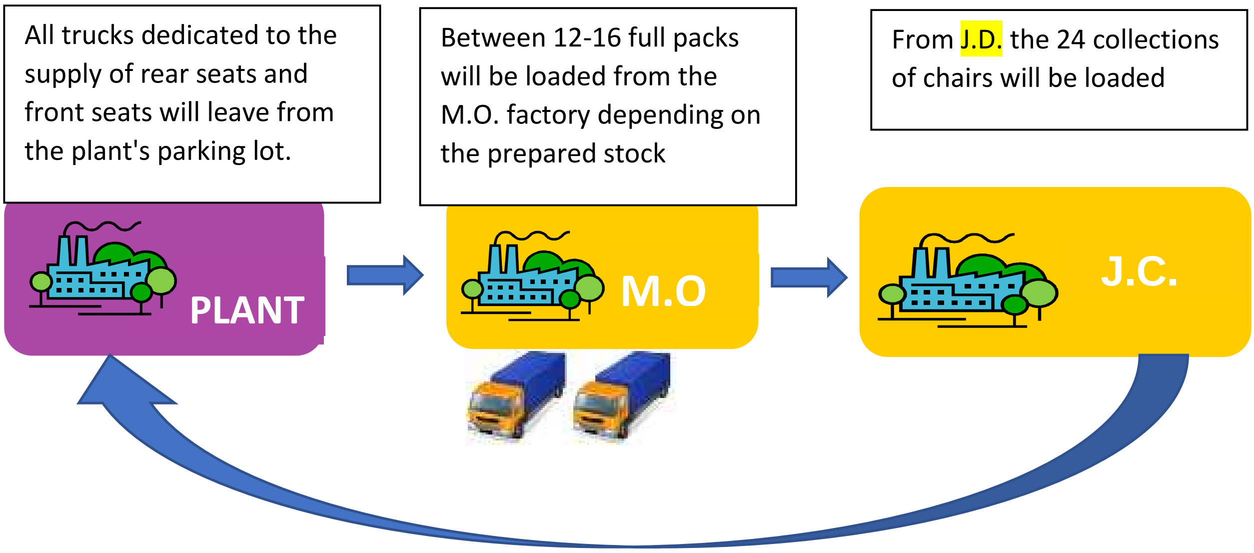

Fig. 3.1 Proposed flow

Therefore, in order to respect the production sequence and therefore the customer orders, the supplier J.C. must load the truck starting with the pile, noted in Fig.5.2 with the serial numbers 24/23; 22/21; 20/19 so that the last pile loaded is the one noted with 06/05; 04/03 and 02/01.

Once arrived at the truck depot in the plant, the unloading of the truck will start from pile 24/23; 22/21; 20/19 which will be stored in the area dedicated to the unloading of trucks, the area will be marked on the ground.

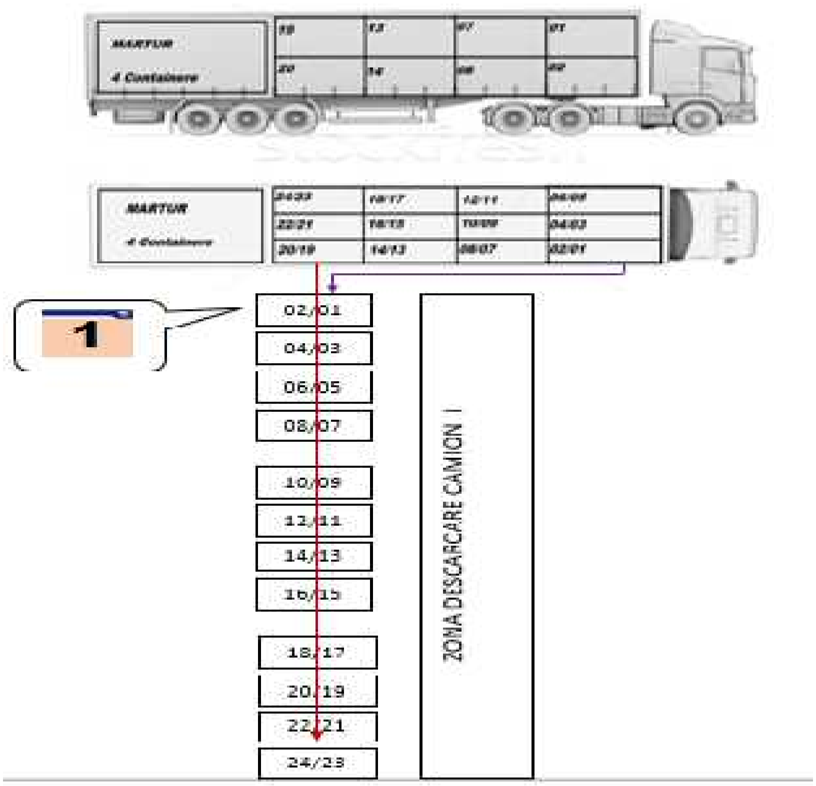

Fig. 3.2 Dedicated truck loading scheme

In the area marked on the ground, "Truck unloading area I", each four packages will be placed in series of three in order to facilitate loading onto the special rolling bases, in which, as mentioned above, eight front seats can be placed and four rear seats in the second type.

A logistics operator will pick up the packages from the unloading area and transport them to the loading area onto the rolling bases, thus completely eliminating the intermediate storage area which occupies a considerable surface area.

2.1 Improving the reception activity

Therefore, all packages in the same truck will have the same label colour to easily distinguish any potential errors.

The labels will be removable and will be placed by the suppliers in the metal holder on the back of each specific package.

Therefore, in addition to providing references and loading them into packaging, the suppliers in question will also carry out labelling activities.

All labels will be provided by the Plant, three sets will be printed, one for each participant in the flow.

Fig. 3.3 Packaging labelling

Fig. 3.4 Labelling activity

Once arrived at the Plant, the packages will no longer be scanned and then labelled, they will be loaded directly onto the rolling bases, thus eliminating the two logistical operations but also the operator carrying out this activity. If we look at the continuous manufacturing flow in the Plant, we see that each shift requires one operator to take the packaging and another to transport the packaging to the intermediate storage area.

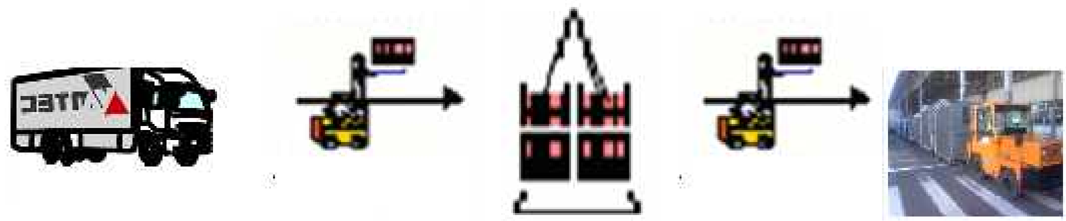

Fig. 3.5 Proposed flow

The initial situation *The proposed situation*

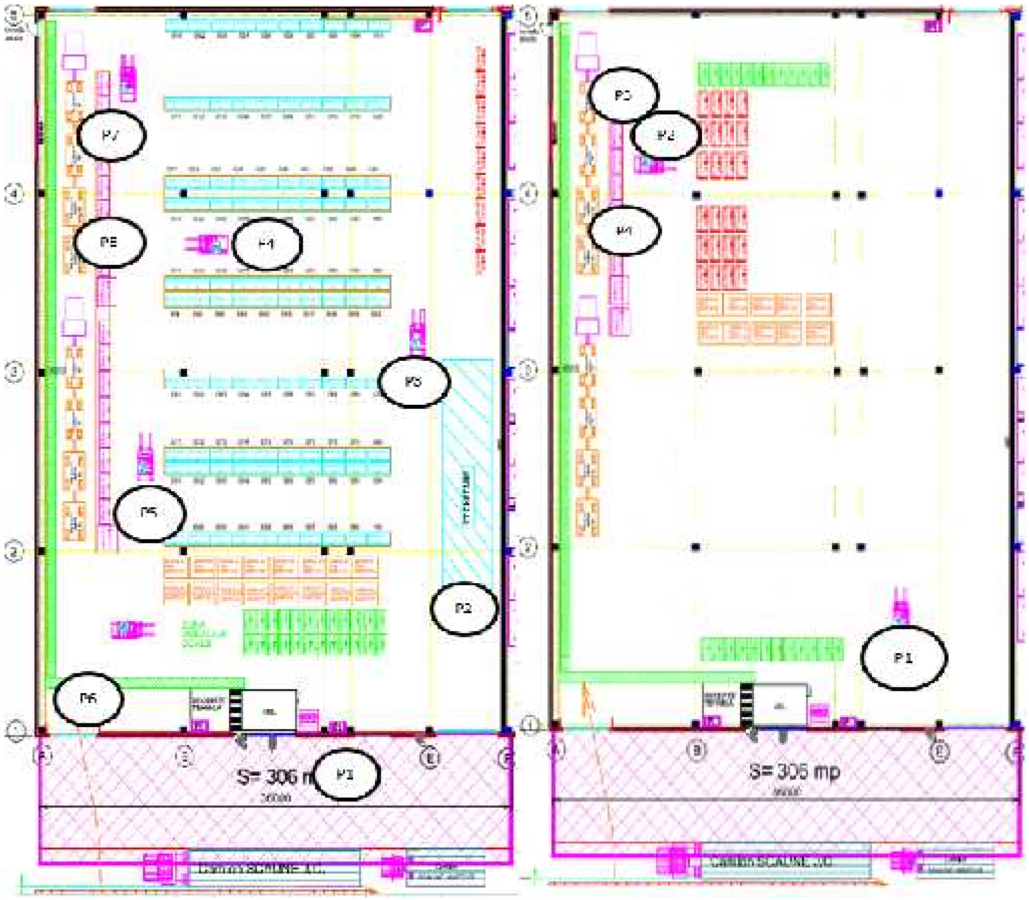

Fig. 3.6 Analysis and effectiveness monitoring of the proposed measures

Conclusions

The following conclusions can be drawn from the information presented in the previous chapters:

- ❖ Improvement of assembly line supply by introducing synchronous supply;
- ❖ Elimination of the intermediate storage area on the ground in order to reconstitute the firm manufacturing sequence;
- ❖ Elimination of labelling operations and by extension scanning, practically no more reception will be carried out;
- ❖ Elimination of the operators performing these operations mentioned above;
- ❖ Elimination of reception of reverse labelled packaging;
- ❖ Improvement of working and environment conditions by introducing AGVs on the transfer flow

It also means a significant decrease in product stocks, the total elimination of the intermediate storage area, which occupies about 70-80% of the total warehouse area, the reduction of lead time, the commitment modification and the reduction of the number of posts.

The improvement must be continuous, the actions to be taken in the future being: replacement of sectional doors in truck depots with automatic ones, elimination or reduction of reference swapping, increase of operational efficiency in the supply process.

Stocks generate costs. As stocks decrease, so do costs.

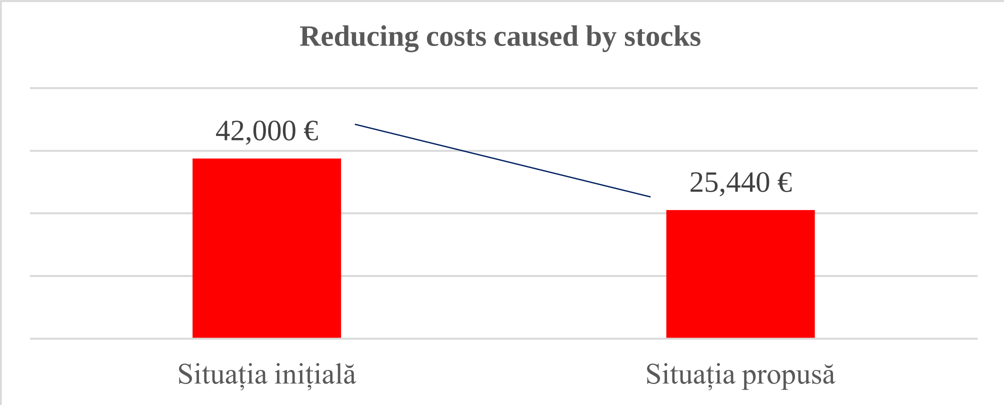

Fig.2.9 Reducing the percentage of storage area out of total area

42,000€ - 16,560€ = 25,440€

The costs caused by stocks have decreased by $\frac{25440*100}{42000} = 60.57\%$

Index I1 =17,160 (€)

Also, as stocks decreased, the percentage of storage area in relation to total area also decreased (Figure III.2).

Index I2 = $\frac{\text{Storage surface}}{\text{Total surface}}$ varies as in table 1.

Table 1 Variation of the I2 index

I2 – initial situation	I2 – proposed situation
I2 – initial s $\frac{840m^2}{1400m^2}*100$= 60 %	2 – propose $\frac{100\ m^2}{1400\ m^2}*100$= 7.14 %

1,400m² – 848m² = 552m² – area gained by eliminating stocks.

The storage area for seating collections decreased by $\frac{552*100}{840} = 65.71\%$

Thus, it can be seen, through the reduction of stocks of finished products, and at the same time their related costs and areas, that the synchronous supply method is much more advantageous. Also, once the reception activity, which involved labelling and scanning the packaging, was eliminated, 2 operators per shift were also eliminated.

