EVALUATING THE POSSIBILITY OF REPLACING SOME COMPONENTS WITH PARTS MADE BY USING ADDITIVE TECHNOLOGY

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ABSTRACT: The paper tries to identify if the possibility of replacing some industrial components frequently used in industrial area that performs assembly operations is a viable solution. Within the paper, these components are proposed to be made through Fused Filament Deposition-FFD additive technology. As an example, a simple and well-known model of gripper was chosen so that it can be easily compared with those already existing on the market. Research has shown that, from an economic point of view, it is feasible to use this solution, especially where the assembly processes are affected by frequent changes and the geometry of the assembled parts is very different.
KEYWORDS: fused filament deposition, gripper, additive manufacturing, 3D print, costs evaluation

1. INTRODUCTION

A gripper is the device at the end of a robotic arm, designed to interact with the objects. The exact structure of this device depends on the application of the robot. Although the structure of the mechanisms in the structure can be diverse, the shape of the gripping surface must be chosen depending on the shape of the objects to be handled. This is a real problem when the shape of the objects is varying due to frequent changes in the production structure. Of course, there is a known solution to replace the gripper, but this is not the best one from an economic point of view. At least for this reason, the paper aims to highlight the costs of production for the elements of a gripper by using additive manufacturing, more precisely by Fused Filament Deposition-FFD.

3D printers that use filament are based on additive technology for depositing successive layers of material. The material to be deposited is stored on a filament spool, which ensures the continuous feeding of the extruder. The extruder heats the material a specific temperature, and places it in successive layers of a same thickness and in a certain shape following a specific path of each layer. In other words, in this process, a thermoplastic filament is extruded through an extruder and deposited into successive layers [1, 2].

The paper also exemplifies the operation of the gripper by a semi-automatic method. For this paper, a small prototype was developed for handling light objects.

2. GRIPPER COMPONENTS

The manipulator components, presented in figure 1, were printed on a Zortrax M200 3D printer [3]. Considering the destination, it is necessary that the material from which the parts are printed can maintain its properties under stiffness conditions. One of the materials that meets this condition is the polylactic acid PLA type [4]. PLA is the most common 3D printing material because it is easy to use and is made from renewable resources and thus, biodegradable. PLA filament is useful in a broad range of 3D printing applications, being both odourless and low-warp, and does not always require a heated bed [5, 6].

For simplicity, the Standard printing mode of the slicer application Z-Suite of the Zortrax printer was used. Depending on the concrete requirements, the degree of finishing can be improved by a number of additional layers. For the components described in this paper, the following were chosen: two outer layers, 20% infill percentage of linear geometry pattern, and normal print speed.

Aside printed components the following components are also required: 12 V stepped motor, a 3D joystick, one 12V voltage supply, one start / stop button, one reset button and an Arduino Due development board.

The claws are equipped with saw-like ends for a better grip of irregularly shaped materials. In application, they can be changed with any type of shape. This modification is easily done in the CAD file and does not impact on the obtaining of objects by additive technology.

The left claw of the manipulator has a shoulder (figure 2) that will be used to actuate the limit switch. The claws will be assembled with the help of fixing rods (figure 3). To reduce the production costs of the gripper, assembly was made with fastening rods printed from the same material as the rest of the parts. They have the same exterior diameter as the holes in the gripper parts. At the same time, they have a support at one end, being hotly fixed at the other end.

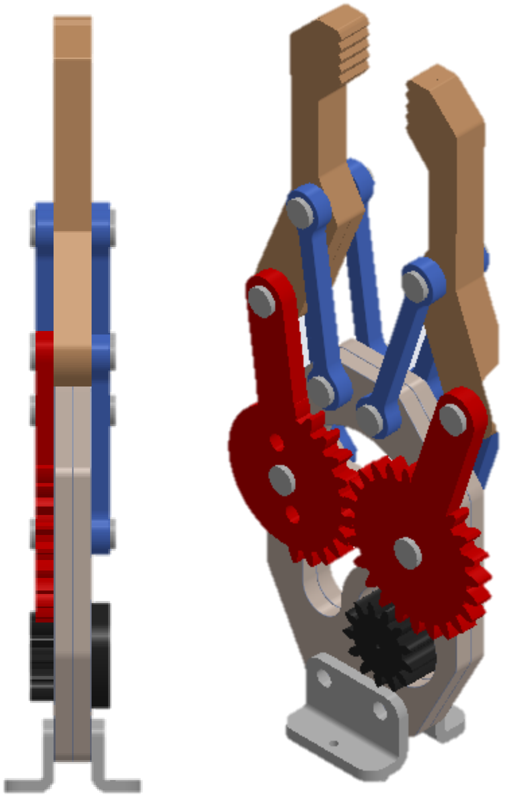
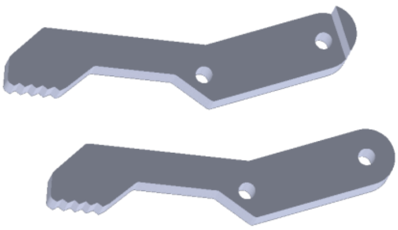


