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

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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.

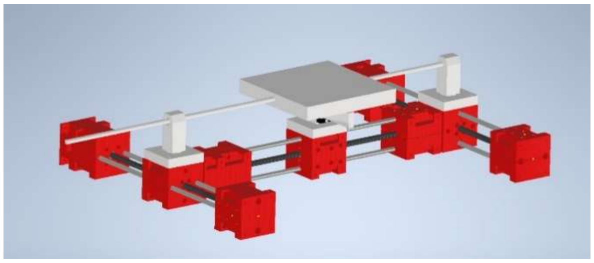

Fig. 1. Digital Twin of the X-Y-Theta modular platform

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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.

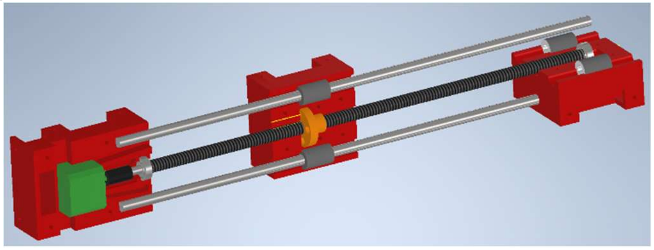


Fig. 2. Internal structure of a single axis

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.

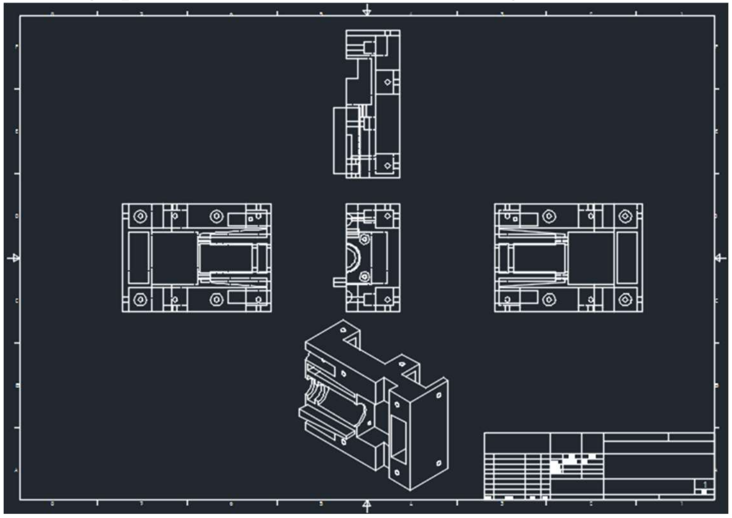


Fig. 3. Drafting views of the motor cover

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.

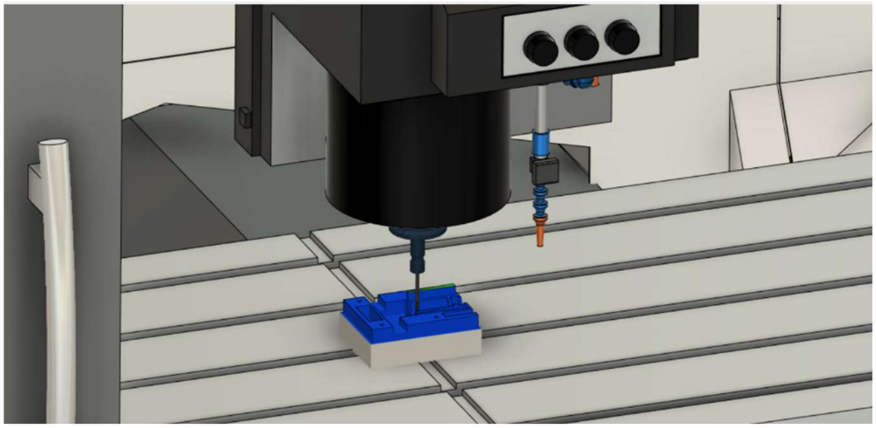
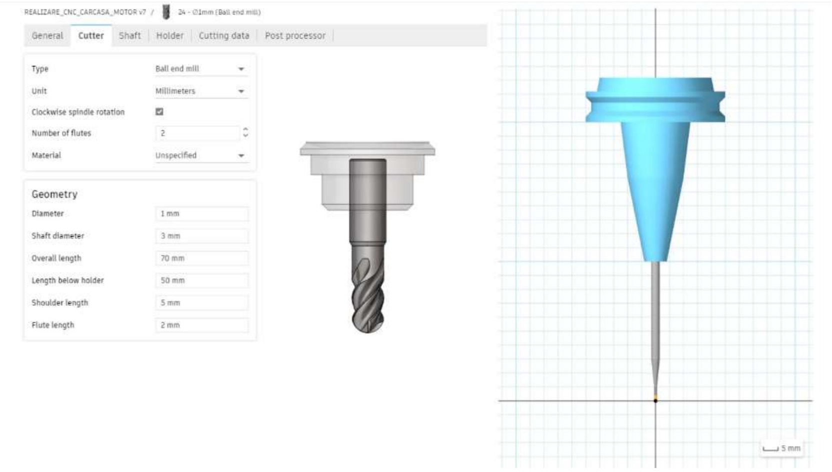