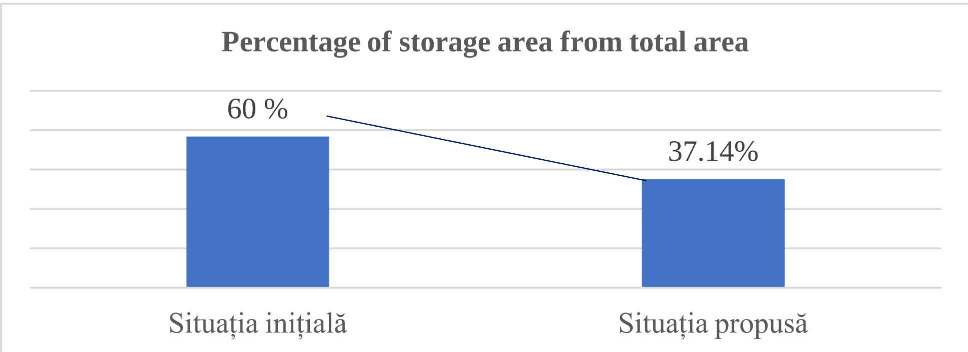

Fig. 2.10 Reducing the percentage of storage area out of total area

Table 2. General analysis (initial situation vs. proposed situation)

Process	Supply and storage of parts in an intermediate warehouse in the Plant	Supply and storage of parts directly at the truck depot in the proximity of the car assembly line in synchronous mode
ETP	27	15
forklifts	9	5
electric tractor unit for internal transport	3	0
AGV	NO	NO
No. of shifts	3	3
surface (m^2)	2500	1600
no. of quality incidents (monthly average)	6	2

Personal contributions

In terms of personal contributions to the study, these took the form of:

- Documentation and bibliographical study;
- Centralisation of the supply system information analysed;
- Participating in identifying weaknesses;
- Participating in interpreting the results and drawing the conclusions;
- Analysis of the current system;
- Identifying opportunities for improvement and proposing solutions;
- Analysis of the proposed situations;
- Identifying the optimal solution.

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THE STAMPING PROCESS AND THE MANAGEMENT OF A SPECIFIC PROJECT

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REZUMAT: The design of auto body dies and dies is an ongoing activity as automobile manufacturers are constantly looking to improve their production processes to increase the efficiency and quality of their products. The design and development of high-precision dies and dies for auto body manufacturing is a critical and ongoing activity, as a number of factors such as tolerance, complex shapes and non-uniform geometries require advanced technologies and special expertise. The objective of the chosen theme is to make a hood according to the specifications. The design of the technological process is realized in Catia V5 and its simulation in Autoform. The technological process contains all the operations that each piece goes through from the semi-finished product to the final shape. Each operation is accompanied by the technical time norm.
The landmark for which we realized the technological embossing process with the related time norm is the "Hood", which is an exterior part, with a complex, asymmetrical shape, which is part of the entire car body.

CUVINTE CHEIE: embossing, punch, mold, technological process, simulation.

1. Introduction

The objective of the chosen theme is to make a hood according to the specifications.

The hood of a car is a body component that protects the engine and allows quick access for maintenance to the engine or other components.

The construction of the hood differs from car to car, but most can be accessed easily, opening from inside the car with the help of a special button.

Usually the hood is made of steel, but materials such as aluminum or carbon and fiberglass are quickly gaining popularity.

2. Current status

The design of auto body dies and dies is an ongoing activity as automakers are constantly looking to improve their production processes to increase the efficiency and quality of their products. The design and development of high-precision punches and dies for auto body manufacturing is a critical and ongoing activity, a number of factors such as tolerance, complex shapes and non-uniform geometries require advanced technologies and special expertise.

The design and construction of the embossing dies are elaborated in close connection with the shape and dimensions of the workpieces, with the required precision, the material from which they are made, the production volume, what machines the press department has.

When designing the molds, both ensuring the functionality for the given conditions must be taken into account, as well as the possibility of easy production of the component parts, by providing the most technological constructive forms. From this point of view, it is necessary to choose the simplest standardized and normalized constructive solutions, which at the same time offer the possibility of easy and convenient assembly and maintenance.

In general, when designing the embossing dies, certain conditions must be ensured, such as :

- high quality of mold parts;
- high productivity;
- easy execution and low cost;
- durability as high as possible;
- high security in the work process.

The design and manufacture of embossing dies starts from certain initial conditions, such as:

- drawing of the molded part;
- the operations plan in case the part is obtained in several successive operations, which require different tools;
- the cutting plan of the semi-finished product;
- working diagram of the mold;
- a copy of the part to be molded.

According to the mode of operation, they can be classified as:

- simple effect embossing dies;
- double effect embossing dies;

In the structure of the embossing dies we find four main elements:

- Punch;
- Superior package;
- Lower package;
- Retaining element.

3. The case study

For this case study, we chose the benchmark Bonnet Panel, made of steel-HX220BD with a thickness of 0.65 mm.

The input data for this type of landmark are the following:

- 3D digitization;
- Pregame;
- TG plan.

Fig.1 shows the 3D Digitization, designed by Design. This is the part drawing in Catia – Catpart format.

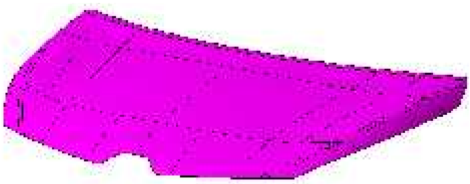

Fig.1 Digitization 3D

Pregama – is an official document, a pre-study carried out for this range, in which various technical details are presented, such as:

Number of operations;

- The manufacturing site;
- Main and secondary press lines;
- Material and thickness;
- Dimensions of the flan:
- Commitment of the material.

In the figure 2, the pre-model of the hood with the characteristic specifications is attached to her:

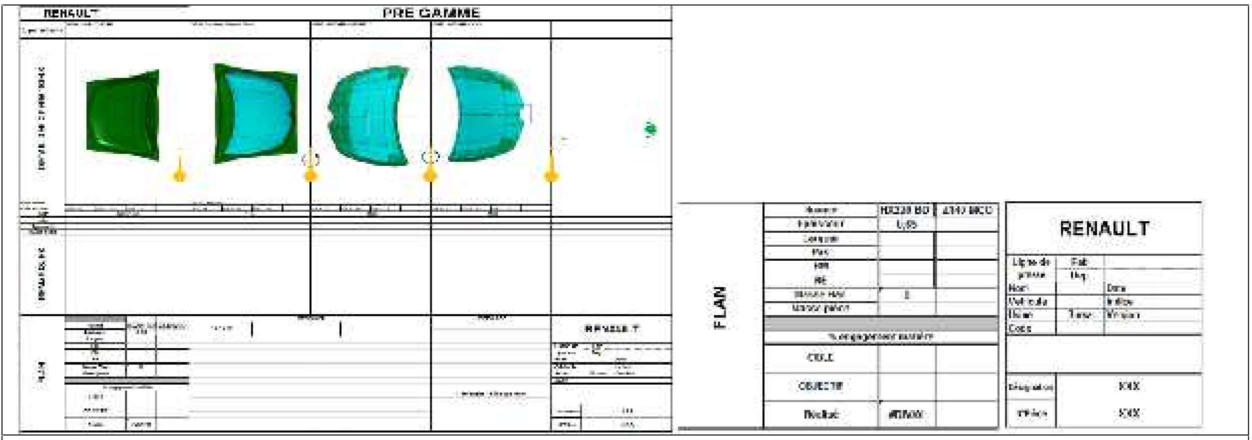

Fig.2 Hood pregama

The TG plan is illustrated in Fig.3 This represents the part drawing, in the machine assembly,with all the details (ex: contact areas with other parts):

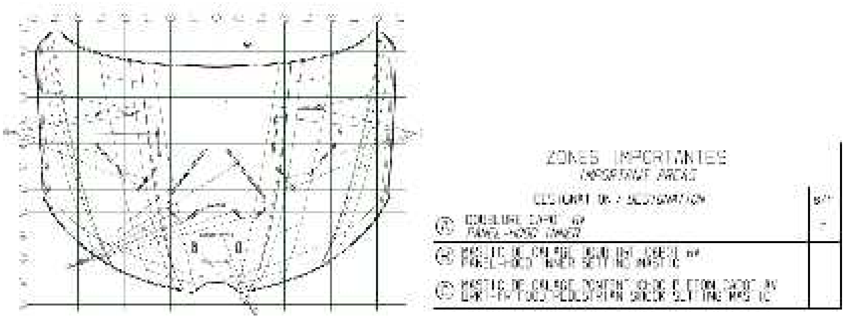

Fig.3 TG PLAN

After analyzing the input data, the surfaces specific to this type of landmark are built, respecting Renault-Nissan norms and standards.

The analysis of the piece consists of:

- Identifying the appearance areas;
- Identification of mooring areas,
- Checking if the piece complies with the Product/Process design standards (material/ plate thickness, depth, radius values, etc.).

The design of the technological process is realized in Catia V5 and consists of the following actions:

1. The part received from Design is in the car axles, more precisely in its position on the vehicle.

This position does not allow a correct embossing. Balancing (fig 4.8) the piece allows:

- Balancing the embossing depth;
- Avoiding negative areas;
- Protection of appearance areas;
- Favoring the poincon attack.

In the following figure (Fig. 4), the swinging of the hood at the angle mentioned in the preamble is represented.

2. The surface of the greenhouse-flan (prestable) is the support surface of the sheet during time the embossing process. Especially for appearance parts, this surface must be developable and as close as possible to the part received from the customer in order to privilege the commitment of the material. In Fig. 5, the front panel of the hood is illustrated:

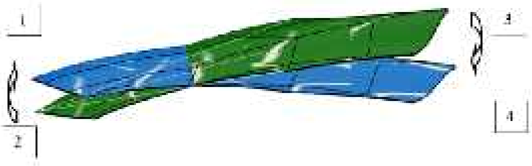

Fig.4 Balancing

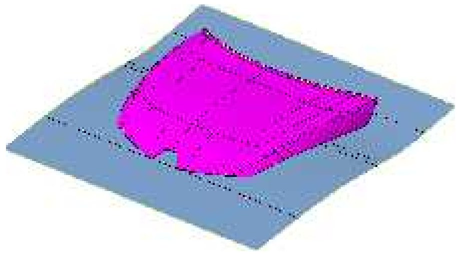

Fig.5 Preset

3. Making the habillage (fig 6) - represents the "clothing" of the piece -the joining area of the part with the pre-stable surface.

Habillage construction criteria:

- Regularization of embossing;
- Protection of appearance areas;
- Respecting the mowing areas, directly or with a cam;
- Optimization of material consumption;

Figure 6 highlights the habillage built on the basis of the initial piece.

4. During the construction of the habillage and the prestable, the presented process is taken into account in pre-cut (live trimming/bending areas, etc.).

Figure 7 shows the form of the mold (preset with habillage):

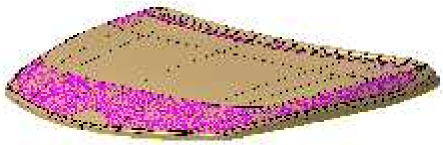

Fig.6 Habillage-ul

Fig.7 Molded form

After finalizing the mold surface, all the data are entered into an FEA-Autoform software. It allows analyzing the reliability of the part both from the point of view of formability and appearance.

Required data for a simulation in AF:

- The mold surface (Fig 8);
- Material book (Fig 9);
- Sheet thickness;
- Flan (Fig 10);
- Junci (mechanical brakes) (Fig 11).

Brakes are mechanical brakes that have the role of:

- To brake the plate in its movement, to favor the elongation of the material;
- To let the plate "flow" in certain areas, to avoid breakage;
- To limit the formation of folds in certain areas.

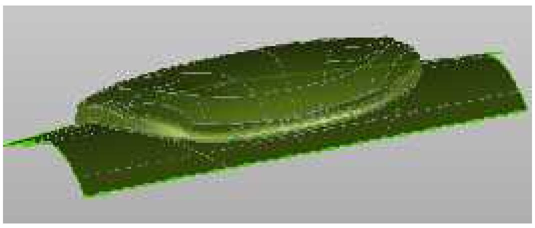

Fig.8 Molded surface

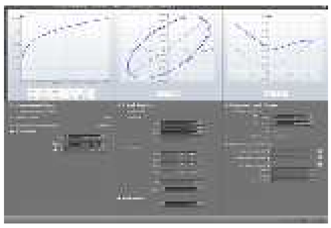

Fig.9 Manual Book

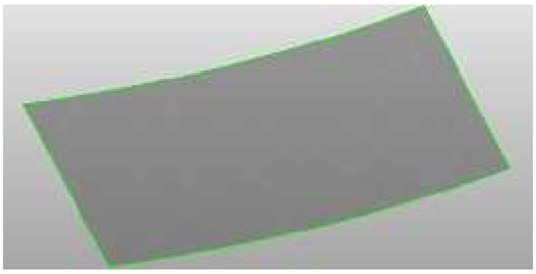

Fig.10 Flan

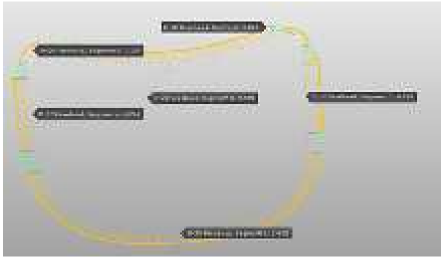

Fig.11 Junks

In AUTOFORM, the embossing forces are automatically calculated and the most important analyzes are performed, such as:

- Formability;
- Plasticity;
- Analysis of scratches;

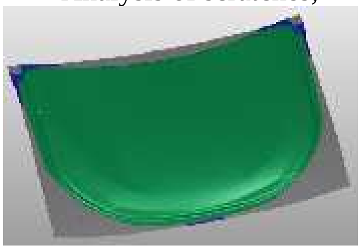

Fig.12 Formability check

Fig.13 Plasticity check

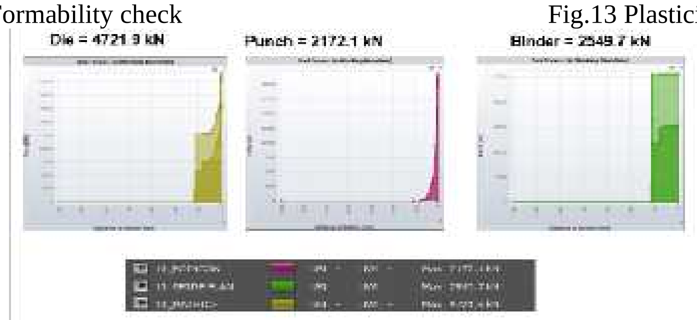

Fig. 14 Calculation of embossing forces

If the part is not feasible, following the optimization of the pre-installation and the habillage, product modification requests are made (DFPP-process-product feasibility requests).