Figure 1. Gripper (side and 3D view)



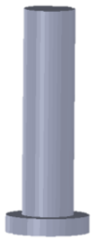


Figure 2. Left and right claws **Figure 3.** Fixing rod

The sprocket (figure 4) has a through hole so that it can be easily mounted by pressing on the stepper motor shaft. It has teeth with the same pitch as the toothed arms for easy mounting and actuation. It is very important to mount the gear as firmly as possible in relation to the gears sectors from claws, to reduce the risk of the motor turning idle.

The gripper components will be mounted on a fixing plate (figure 5). The plate will be fixed with two screws to the gripper support.

To be able to assembly all the parts and the electric motor, a gripper support has been designed (figure 6). The support has a bracket on which the microswitch will be mounted with screws. Similarly, the gripper will be fixed to the support with four screws.

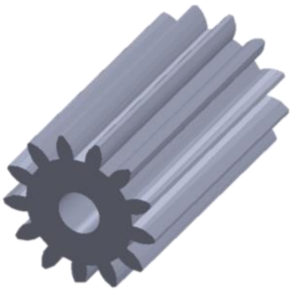


Figure 4. Sprocket **Figure 5.** Fixing plate

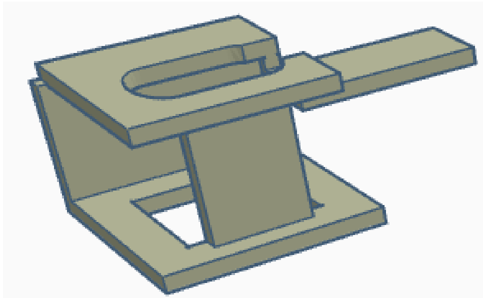


Figure 6. Gripper support

To create a system with all the components, a small box has been designed that will protect the parts and will leave only the gripper visible. The box has clearances for the power cord and the USB cable from the development board. The box features mounting rods for the joystick and development board (figure 7).

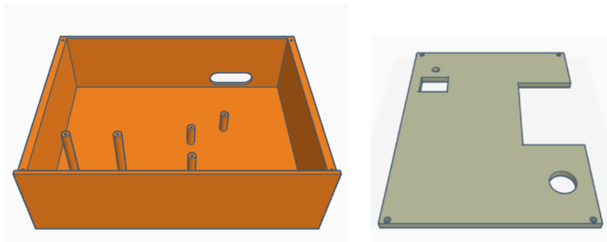


Figure 7. Box and top plate

The described parts are assembled inside the box, the final form being presented in the figure 8.

Figure 8. Assembled system

3. DESIGN OF THE ELECTRONIC SYSTEM

To start the electrical design, a diagram containing the blocks needed for system development was designed, as can be seen in figure 9.

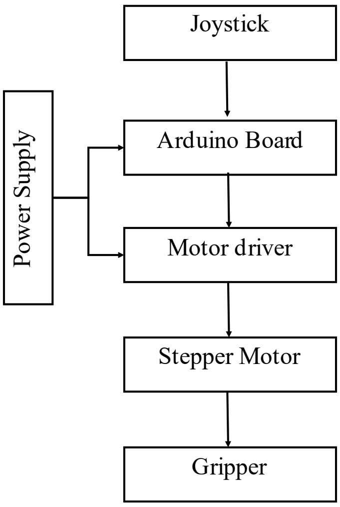


Figure 9. Block diagram

Arduino Uno is a board based on the ATmega328P processor [7]. This development board is having 14 digital input/output pins, 6 analogue inputs, a 16 MHz ceramic resonator, a USB connection, and a power jack.