Fig. 4. Capture during the CAM simulation



REALIZARE_CNC_CARCASA_MOTOR v7 / 24 - Ø1mm (Ball end mill)

Type: Ball end mill
Unit: Millimeters
Clockwise spindle rotation: ☑
Number of flutes: 2
Material: Unspecified

Geometry
Diameter: 1 mm
Shaft diameter: 3 mm
Overall length: 70 mm
Length below holder: 50 mm
Shoulder length: 5 mm
Flute length: 2 mm

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.

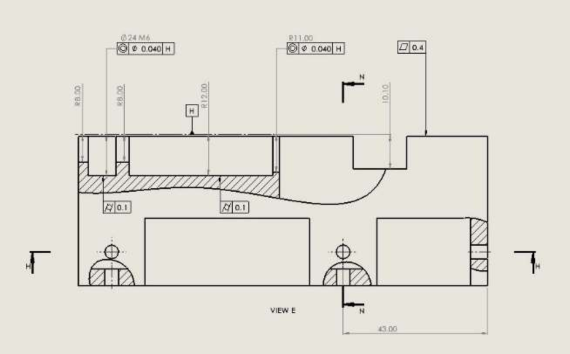


Fig. 7. GD&T prescriptions on the main drafting

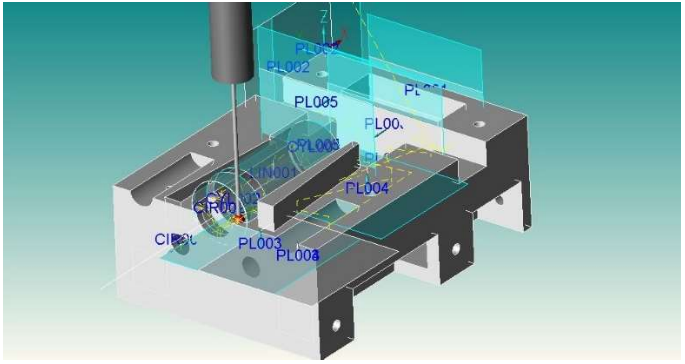


Fig. 2. Geometrical characteristics inspected on the CMM

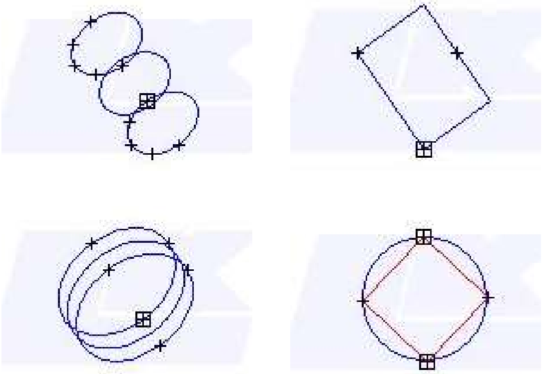


Fig. 3. A number of outputs resulted at the end of CMM inspection

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.