These DFPPs are analyzed by the studies office and can be integrated or not. If they cannot be integrated, meetings are held to find a solution to satisfy the needs of all the departments involved (embossing, dyeing, assembly...etc).

Figure15 shows an example of DFPP with the corresponding details.

Fig.15 DFPP example

After completing operation 10 - embossing, proceed to the construction of the half operation - operation 20 - trimming, represented in (Fig. 16).

Trimming can be done directly or with a cam. Operation 30 - direct bending, we have it illustrated in Fig. 17.

Figure 18 shows the operation 40, necessary in the case of the chosen landmark. This operation represents cam bending in the logo area.

The output data for this milestone are the 3D and 2D Manufacturing Sheet. Figure 19 shows the 3D Manufacturing Sheet.

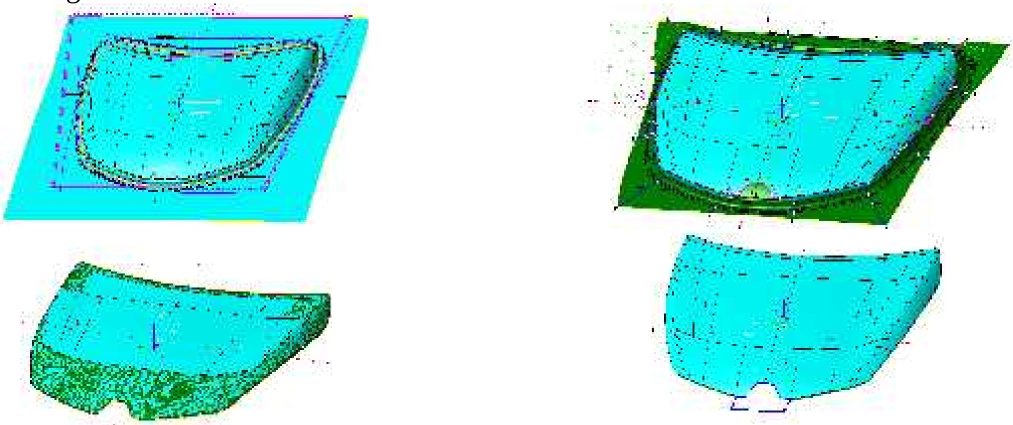

Fig.19 Manufacturing sheet

The 2D manufacturing sheet includes an administrative sheet in which all the administrative details are specified (manufacturing site, press lines, type of automation, inventory number, etc.) and a technical sheet for each individual operation.

4. Conclusions

Establishing the optimal technological process of execution leads to obtaining the final product in quality conditions, in the terms requested by the client and at minimum costs.

The technological process contains all the operations that each piece goes through from the semi-finished product to the final shape. Each operation is accompanied by the technical time norm.

The landmark for which we realized the technological embossing process with the related time norm is the "Hood", which is an exterior part, with a complex, asymmetrical shape, which is part of the entire car body.

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STUDY OF ACTIVE ORTHOSIS

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ABSTRACT: The design and prescription of orthoses can be aided by an understanding of the biomechanical principles of the upper limb.Orthoses are classified into static, dynamic and hybrid orthoses. Upper limb orthoses are more often accepted by patients when there is a well-defined therapeutic programme and when the orthoses provide a desired function that cannot be achieved otherwise. The complexity of the hand, elbow or shoulder requires that orthosis design places equal importance on mechanical efficiency and precision of fit, as comfort is essential for acceptance. Specific training is required to meet the high design and fabrication requirements resulting from small segments (levers), limited soft tissue padding and multiple joints. If the biomechanics can be optimised, then the resulting improvements in kinematics will not only have an immediate effect on gait, joints and muscles, but can also provide a therapeutic environment that can contribute to long-term benefits.

Keywords : Orthosis, dynamic, active, AFO, metal

1.Introduction

Since antiquity the human body has been studied in its totality even today, it, by its amazing complexity, leads researchers to describe it as a "machine built down to the smallest details reached perfection". Optimal communication and transdisciplinary education occurs when the patient, doctor, orthotist and therapist are all present for the assessment of the patient. The goal of active orthotics is to provide a low amplitude force for a period of time to reshape new tissue. The force is provided by the traction of the elastic band located in the supporting part of the orthosis. The dynamic orthosis should heal the tissue and joint stiffness, but the stretching should not be painful. The patient should bring the medical device to each visit for reassessment and readjustment. There is no specific time for how long the orthosis should be worn, as many factors can have a great influence such as: soft tissue tolerance to stretching and the patient's adaptation to the medical device. My goal is to bring different orthotics from a structural and functional point of view to the patient's attention, due to the lack of information and possibilities in our country from an orthotic point of view.

2. Types of orthoses

There is a wide range of orthoses on the market designed for use in certain conditions of the osteo-articular system, made of quality material in accordance with the latest technology and the requirements of the European Community in the field of orthopedic equipment and devices. The purpose of the orthosis is to replace atrophied or absent muscles, protect injured segments by limiting range of motion or loading, or prevent anatomical deformities. Orthotics are used in hand rehabilitation, their therapy consists of maintaining a fixed position in both dynamic and static cases. Their design is such that they do not injure tissue following trauma, once designed and molded they support weak muscles and counteract the pull of healthy muscles, applying an external force to counteract the imbalance of internal forces. The dynamic orthosis is the application that contains an active force that remains constant as part of the movement, the use of that guidance system ensures the direction of the traction force obtained by pulling the elastic (see figure 1).

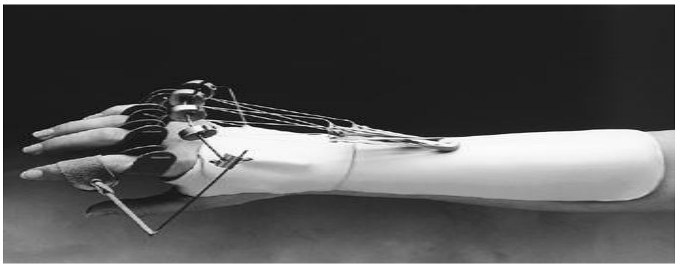


Fig. 1. **Dynamic hand-fist-finger orthosis**

Elbow orthoses (EO) are commonly used immediately after trauma or surgery. Typically, a three-point force system is used, along with a hydraulic lock of the semiliquid tissues around the fragments, to hold the fracture fragments as a single unit during the healing process (Figure 2).

Fig. 2. **Active elbow orthosis**

The hip orthosis used to treat a posteriorly dislocated hip is generally proximal to the knee. A well-fitting pelvic band suspends the orthosis and provides a fixation point for the hip joint. A hip joint with adjustable range of motion, placed laterally, capable of controlling flexion, extension, abduction, and adduction, attaches to a hip joint that fits snugly. thigh cuff that maintains the hip in 10 to 20 degrees of abduction and allows 0 to 70 degrees of flexion [7]. This joint position combined with properly fitting pelvic and thigh components provides a kinesthetic warning against excessive flexion, adduction, external rotation (see figure 3).

Fig.3. **Hip orthosis**

Knee-ankle orthosis adapted to provide independent methods of walking for a person with impaired gait, paralysed lower limb or lost muscle function due to spinal injury or accident. A knee-ankle orthosis presents problems in locking and unlocking the knee joint [4].

The simplest orthoses have a manual locking and unlocking device for the thigh frame and calf frame, when walking the user locks the joint, while when sitting, they unlock the joint to flex the knee With such an orthosis the knee joint is locked during gait and the user is forced to walk with a fixed knee, the gait is no longer natural and he is forced to exert more effort [3].The aim of dynamic orthoses is to provide a low amplitude force for a period of time until the new tissue remodels. The force is provided by the traction of the elastic band located in the supporting part of the orthosis [9].The dynamic orthosis should heal the tissue and joint stiffness, but the stretching should not be painful, e.g. HKAFO orthosis (see figure 5).

Fig. 5. **Orteza HKAFO**

The foot, an integrated part of the human skeleton, together with the ankle, forms the anatomical-functional complex that supports the entire body and plays a significant role during gait due to its major importance in both static and dynamic gait [12].

The foot provides stability, mobility, balance, acceleration and deceleration during gait. The ankle joint is a particularly important joint because of its role in the execution of lower limb movements and can have major consequences for the stability and mobility of the lower limb, and therefore the whole body.

Various orthotic devices are used in modern medicine to correct various dysfunctions that occur in the ankle joint and the foot. Ankle and foot orthoses are recommended for numerous conditions such as ankle sprains, ankle and foot fractures, Achilles tendon ruptures, plantar fasciitis, Hallux - Valgus, Tallus - Valgus, Varus Equinus, flatfoot, but also to protect the ankle joint during various sports [5].

The clinical objectives to be achieved by the use of orthotics are: pain relief, deformity correction, motion control, increased range of motion, reduced healing time, injury prevention, etc.. In their achievement, orthoses must decrease or eliminate dysfunction of the segment on which they are applied,with a high degree of comfort, aesthetic, and low manufacturing cost. Orthoses are external devices applied to an anatomical segment of the body to prevent or correct dysfunctions of that segment (restoration of normal functions and abilities by controlling movement, correcting deformities and compensating for various dysfunctions) [7].

The ISO/TC Technical Committee in conjunction with the American Academy of Orthopaedic Surgeons and the American Orthotic and Prosthetic Association have proposed naming prosthetic devices according to the anatomical segment and the joint(s) undergoing bracing (Table 1). The proposed acronyms have been accepted and used internationally, even by non-English speakers [2].

Tabel 1 [6]

Categoria	Denumirea	Acronimul	Denumirea	Acronimul
Orteze de membru inferior Lower Limb orthoses	Orteză pentru picior Foot orthosis	FO	Orteză pentru gleznă-picior Ankle-foot orthosis	AFO
	Orteză pentru genunchi Knee orthosis	KO	Orteză pentru genunchi-gleznă-picior Knee-ankle foot orthosis	KAFO
	Orteză pentru şold Hip orthosis	HO	Orteză pentru şold-genunchi-gleznă-picior Hip-Knee-ankle foot orthosis	HKAFO
			Orteză reciprocă de mers Reciprocal Gait orthosis	RGO
Orteze de coloană vertebrală Spinal orthoses	Orteză cervicală Cervical orthosis	CO	Orteză cervico-toracică Cervical-Thoracic orthosis	CTO
	Orteză toracică Thoracic orthosis	TO	Orteză cervico-toracică-lumbosacrală Cervical-Thoracolumbosacral orthosis	CTLSO
	Orteză sacrală Sacral orthosis	SO	Orteză toraco-lumbosacrală Thoracolumbosacral orthosis	TLSO
	Orteză sacroiliacă Sacroiliac orthosis	SIO	Orteză lumbosacrală Lumbosacral orthosis	LSO
Orteze de membru superior Upper Limb orthoses	Orteză pentru mână Hand orthosis	HdO	Orteză pentru încheietura mâinii şi mână Wrist-Hand orthosis	WHO
	Orteză pentru încheietura mâinii Wrist orthosis	WO	Orteză pentru cot, încheietura mâinii şi mână Elbow-Wrist-Hand orthosis	EWHO
	Orteză pentru cot Elbow orthosis	EO	Orteză pentru umăr şi cot Shoulder-Elbow orthosis	SEO
	Orteză pentru umăr Shoulder orthosis	SO	Orteză pentru umăr, cot, încheietura mâinii şi mână Shoulder-Elbow-Wrist-Hand orthosis	SEWHO

3. Action of orthoses

There are 3 categories of orthotic devices, grouped according to the anatomical areas of the human body: trunk, upper limb and lower limb.

Clinical objectives of orthotic treatment [2]:

- Pain relief.
- Correction of deformities.
- Prevention of excessive range of motion, postoperative immobilization .
- Development of range of motion.
- Compensation of dimensional abnormality of anatomical segments.
- Stimulation of abnormal neuromuscular function.
- Reduction of healing time and tissue protection.
- Suppresses motor deficit or postural feedback or injury prevention, etc.

Types of actions performed by the orthosis :

Stability refers to fixing an anatomical structure in a balanced position so that its shape does not change. Given the exoskeletal application of the orthosis, the affected area must be well immobilized if the orthosis is extended and stabilizes the supra and underlying joints.

Posture is a position, an attitude different from normal. In orthotics, a joint or anatomical segment must be maintained or even forced into a certain adapted position, and there are two types of position:

- Static when the orthosis is fixed, does not allow any movement and does not change with changes in position. This allows a balance of forces to be established.
- Dynamic when a posture is maintained with an orthosis that adapts to changes in anatomical position, developing a constant direct force that generates energy capable of producing movement.

In terms of joint movement, there are two main types of ankle and foot orthoses:

1. Static (fixed) orthoses: they restrict movement around the joint or the anatomical segment they surround and their main objective is stabilisation. Static orthoses are flexible or rigid orthoses that keep the joint in a fixed position, with the vertical part at the back of the calf and the horizontal part below the sole of the foot supporting weakened or paralysed segments of the lower limb.