The motor used in the development of the system is a bipolar stepper motor, with a pitch of 1.8°, which develops a torque of 0.23 Nm. The motor driver is Big Easy Driver, produced by SparkFun and is based on an AllegroA4988 integrated circuit [8]. This board can drive up to a max of 2A per phase (1.4-1.7A/phase without cooling) of a bi-polar stepper motor. It is a chopper micro stepping driver which defaults to 16 step micro stepping mode.

Motor control is done by providing two parameters from the development board, direction, and step. The driver circuit has implemented the micro-step control algorithm for stepper motors, this means that the motor step is divided into a number of micro-steps. This circuit divides the engine pitch from 1.8° to 16, which means that, after receiving a step command, the engine will rotate 0.11° and considering the gear ratio, precise control is ensured, even beyond requirements.

The connection of the stepper motor, through the driver, to the Arduino development board was done according to Big Easy Driver User Manual [9] and is presented in the figure 10.

As can be seen in diagram, the development board is connected to the driver board via two pins at the "Step" and "Direction" outputs which provide information for stepper motor control, and a connection to the ground between the two circuits.

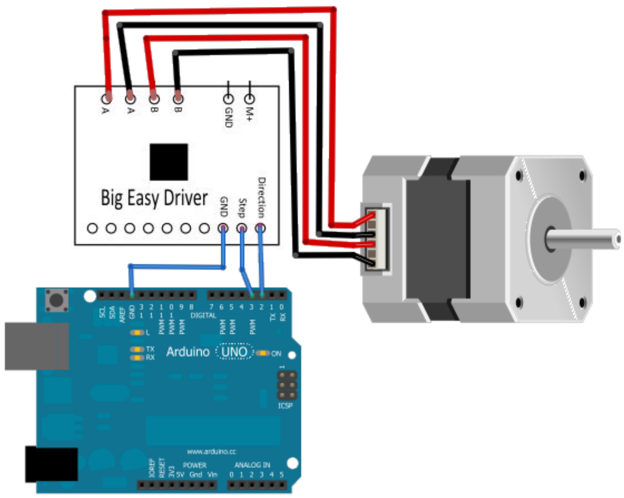


Figure 10. Stepper motor - driver - development board connection [9]

An Omron microswitch is used to determine the reference point and the end of travel of the gripper. The pins used were GND and NO. The microswitch is connected to a digital input of the development board, and to the ground.

It was chosen to implement a button to reset the position of the manipulator in case of a fault during its operation. Pressing this button calls up the reference mode of the manipulator. The button is connected to a dedicated digital input RESET of the development board, and to the ground.

A 3D joystick is implemented to operate the closing / opening movements of the gripper. It provides two-axis movement but for the project presented, only the movement on the Y axis of the joystick was used. To be able to mount it, a small PCB was designed on which both the joystick support pins and the pins on which its position is read were soldered.

4. SOFTWARE IMPLEMENTATION

The Arduino board is the central component of the whole system, because it controls all actions, through a program loaded in its memory. The integrated software development space for this board is called Arduino Software (IDE), it is open source, having the advantage of free use. The software used was Arduino code libraries already developed, and adapted to this specific application [10, 11].

The first step is to load the program into the Arduino development board. The next step is to initialize the variables and configure the pins used.

The motor driver needs a small delay to be able to connect, then the gripper enters in the reference mode. Here it will make as many closing-opening movements as specified in the source code, to see if its movement and movement limits are correct.

After completing the reference movements, the gripper will stop in the fully open position when the limit switch is actuated. This is the reference point. The maximum closing position is determined by a value specified in the source code. That value represents the maximum number of steps that the stepper motor can perform from the reference point.

If the joystick is operated upwards and the maximum number of steps of the stepper motor has not been reached, the manipulator will close, it will continue its closing movement if the joystick is operated upwards and as long as the maximum number of steps has not been reached.

If the joystick is actuated downwards and the limit switch is not actuated, the manipulator will open, it will continue its opening movement if the joystick is actuated downwards and the microswitch is not actuated. At each engine opening step, the total number of steps performed by the motor will decrease by one unit, so the manipulator will always have the same closing point.

If the joystick is not operated, the manipulator will remain at rest. If the user presses the Reset button, the manipulator will enter the reference mode again.