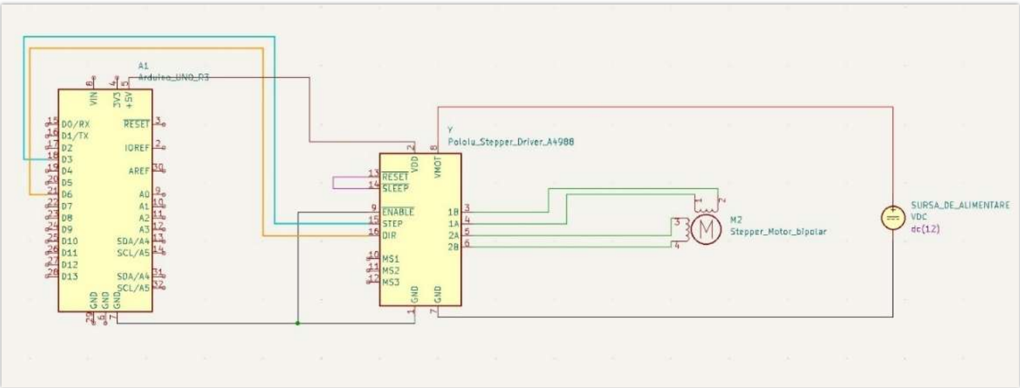


Fig. 4. Electrical diagram designed in Kicads

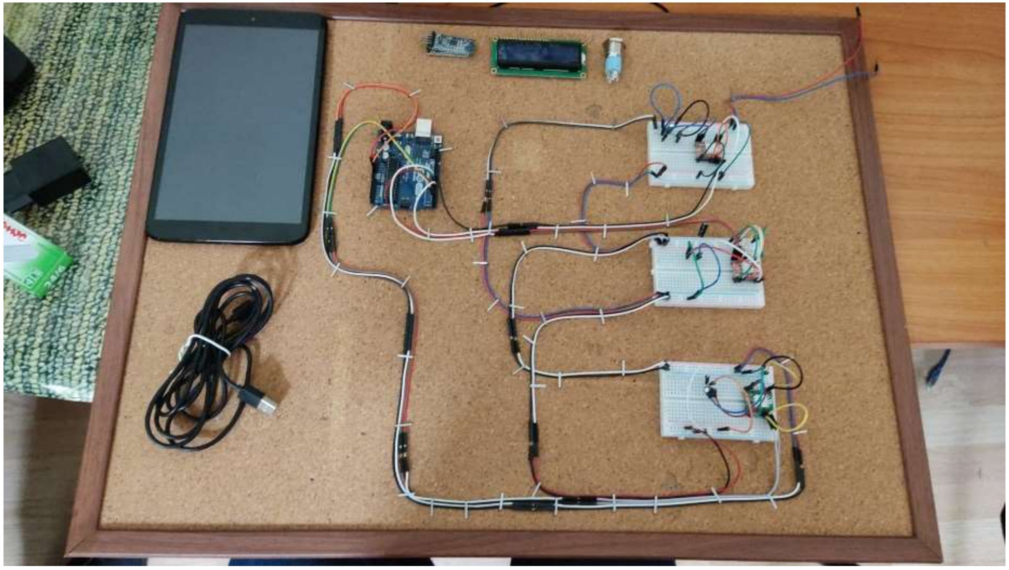
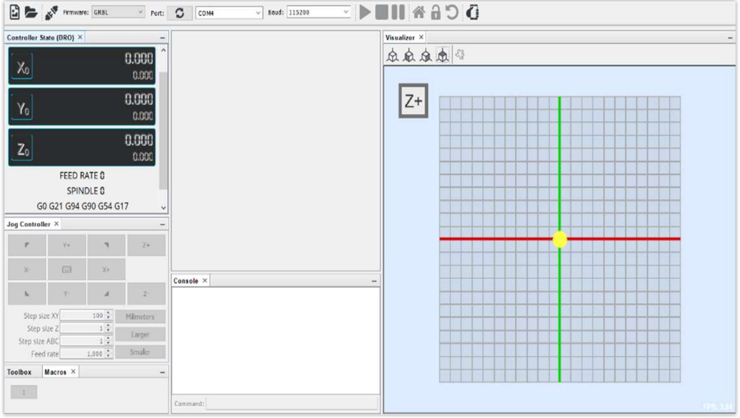


Fig. 5. Real life electrical pannel

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.



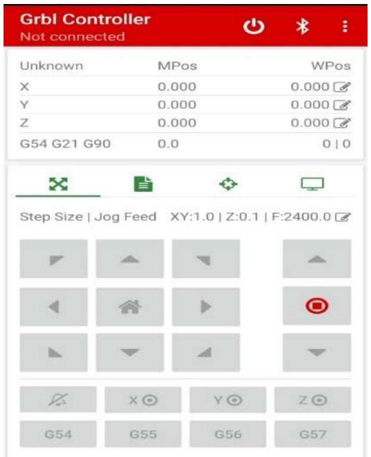
Firmware: GRBL
Port: COM4
Baud: 115200

X0 0.000 0.000
Y0 0.000 0.000
Z0 0.000 0.000
FEED RATE 0
SPINDLE 0
G0 G21 G94 G90 G54 G17

Step size XY 100
Step size Z 1
Step size ABC 1
Feed rate 1,000

Command:

Fig. 6. Windows interface used for communication



Not connected

Unknown	MPos	WPos
X	0.000	0.000
Y	0.000	0.000
Z	0.000	0.000
G54 G21 G90	0.0	0 | 0

Step Size | Jog Feed XY:1.0 | Z:0.1 | F:2400.0

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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