2. Dynamic orthoses (Ankle Foot Orthosis AFO): these are orthoses used to facilitate body movements and allow the anatomical segment to function. These orthoses provide subtalar stabilisation, allow ankle dorsiflexion and plantar flexion, which can be free or limited, in some cases even blocked [5].

Active Ankle Foot Orthosis (AAFO): is a new generation of dynamic orthoses powered by an actuator. Actuation provides controlled force to compensate for muscle deficiencies around the ankle. This force is calculated by a controller that receives both biological (EMG) and physical (ground reaction, angle in the joint) feedback. Regardless of the type of actuator, it must be able to provide sufficient force for the movement and have the properties required by the muscle (low impedance, low friction, etc).

The impedance of the orthotic joint can be changed throughout the gait cycle. During controlled plantar flexion, biomimetic control is applied by torsion spring where the stiffness of the orthotic joint is actively adjusted to minimise foot collision with the ground (see figure 6).

All orthotics control spinal motion through a combination of dynamic and passive mechanisms. Dynamic control describes the significant role of the intrinsic musculature in actively stabilizing the spine and is a major component in the effect of most orthoses [17].

In addition to improved function through better posture, improved proximal/distal stability and reduced involuntary movements, other benefits may include pain relief, reduced associated reactions, easier transfers and improved therapy sessions. Over time, the desired effect would be to experience improved function and movement control when the orthosis is removed - i.e. continuation of the effects experienced when wearing the orthosis [18].

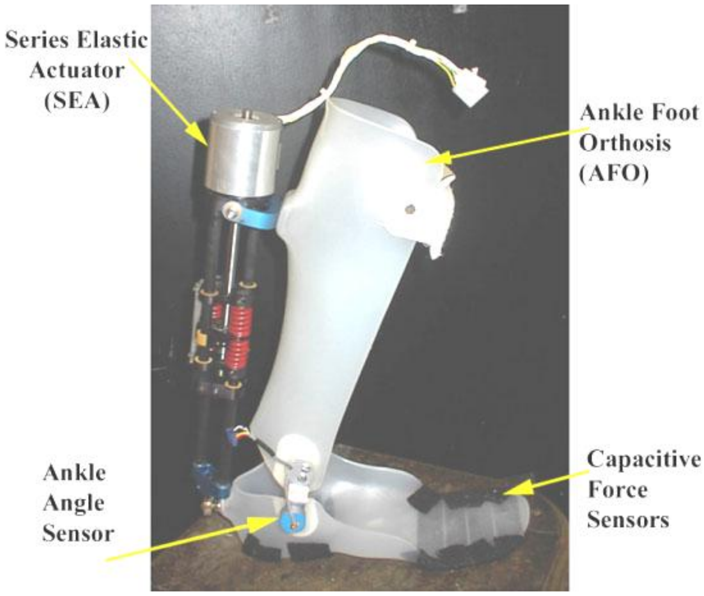


Fig. 6. **Orthosis AAFO**

Depending on the pathology of the ankle or foot, various types of ankle-foot orthoses are recommended to be used:

- Method of manufacture: Typical, available in different sizes, they are used directly.
- Pre-fabricated (custom-fitted), custom-made orthoses, custom-fitted/modified.
- Custom-made, specially made, individualised for a specific patient.

A custom-made orthotic device is manufactured based on a model (physical or computerized) of the patient's affected anatomical segment. The purpose of use is (functional) treatment, rehabilitation or sport [14].

Period of wear: day/night or duration of wear: temporary or permanent or mode of wear, in shoe or over shoe.

There are four main types of Ankle-Foot Orthosis (AFO) [1]

- Flexible AFO (see figure 7a).

- Dorsiflexion support.
- Subtalar joint stabilisation.

- Rigid AFO (see figure 7b).

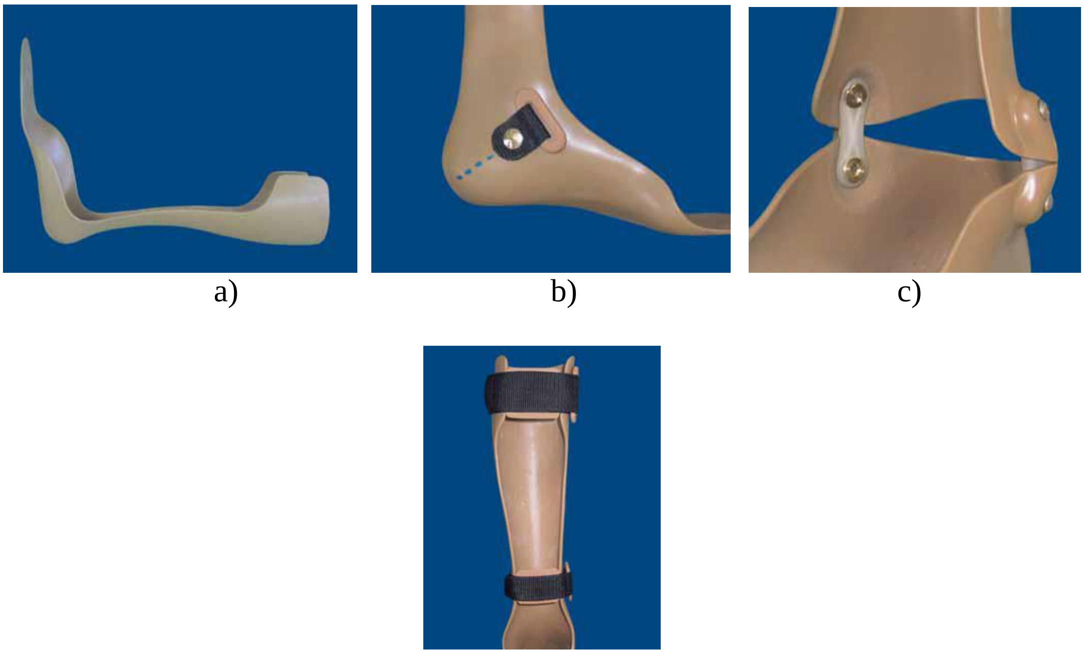
- Blocks ankle movement.
- Mediolateral stabilisation of the subtalar joint.
- Ability to control forefoot adduction/abduction.

- AFO with Tamarack Flexure Joint TM (see figure 7c).

- Mediolateral stabilisation of the subtalar joint.
- Free dorsal ankle extension.
- Free or restricted plantar flexion of the ankle.

- Anti-talar AFO (see figure 7d).

- Blocks ankle movement. Particularly effective in preventing dorsiflexion of the ankle.
- Poor mediolateral stabilisation of the subtalar joint.



a) b) c)

d)

Fig 7. **Ankle-Foot Orthosis (AFO)**
AFO FLEXIBLE (a), AFO Rigid (b), AFO Tamarack (c), AFO anti talus (d)

Foot orthoses for various pathologies such as Hallux Valgus with prominence of the first metatarsal and medial displacement of the hallux to the inside of the foot. Hallux - Valgus pathology can occur due to certain diseases such as rheumatoid arthritis, uncomfortable, tight shoes and heels aggravate this condition,also flat feet and obesity can favor the occurrence of this deformity [13].

Hallux Valgus Orthosis - the principle of correction applied by this orthosis is based on the principle of leverage, by applying pressure force to the hallux at the metatarsophalangeal joint and laterally in the metatarsal area (Figure 8a). An orthosis is made up of the following components: the hallux support, the foot support, the guide piece, the multifilar cable and the assembly elements (screws, rivets and staples).The materials proposed for the construction of the orthosis are: thermoformable material (hallux support and foot support), aluminium (guide piece), rolled stainless steel (multifilar cable) and Velcro strips (see figure 8b)[2].

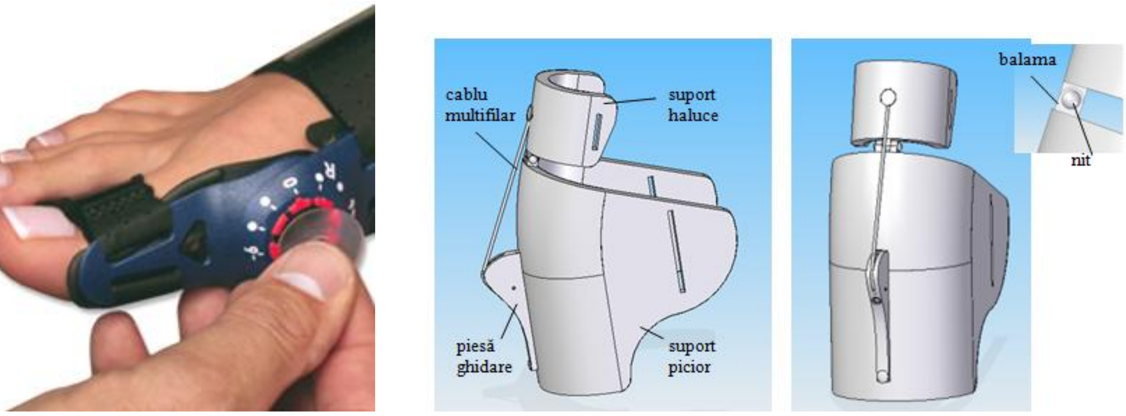


Fig. 8. **Hallux Valgus Orthosis**
a) active hallux orthosis b) hallux valgus orthosis

4. Conclusions

Orthoses are tailored to individual patient variables, these generate a wide variety of orthosis configurations specifically designed to achieve distinct therapeutic goals.

The patient must understand the purpose of the orthosis, accept the benefits it can provide and have the appropriate knowledge and skills to use the orthosis appropriately.

Orthoses are orthopaedic devices that are applied directly to the human body to: supplement, compensate for or correct a physical deficit.

Orthoses need to be accepted by the patient and a real process of acceptance, integration and identification needs to take place where they lose their status as an object of external reality in relation to the patient and become parts of his body.

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ADAPTING PLAYGROUND FOR CHILDREN WITH DISABILITIES

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Scientific coordinator: **Prof. Dr. Eng. Cristina MOHORA**

ABSTRACT: The paper is based on adapting playgrounds for children with disabilities, focusing on an existing space. The playgrounds, both indoor and outdoor, are not equipped with the minimal activities that a child with disabilities can do. Therefore, throughout the paper, I revealed the first steps to be taken, in terms of ergonomics, accessibility and playground safety. This will take into account access to the playground via ramps, the optimal arrangement of hygiene areas and also access to the table and the staff area. Finally, the visual, thermal and sound environment will be assessed, which is an important aspect when discussing children with behaviour disorders.

KEYWORDS: Children with disabilities, accessibility, playground

1. Introduction

The paper presents aspects, observations and ideas through the children with disabilities and the lack of playgrounds needed by them. During this paper we will discuss the relationship between children - the play and relaxation environment, the arrangement of the space according to children's needs, the layout of the furniture and equipment, as well as tips to follow within the space.

The research aims to highlight the needs of children with disabilities and their desire to express themselves and collaborate with people of the same age and interests. They all share the passion to play. Playgrounds should be designed to give all children the right to play according to their disabilities. It will show the possibility of reintegrating into social life people with physical or locomotor disabilities who require rehabilitation and specific assistive devices.

In this paper we are focused on the implementation of a playground, designed according to the needs and requirements of children with special needs. The place is the one where I work, and along the way I have noticed irregularities in its design to be suitable for children with disabilities.

The objectives of the paper are related to the benefits needed to enable children with disabilities to enjoy and experience themselves in conditions of adaptation and equality with their peers. Therefore, we will focus on providing the place with:

- Ramps (both at the entrance into the room and in the play area itself).
- Handrail (located near a staircase or ramp to allow movement).
- Doors wide enough to allow wheelchair access.
- Non-slip floors.
- Adequate lighting.
- Special bathrooms.

The above objectives are still on the proposal plan, as the entire space is owned by an organization. I will exemplify below how I would intend to change the whole space.

The adaptation of the playground requires a meticulous analysis of the space to ensure that it reflects all the needs of children, parents and staff.

Currently, the space is used to hold dance classes, which allows us to run the activity only at the end of the week. The space owner limits us in making the necessary changes to adapt the existing playground (see figure 1). However, after many discussions, we decided to give up the activity inside the space and to adapt it as follows.

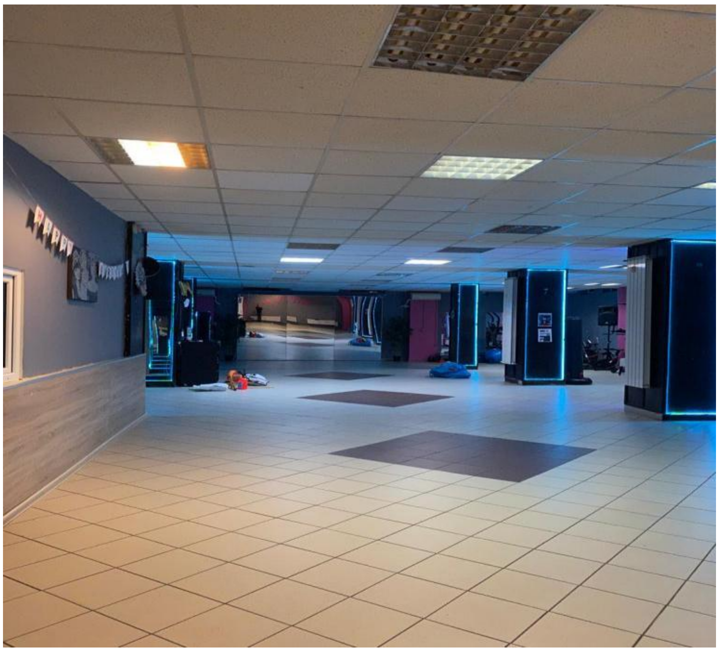

Fig. 1. **The existing playground**

2. Current status

The idea of supervised playgrounds has its origins in Germany as a way of preventing children from playing in the streets. These playgrounds were piles of sand and the police kept an eye on the children. Dr. Marie E. Zakrzewska, a German citizen, brought the idea to Boston in 1885. Boston Sand Gardens became the first supervised playground in the US. A few years later, also in Boston, the Charlesbank Outdoor Gymnasium opened. This large playground included a running track, canoeing activities on the Charles River, and play equipment such as swings, seesaws and ladders. With the development of more durable materials and increased safety standards, companies began manufacturing safer equipment for children. In 2010, the U.S. Department of Justice passed a special law to design accessible equipment for children with disabilities. When existing playgrounds are modified or new ones are built, they must comply with government requirements [1].

Deficiencies, whether sensory (concerning the activity of the analysers, especially visual and auditory), psychological (concerning the development and maturation of the S.N.C., with consequences on the development of intellectual and instrumental faculties), or neurological (developmental defects of the S.N. C, with consequences on functionality, especially in the motor sphere), cause adaptation difficulties, reduced communication capacity (or loss of this capacity) and consequently, changes in the behavioural sphere. The disabilities that appear during life are the results of diseases or therapeutic accidents. If they occur during life in people who were structurally and functionally intact, they form the category of disability (aphasia, paraplegia, amputations, etc.) [2], [3].

3. Adapting the playground for children with disabilities

ACCESS TO THE PLAYGROUND

At the present, access to the hall is provided via the staircase, which is on the ground floor (see figure 2). Our recommendation is to design an access ramp with a handrail and non-slip surface to avoid the risk of slipping.

The stair access is quite wide, so the ramp can be on one side and the rest of the steps on the other side. Another recommendation would be to place a disabled lift.

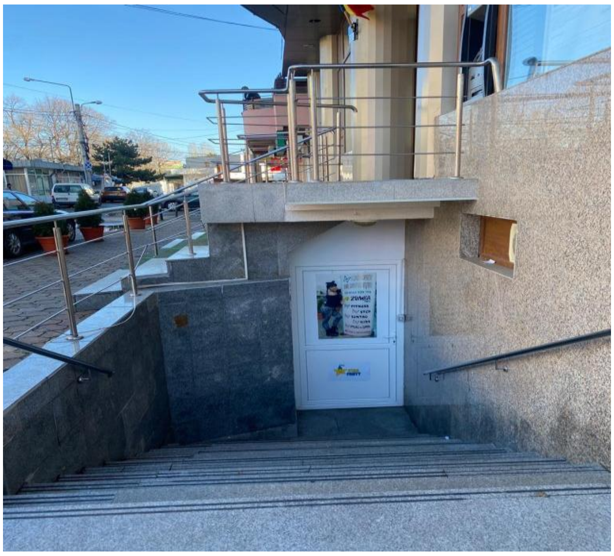

Fig. 2. **Initial access to the playground**

THE CONFORMITY OF STAIRS, STEPS AND RAMPS

- Steps shall be configured with a maximum step width of 34 cm and a maximum step height of 16cm or 32cm/15cm.
- Steps shall have a non-slip surface or non-slip strips in the step edge area.
- The staircase will have a handrail on both sides of the ramp (at a height of 90cm-1m for adults and 60-75 cm for children) - will go over the first and last step by 30cm and will be turned down.
- The minimum clear width between the 2 current hands will be 1.50m for a staircase bordered by 2 walls.

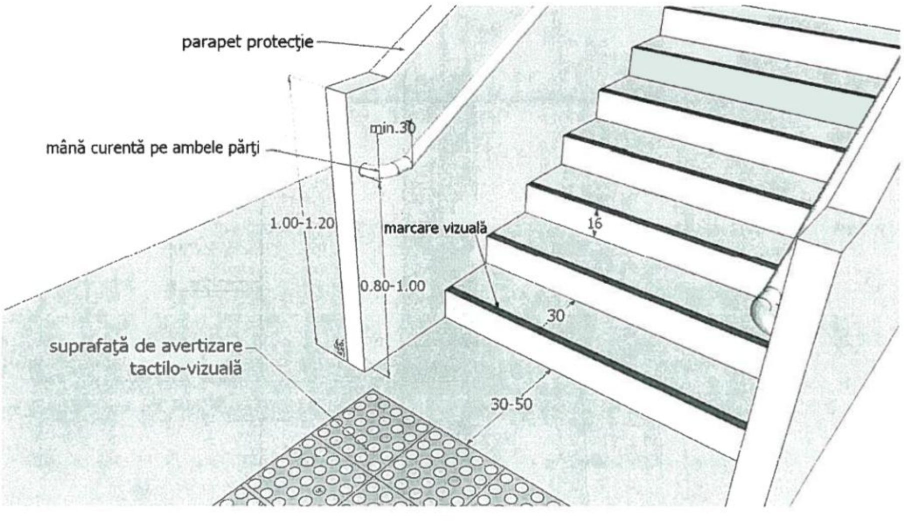

Fig. 3 **Proposal for entrance**

- Where a mobile platform for wheelchair users is mounted along the staircase ramp, with the staircase parallel to the ramp, the clear width of the staircase between the two current hands shall be min 1.50m, the width of the staircase ramp min 1.70m (see figure 3, 4) [4].

So, the new improvements must assure:

- Accessible path from building and/or parking.
- Accessible path from the edge of the play area to the play components.

- Equipment with transfer stations.
- Equipment is approximately 25% above ground level.
- Ramps leading to play areas.
- The floor should be covered with a rubberized material to mitigate falls.

Fig. 4. **The for access to the playground**

PERSONAL HYGIENE AREAS

- Personal hygiene areas should be accessible to both sexes. The initial space is presented in figure 5.

Fig. 5. **The initial bathroom**

The design for the new bathroom must take into account the following:

- Clear floor space in front of the toilet bowl should be 1.50 x 1.50m to allow wheelchair use.
- Clear space at the side of the toilet should be min 90cm, preferably 1.20m to allow transfer of the person from the wheelchair to the toilet space.
- The operating space in the room must allow the transfer of the wheelchair user from the wheelchair to the front, side and oblique (see figure 6,7).

 For children, the toilet bowl shall be positioned so that the distance from the longitudinal axis to the adjacent wall is between 30.5-38cm. The height of the toilet bowl should be between 20.5-38cm. The horizontal support bars should be positioned at a height of 51-63.5cm.

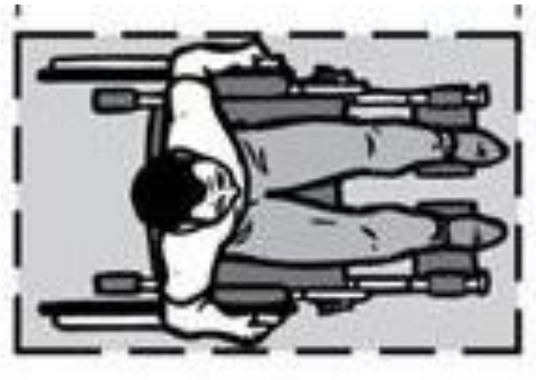

Fig. 6. **Plan view showing an outline of a clear floor space of 80 cm by 135 cm**

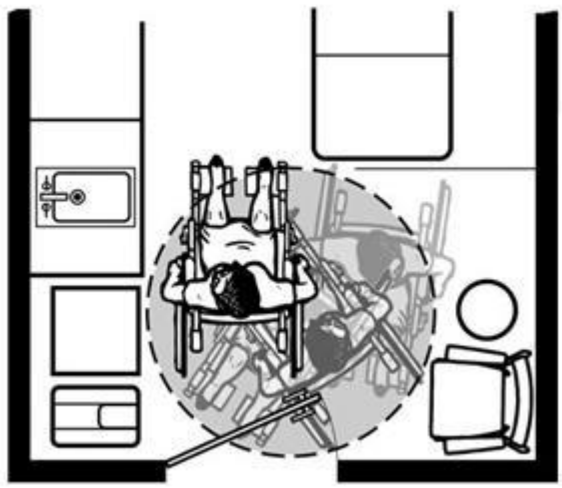

Fig. 7. **Plan view of part of an examination room showing clear floor space for turning a wheelchair. This space can also make it possible for the lift**

ACCESS TO THE TABLE

We also offer children a meal break during the programme in the built play area. So we have to provide a special place for children with disabilities and the possibility to stay at a table in a wheelchair.

 The space required for a table place will be min 80cm x 135 cm (see figure 8).

 The table top must be 80 cm above the finished floor level and the table must be shaped so that there is enough knee room.

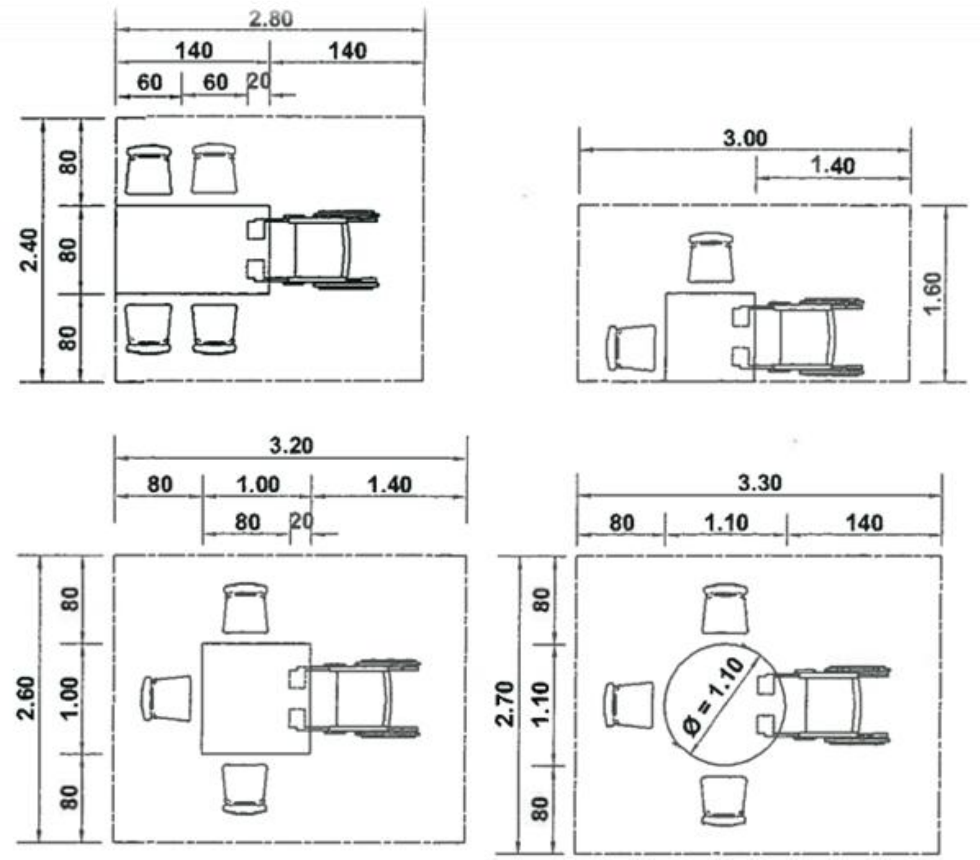

Fig. 8. **Required table space for wheelchair users**

EMPLOYEE SPACE

Analyzing the space, we noticed a lack of storage space for the accessories and equipment we own (various games, tables, bouncy castles, chairs), and this requires transporting them from the car and arranging them in the play area. This happens before and after each event because the space has to be cleared.

Another need for space would be to set up an office for the supervisor and staff. This should include a desk and an ergonomic chair to avoid various back problems, as well as chairs or a sofa for the rest of the staff because the hours spent at the playground are quite long.

The space should be bright and well ventilated

The presence of a kitchen is necessary in order to be able to serve meals between events and to prepare children's meals.

VISUAL, THERMAL AND SOUND ENVIRONMENT

The light sources in the room should be both artificial and natural. Children need enough light to carry out their activities and to see the obstacles around them and the equipment they use. An adjustable light can be used.

Colour perception of objects is determined both by the spectral characteristics of the light reflected from them and by the position and spectral composition of light sources. Variations in light intensity change the colour, which makes it necessary to choose light sources carefully according to the work task (see figure 9).

The thermal environment is very important, changing from day to day depending on the outside temperature. The playground must have its own heating source. A temperature of 22-24 degrees is recommended in winter.

The play area can also be equipped with air machines, which can cool or increase the temperature.

Soundproofing is very important because it is what we use to carry out our work.

It is recommended that it is within acceptable limits and does not disturb children or parents.

It is good to know that some children are very sensitive to noise (the children with autism) and it can affect their mood in a negative way. [5].

Fig. 9. **Proposed visual environment**

4. Conclusions

In conclusion, playgrounds should be adapted to ensure that all children can enjoy playground experiences. It would be unfair to exclude them simply because they cannot move, react or feel the same way as everyone else does. Spaces must allow access for all children to interact, communicate, share experiences and form friendships. In this way, a child with a disability will feel a considerable difference in his or her physical and mental state, knowing that he or she is finally integrated into society.

During the research, I tried to adapt the playground as I imagine it, in terms of accessibility, comfort and safety in the room. In the future, my plan is to complete the design of the playground accessories and platforms, including swings, slides, sensory boards, interactive walls, etc.

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AUTOMATED HANDLING OF MATERIALS IN LOGISTICS 4.0

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Summary: The purpose of this research was to create an AGV (Automated Guided Vehicle) to transport pallets from the warehouse and reduce work accidents. The following components were used: an Arduino board, an L293N2 motor driver, two geared motors and two wheels, an HC-SR04 distance sensor to avoid obstacles on the way, 2 infrared sensor modules for line tracking, a holder for 2 Li-ion batteries and the batteries themselves. A pallet grabbing system was also implemented using an SG90 servo motor.

Keywords: AGV, distance sensor, Arduino, Li-ion 18650 battery, L298N driver.

1. Introduction

In the context of logistics 4.0, technology plays an increasingly important role in the process of handling and transporting products. However, handling and transport issues remain one of the main challenges of the logistics industry. In this regard, the development and implementation of automated product handling solutions represent a priority for the logistics industry. In this study, we will analyze the technologies of automated product handling used in logistics 4.0 and present the integration of an AGV project in this context.

In the logistics industry, automated product handling technologies are becoming increasingly important. In this trend, robots and AGVs (Automated Guided Vehicles) are the most used solutions. Robotic wheels and arms are capable of performing a wide range of tasks, such as lifting and placing products in specific locations, while AGVs can be used to transport products between different points within a logistics facility.

Additionally, process control systems, which integrate sensors and artificial intelligence, can be used to automate and optimize the product handling process.

2. The current stage

Human operators traditionally have several disadvantages compared to automated guided vehicles (AGVs). Logistics service providers need to pay salaries on time, provide vacation time, and sick leave in case of accidents, which in many cases are inevitable. In contrast, an AGV only needs to be refueled from one working cycle to another and can avoid accidents and obstacles using a distance sensor that helps estimate the distance from the object to the AGV.

Moreover, when using a human operator for providing logistics services in a warehouse, unintentional human errors may occur, causing products to be mixed up or not stored in the designated location. However, in the case of using an AGV, these events cannot occur because they repeat the algorithm and route for which they were assigned. Before we begin, it is worth noting that using an AGV represents a major advantage for a logistics center looking to obtain high-quality logistics services, without errors, and in the shortest possible time.

Let's start by presenting the block diagram of the AGV's component connection, designed as a prototype to make it easier to understand the process of picking up a pallet with goods and transporting it from one point to another.

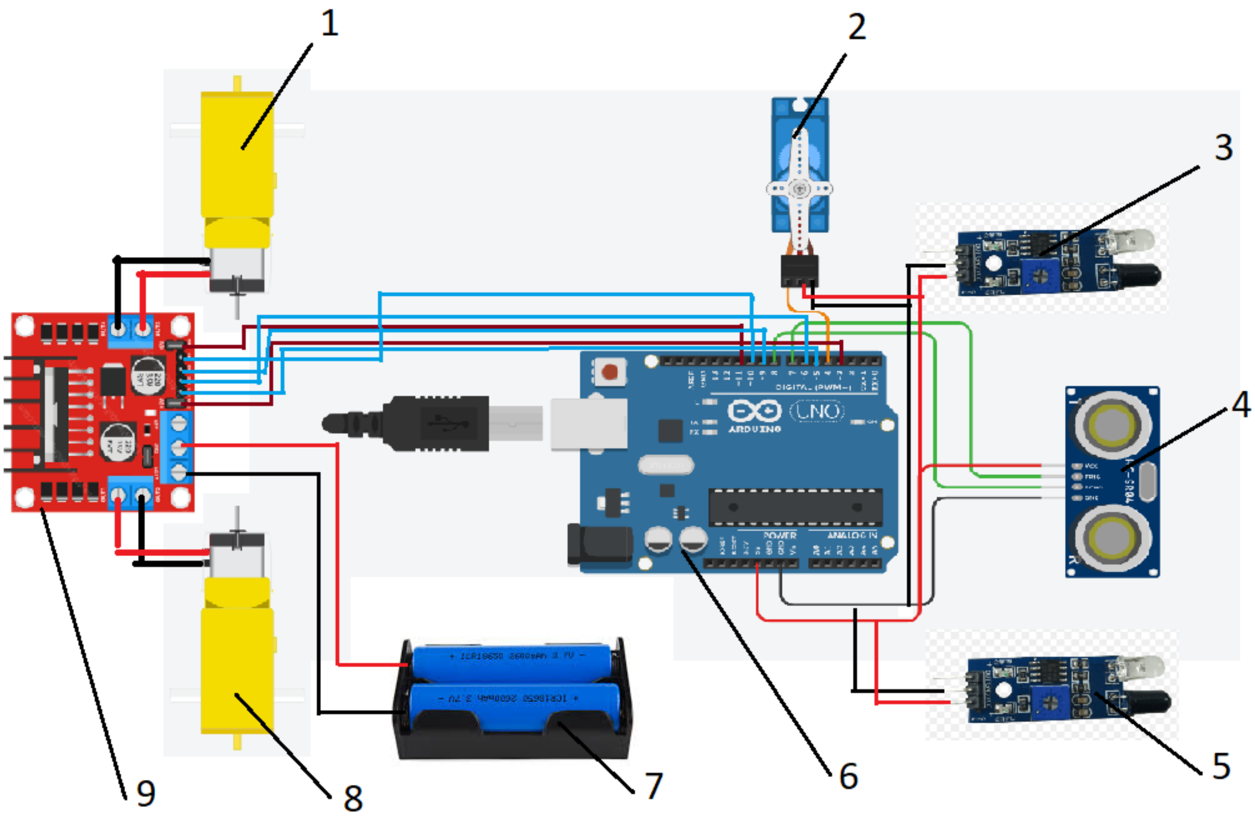

Fig. 1. Wiring diagram

Table 1. Components table

Nr.crt	
1.	Left gearbox motor
2.	SG90 Servo motor
3.	Left IR sensor
4.	HCSR-04 distance sensor
5.	Right IR sensor
6.	Arduino board
7.	Li-ION 18650 batteries
8.	Right gearbox motor
9.	L298N driver

The 3D model of the AGV that led to its physical creation from the virtual model is presented in Fig. 2.

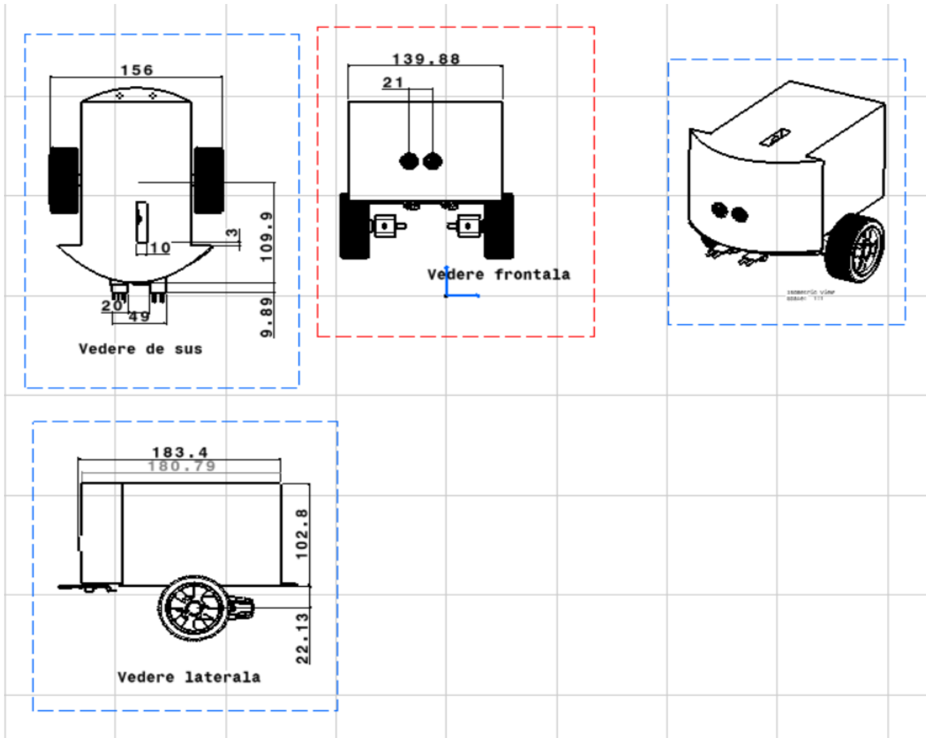

Fig. 2. 3D model of the AGV

The chassis model is made of plexiglass, measuring 20x10, on the back of which the 2 wheel motors were attached, and on the top surface the Arduino board was attached, a L293N motor driver, which was interconnected with the Arduino board, the battery holder with 2 Li-ION batteries. The HC-SR04 distance sensor was also connected to the board to avoid obstacles and the 2 IR infrared sensor modules to track the AGV guide line. The connections between the driver, board, and sensors were made through jumper wires. The casing was made of cardboard, which was later painted to give it a unique and pleasant appearance, according to the virtual model. First, the input variables must be defined (for example, pins of the distance sensor, motor pins, and IIR pins). Then, the algorithm for detecting objects is introduced.

```
#include <Servo.h>

Servo myservo;

int trigPin = 7;
int echoPin = 8;
int IR1 = 12;
int IR2 = 13;
int ENA = 3;
int ENB = 11;
int IN1 = 5;
int IN2 = 6;
int IN3 = 9;
int IN4 = 10;
```

Fig. 3. The pin definitions for the AGV components

```
  // Setarea vitezei motorului
  int motorSpeed = 150;

  if (line1 == LOW && line2 == LOW) { // dacă robotul este pe linia albă
    digitalWrite(IN1, HIGH);
    digitalWrite(IN2, LOW);
    digitalWrite(IN3, HIGH);
    digitalWrite(IN4, LOW);
    analogWrite(ENA, motorSpeed);
    analogWrite(ENB, motorSpeed);
  } else if (line1 == HIGH && line2 == LOW) { // dacă robotul este la stânga
    digitalWrite(IN1, LOW);
digitalWrite(IN2, LOW);
digitalWrite(IN3, HIGH);
digitalWrite(IN4, LOW);
analogWrite(ENA, motorSpeed / 2);
analogWrite(ENB, motorSpeed);
} else if (line1 == LOW && line2 == HIGH) { // dacă robotul este la dreapta
digitalWrite(IN1, HIGH);
digitalWrite(IN2, LOW);
digitalWrite(IN3, LOW);
digitalWrite(IN4, LOW);
analogWrite(ENA, motorSpeed);
analogWrite(ENB, motorSpeed / 2);
}
```

Fig. 4. The algorithm for the AGV movement

The operating principle is as follows: The L293N driver works with the 2 gear motors through the transmission and distributes the power supply received from the battery. The Arduino board orders the movement of the AGV by transmitting commands from the board's microprocessor to the driver. The HC-SR04 distance sensor detects objects appearing on the path and, if they are within 10 cm, redirects the AGV off the path to avoid collision.

```
void loop() {
  // Măsurarea distanței cu senzorul ultrasonic
  long duration, distance;
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
  duration = pulseIn(echoPin, HIGH);
  distance = (duration/2) / 29.1;
```

Fig. 6. The algorithm for distance calculation

Set the trigger pin of the HC-SR04 distance sens the infrared IR sensor modules detect the base color of the floor and follow the black line, and when the line is perpendicular to the direction of travel, it sends a command to the Arduino board to stop the motor reducers, as the AGV has reached its destination.

```
// Detectarea liniilor negre
int line1 = digitalRead(IR1);
int line2 = digitalRead(IR2);

// Setarea vitezei motorului
int motorSpeed = 150;

if (line1 == LOW && line2 == LOW) { // dacă robotul este pe linia albă
  digitalWrite(IN1, HIGH);
  digitalWrite(IN2, LOW);
  digitalWrite(IN3, HIGH);
  digitalWrite(IN4, LOW);
  analogWrite(ENA, motorSpeed);
  analogWrite(ENB, motorSpeed);
} else if (line1 == HIGH && line2 == LOW) { // dacă robotul este la stânga
  digitalWrite(IN1, LOW);
digitalWrite(IN2, LOW);
digitalWrite(IN3, HIGH);
digitalWrite(IN4, LOW);
analogWrite(ENA, motorSpeed / 2);
analogWrite(ENB, motorSpeed);
} else if (line1 == LOW && line2 == HIGH) { // dacă robotul este la dreapta
digitalWrite(IN1, HIGH);
digitalWrite(IN2, LOW);
digitalWrite(IN3, LOW);
digitalWrite(IN4, LOW);
analogWrite(ENA, motorSpeed);
analogWrite(ENB, motorSpeed / 2);
}
```

Fig. 7. Algorithm for setting up IR sensors and motor-reducer speed

At that moment, the SG90 servo motor makes a 180-degree movement to pick up the pallet.

```
// Așteaptă 30 de secunde după ce detectează o linie neagră pentru a continua
int waitTime = 30000; // 30 de secunde
static unsigned long lastDetectionTime = millis();
if (line1 == LOW && line2 == LOW && millis() - lastDetectionTime > waitTime) {
lastDetectionTime = millis();
myservo.write(180); // ridică paleta
delay(3000); // păstrează paleta ridicată timp de 3 secunde
myservo.write(0); // lasă paleta
delay(3000); // păstrează paleta jos timp de 3 secunde
}
}
```

Fig. 8. Algorithm for pallet handling mechanism

After connecting the elements and uploading the code to the Arduino board, we obtained a prototype as shown in fig.9.

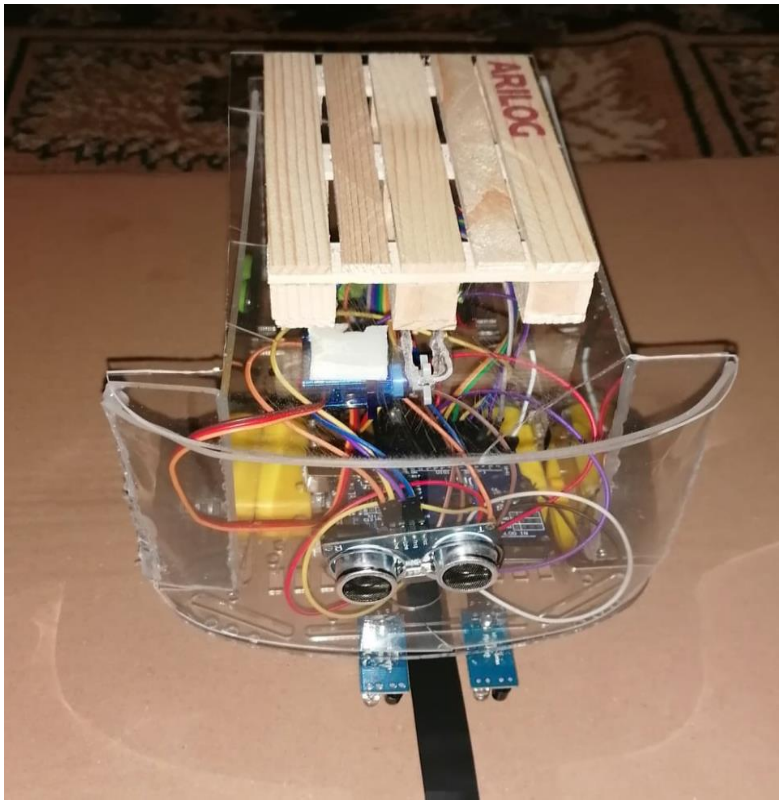

Fig. 9. Prototype of AGV

3. Conclusions

In conclusion, automated product handling technologies are playing an increasingly important role in the logistics industry, and Logistics 4.0 offers excellent opportunities for optimizing product handling and transportation processes. The AGV project presented in this study can be integrated into a Logistics 4.0 system through the use of sensors and artificial intelligence. Implementing these technologies can lead to improved efficiency and cost reduction in the logistics industry.

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Study on the development of a conveyor with reorientation system

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SUMMARY: The study wants to identify, model and automate the way, which will lead to the development of a new conveyor with a system for reorienting the boxes, to be integrated in the palletizing process. Such an automated system must shorten the palletizing time and reduce certain costs in this process. Together with other colleagues, I want this study to materialize in the creation of a teaching stand for the Industrial Logistics specialization laboratory within the faculty. On a personal level, I want to improve this system next year as well, for the completion of my bachelor's thesis.
KEYWORDS: conveyor, reorientation system, palletizing

1. Introduction

Following the manufacturing flow of a product, after the packaging stage, a chaining of equipment used in the palletizing process is defined.

Palletizing is the process of placing the boxes on a layered pallet, where a system of reorientation of the boxes is used so as to obtain, at the end, a pallet consisting of 4 or 5 layers. The layers are oriented so as to create a link between them for a better stability of the boxes on the pallet.
The boxes, already formed and containing products, are taken over by a belt conveyor, type Z. The conveyor has two roles: the first is to transport the boxes over a certain distance, and the second is to climb them to a certain height, which is necessary to start the palletizing process.

At the top of the conveyor there is the system of reorientation of the boxes, it has the role of orienting the boxes, so that when creating a layer, it is oriented opposite to the previous one, forming a connection between two different rows on the pallet.

2. Development of a conveyor with a reorientation system

2.1 Belt conveyor, Z-type

It can be used in the food industry, warehousing and logistics industry (Figure 1a), packaging industry, delivery industry (Figure 1b), electronics and electrical industry, pharmaceutical and other industries, and it can improve the efficiency of transportation and loading and unloading of various goods.

Fig. 1 a. logistics industry b. delivery industry

The development of such a conveyor must take into account certain parameters that satisfy the needs of the manufacturing flow. These parameters are illustrated in the diagram (Figure 1).

In addition to dimensional parameters when configuring a conveyor, there are some other criteria that help automate the flow matter, such as:

a. Lane movement speed
b. Weight of the box transported
c. Engine power and type
d. The height at which the transport of the box begins
e. Height to which the box must be raised

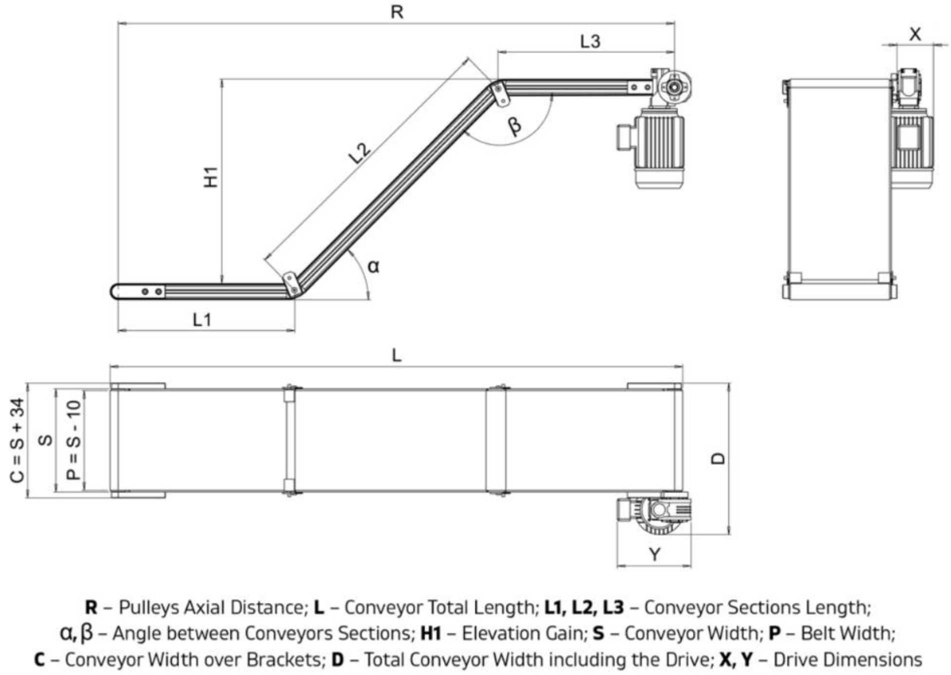
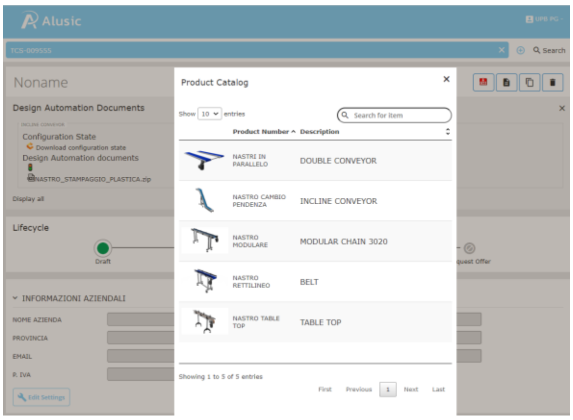


Fig. 1 Diagram of presentation of construction parameters

For the realization of the conveyor in 3D CAD, an online configurator, Alusic, was used by choosing the model (Figure 2a):

a. 

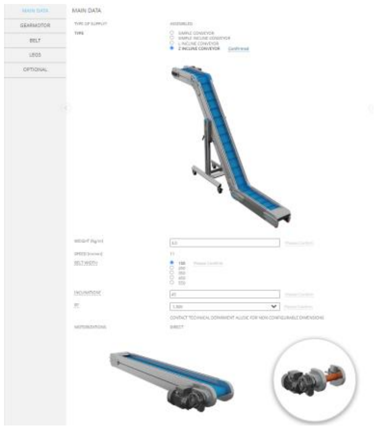
b. 

Fig. 2 Online configurator: a. Choice of model b. Entering parameters

Following the steps in the configurator (Figure 2b), at the end you get the 3D format (Figure 3):

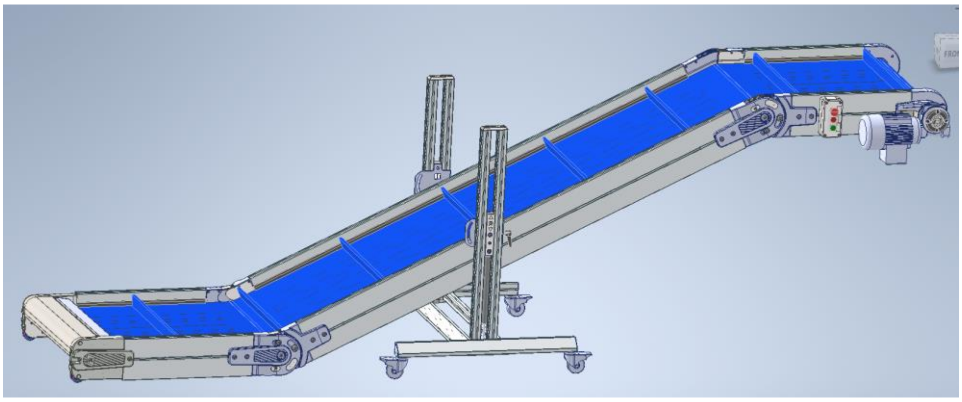


Fig. 3 Belt conveyor, type Z, 3D CAD

2.2 Reorientation system

The reorientation of the boxes can be done depending on the size, weight, and specifications of the boxes (Figure 4).

Fig. 4 Orientation of boxes

2.2.1 Types of re-guidance systems

Taking into account the needs of the palletizing process, there are several types of reorientation systems:

a. Fixed systems (uneven reorientation) that can be mounted / disassembled on the conveyor belt. These systems are frequently used in applications at low speeds and have a low implementation price (Figure 5).

b. A turning system using two conveyor belts, operating at two different speeds. The belts are adjusted according to the size and weight of the boxes (Figure 6).

c. Pushing reorientation system is a side guide that rotates the box 90° and helps to reorient them (Figure 7). The system is pneumatic with air consumption per cycle at 6bar of 1.3 liters and it is fully automated.

Fig. 5.
Bumpy return system

Fig. 6.
Two-band reorientation system

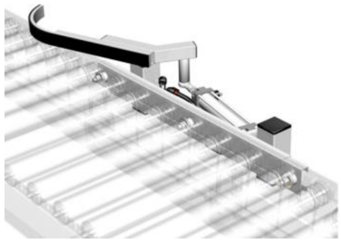


Fig. 7.
Push refocusing system

2.2.1.1 Pneumatic pushing system for refocusing boxes (Figure 8).

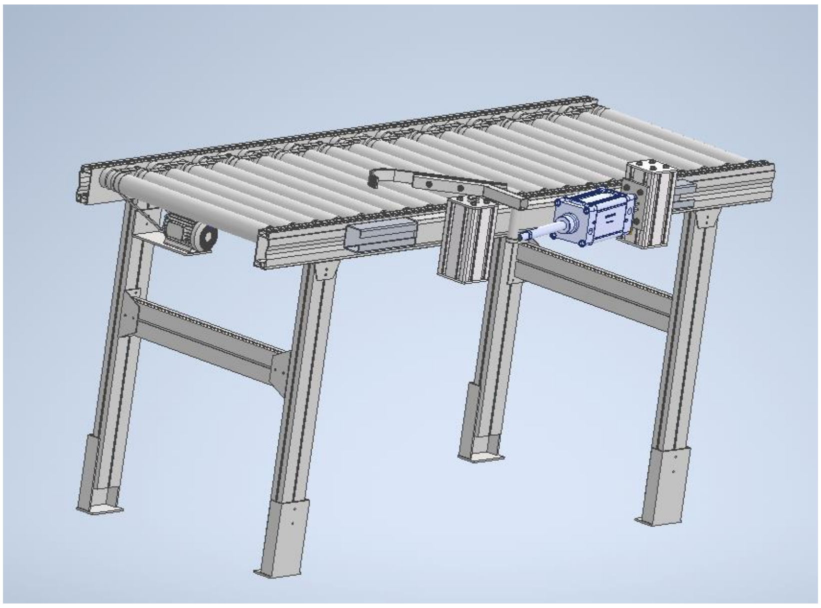


Fig. 8 Pneumatic pushing system

The system uses a rod driven (Figures 9: a and b) by a pneumatic motor, which together with the sensor operates according to a certain algorithm.

a. 

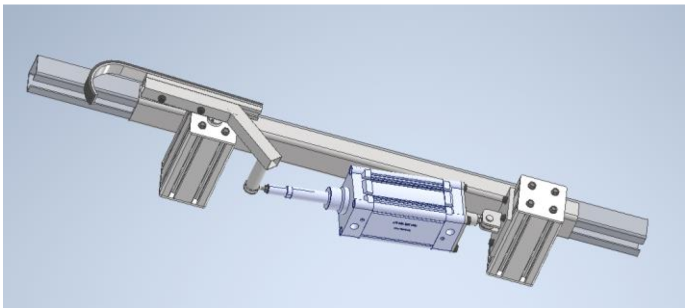
b. 

Fig. 9: a. Real picture b. 3D CAD modeling

The command program algorithm is:

a. Configure the sensor to detect four boxes. This can be done using the compare statement or the counting statement.

b. Pneumatic motor trigger: after the sensor detects four boxes, the pneumatic motor is triggered to action the push rod. This can be done by means of output instructions.

c. After the pneumatic motor has been triggered, configure the sensor to detect two series of three boxes passing by its right. This can be done by means of the counting instruction.

d. Configuring the mirror sensor: in the next cycle, configure the sensor to work in the mirror so that it first detects the two series of three boxes, followed by the last series of four boxes. This can be done by means of the counting instruction.

2.2.1.2 System of reorientation of boxes using the different rotation speed of the reels on the same conveyor (Figure 10).

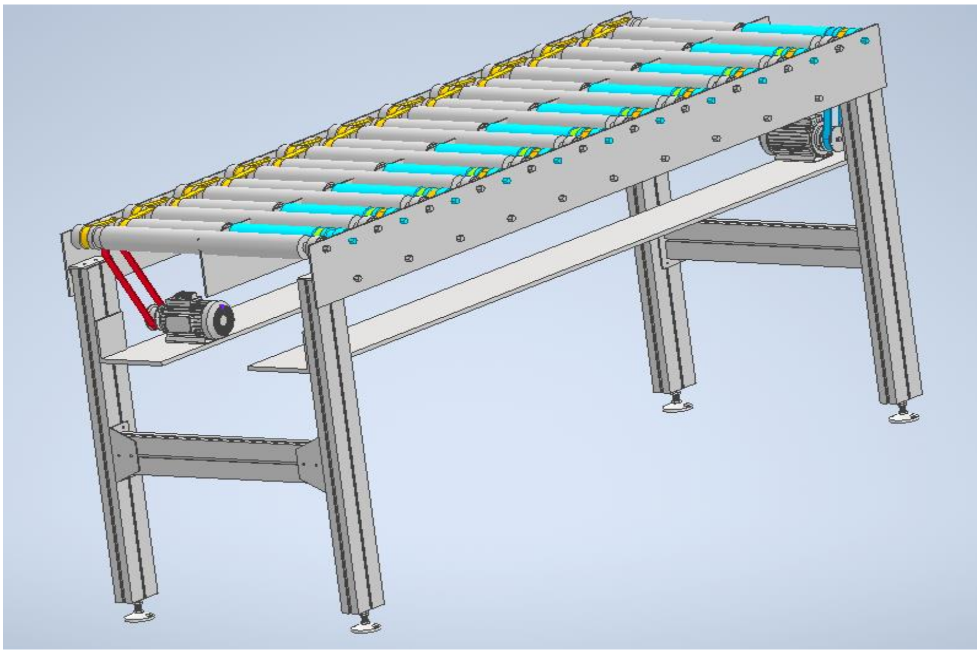


Fig. 10 Roller system that rotates at different speeds

The system also uses two engine systems that act differently on certain rollers of the conveyor. One works normally (Figure 11), thus moving the boxes along the entire length of the conveyor. The colored reels (Figure 12) are inactive (free rotation) when it is not desired to reorient the boxes and run at a different (higher) speed than normal.

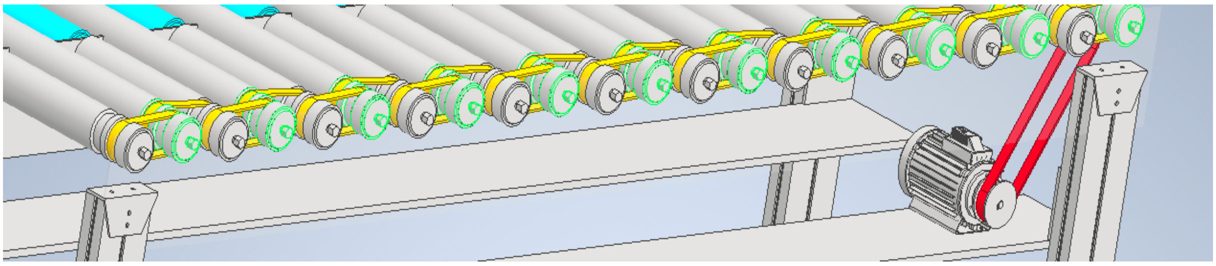


Fig. 11 Normal speed

It is noted that a normal transport speed the transmission is carried out by tying the strap in series, so the transmission is strung from roller to roller.

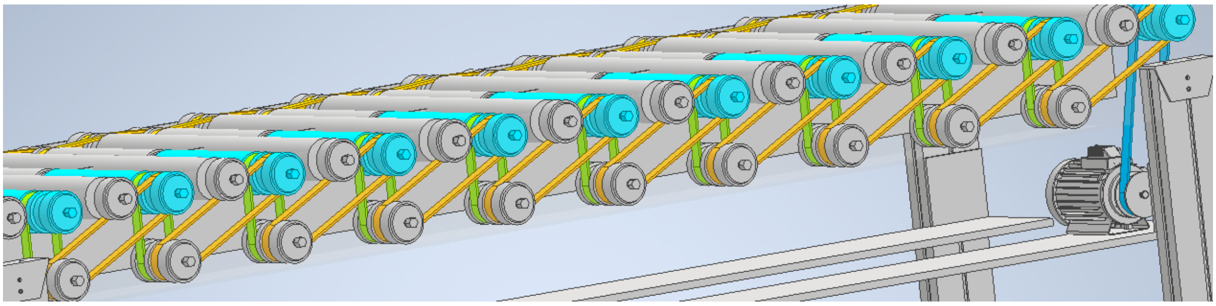


Fig. 12 Different speed

By a separate command to change the frequency, a different speed is obtained. It could be seen that the transmission through the straps is carried out by jumping over a row of rollers, and it is said that they are tied in parallel.

3. Conclusions

As a result of the study, for the first time we used a configurator used in the construction of conveyors, which helps a lot in regarding certain aspects of how they are made.

We have identified ways to achieve the reorientation of the boxes, which led to the realization of two 3D CAD models: the first, that uses a pneumatically operated rod for reorientation of the boxes, and the second one that uses the speed difference between two rows of rollers on the same conveyor.

I want to develop a system to support any graduation work (paper, thesis) and to build a teaching stand with my colleagues.

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OPTIMIZATION OF AGV ROUTES IN A SMART WAREHOUSE

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In this article we have set out to develop a small-scale AGV, where we have designed a virtual model and a wiring diagram of its sensors and components. So far, we have succeeded in making a prototype that can be controlled by remote control and is to be developed to be autonomous. We will explore the technical details and challenges involved in building an efficient and functional low-level AGV. Objectives include evaluating the advantages and disadvantages of forklift AGVs over other types of AGVs and identifying ways to optimize routing and storage using forklift AGVs. The methods used include literature search and study to develop a small-scale forklift AGV system that can be integrated into a warehouse.

1. Introduction

Optimizing AGV routing in a smart warehouse uses IoT technology and artificial intelligence algorithms to collect and analyze data about AGV movement and status, as well as storage inventory. The goal is to reduce delivery time, minimize operating costs and increase warehouse performance by using AGVs efficiently. Optimal planning and scheduling of AGV movements is carried out in real time to avoid congestion and wasted traffic time and to ensure efficient use of resources and warehouse space. Figure 1 shows three types of AGVs used in warehousing and logistics: forklift AGVs, platform AGVs and trailer AGVs.

a) AGV Forklift b) AGV with platform c) AGV with trailer

Fig. 1. Types of AGVs

2. The current stage

Forklift AGVs are increasingly popular in warehousing and logistics due to increased productivity and space optimization. With the ability to move autonomously and handle goods, they are an efficient alternative to traditional forklift trucks. Despite advances in optimizing AGV routes through genetic algorithms or neural networks, challenges such as congestion and safety in the warehouse still exist. Current developments involve using IoT technology and improving AGVs to meet the needs of smart warehouses [1].

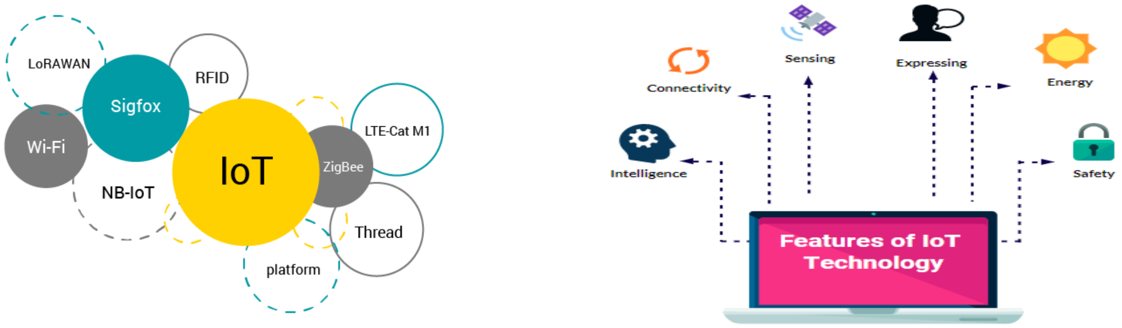

Fig. 2. Internet of Things Technology

The AGV forklift is an innovative solution for storing and handling goods, bringing efficiency and autonomy to any company. Integrated into a smart warehouse, it can transport and handle goods, load, and unload trucks, optimizing space and resources. With IoT technology and real-time data analytics, the forklift AGV improves warehouse performance and reduces human error, helping to streamline operations.


Fig. 3. Example of AGV Forklift

Fig. 4. Example of sensors used in an AGV structure

Currently there are solutions for optimizing AGV routing in smart warehouses, but they are only applied in large and complex warehouses [5]. Future solutions focus on IoT and artificial intelligence and are based on advanced data collection and analysis. Therefore, current technologies for such as 5G networks used to coordinate AGVs will play a crucial role in warehousing and handling of goods.

A major advantage of using forklift AGVs is that they can transport and handle large loads, unlike platform AGVs and trailer AGVs. Its ability to lift and transport pallets of goods makes it ideal for automated warehouse operations.

3. Steps in the development of the AGV

The forklift AGV designed for small-scale production was developed with the aim of being used for research and understanding how this type of automated guided vehicle works.

The stages in the development of this system were as follows:

- Component design and procurement

The designed AGV (figure 5) is driven by four DC motors, which provide the necessary propulsion for travel, and the drive of the lifting system is operated by a stepper motor (figure 6).

Two L298N drivers were used to drive the DC motors (figure 7). These allow control of the direction and rotational speed of the motors, thus ensuring precise movement of the AGV.

The MPP driver (figure 7) was used to drive the specific motor of the lifting system. The stepper motor drivers convert the impulse signals from the controller into motor motion to achieve precise positioning.

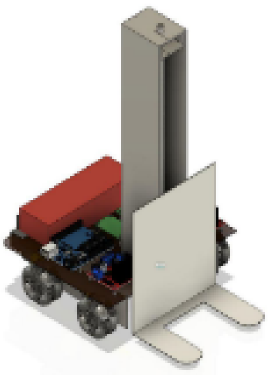

Fig. 5. AGV - virtual model

Fig. 6. Motors used for drive

Fig. 7 Motor drivers

- Processing and assembly of components.

The creation of the AGV system was an extremely important step and involved the processing of the infrastructure components and their assembly (figure 8).

Materials used to make the chassis:

  - Polycarbonate plate
  - Aluminum profile
  - Lead screw
  - Fasteners

Fig. 8. Different phases in the processing and assembly of the designed system

After assembling the mechanical components, the connections between the actuation components and the drivers, respectively the Arduino board and the connections between the sensors and the Arduino board were made. The detailed schematic showing all the components is shown in figure 8.

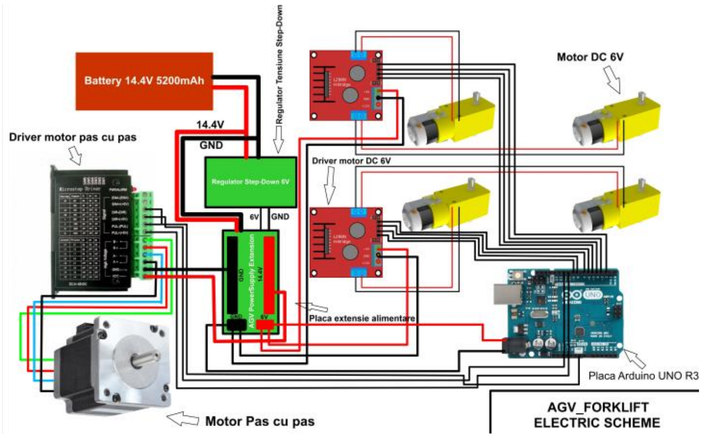

Fig. 8 Wiring diagram of actuator and control components

The AGV is powered by 4 omnidirectional Mecanum wheels, which allow movement in plane, in any direction. This is achieved by means of rollers mounted on the circumference of the wheel that facilitate movement in any direction and at any angle [3].

Figure 9 highlights the directions in which the omnidirectional wheels can move in relation to how they are operated.

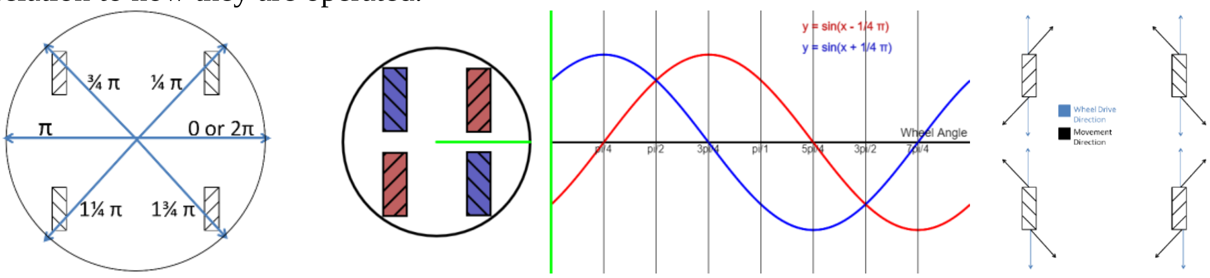

Fig. 9. Omnidirectional wheels movement

4. Conclusions

The design and development of a forklift AGV for the autonomous transport of goods in a smart warehouse, made on a small scale, was presented.

All the steps taken to design, procure, process, assemble, and program the automated guided vehicle, were briefly highlighted.

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