4.1 The reference movement

The reference movement occurs in two situations. The first one is when Reset button is pressed, which is connected to a dedicated input on the development board. The second situation is when the program is loaded into the development board. Within the program is necessary to configure the inputs used on the Arduino board and declare the variables in which the information will be saved. The reading process takes place in a loop, to allow the continuous positioning of the manipulator. The reference movement will always start with the opening of the claws until the microswitch is reached (pressed). After the motor rotation direction is specified, to be able to perform a step, successive HIGH and LOW signals are required on the STEP pin coming from the driver, with a delay between them. After pressing the microswitch, the claws will close. The stroke end for closing the claws is determined by a value specified in the program. That value can be determined by observation, testing or calculation. Knowing that the motor pitch is 1.8° and the microsteping is 16 microsteps / step, the number of microsteps required for a complete rotation of the motor can be calculated as follows $N = (360*16)/1.8=3200$ microsteps. It has been observed that the engine needs about half a turn for the claws to be completely closed, from the reference point. Leaving a margin of error, the value of 1500 micro steps was adopted. Further, knowing this value, the reading steps are the same as the opening movement, only the direction of rotation of the motor is different. The variable "counter" specifies how many closing-opening cycles the manipulator can do.

4.2 Closing movement

After completion of the reference cycle, the claws will remain in the maximum open position, i.e., at the reference point. From here the manipulator will only move at the user's command via the joystick. To determine whether the joystick is operated up or down (close - open), it is necessary to read its resistive value. Joystick is connected to an analogue input of the development board, where this measurement can be made. It has been observed that if the resistive value read is less than or equal to 200 ohms, the joystick is operated upwards, and the manipulator's claws must close. The claws will continue their closing movement as long as the joystick is operated upwards by the user and as long as the maximum number of steps has not been reached.

4.3 Opening movement

In the same way, it has been observed that if the read of the joystick resistive value is greater than or equal to 400 ohms, then the joystick is actuated downwards, and the manipulator's claws must open. The claws will continue their opening movement if the joystick is actuated down by the user and as long as the microswitch has not been actuated. The variable "stepnr" counts the steps performed by the motor. In the reference position, this variable has the value 0, with each closing step its value increases by one unit and with each opening step its value decreases by one unit. If the read resistive value of the joystick is between 200 and 400 ohms, then the gripper will be at rest.

5. EVALUATION OF MANUFACTURING COSTS

To evaluate the viability of the proposed solution, some of the manufacturing costs were determined. Components are printed on the Zortrax M200 printer. To make the printing process faster, the gripper components will be printed first simultaneously, then the support, the box and the cover separately. While the cover, box, and holder are printed, the gripper components are assembled. Assembling the gripper begins by mounting the printed components. The software program for the development board is made and the electronic control system is soldered.

Individual timing and price for every printed part is presented in Table 1.

Table 1. Timing and costs for printed components

Part Name	Mass [g]	Printing time [min]	Material price [E]
Claws	8	79	0,16
Support plate	5	52	0,10
Sprocket	3	44	0.06
Right gear	3	27	0.06
Left gear	2	25	0.04
Fixing rods	1	20	0.02
Fixing arms	1	12	0.02
Gripper support	23	250	0.46
Total 1	46	509	0.92
Box	248	2679	4.96
Box cover	141	1227	2.82
Total 2	389	3906	7.78
Total	435	4415	8.7

The costs for the other components are presented in table 2.

Table 2. The cost of purchased components

Part Name	Price [E]
Arduino board	50
Stepper motor	65
Motor driver	15
Power supply	1.5
Microswitch	2.5
Reset button	2
Joystick	10
ON/OFF switch	2
Total	148

6. CONCLUSIONS

Although there are some rough assessments, the paper shows that there is the possibility of replacing some industrial components with others made by using Fused Filament Deposition additive technology.

If the components for actuation (purchased) are excluded, the gripper reach an almost symbolic cost compared to the rest of the components. Moreover, the latter can be reused in subsequent projects.

The novelty of this project lies in the possibility of remote operation, which can bring great benefits in many applications, in the case of handling hazardous substances, where the operator cannot come into direct contact with them or where the operator must be isolated from all parties in motion.

Due to the easy redesign of the claws, they can be quickly customized to any shape of the components to be handled. This feature is important when the production structure changes frequently. In this case, it is no longer necessary to purchase a new custom gripper for the new shape of the assembled objects.

For remote operation, open-source code sequences were used. This has led to a significant decrease in costs for this activity. Once the source code is created, its customization for future applications is extremely easy to do even by a less specialised user. This is also facilitated by the existence of numerous open-source examples and by the fact that there is a large base of experienced users. In this context, significant additional costs with the payment of specialised personnel and with the purchase of dedicated software modules are avoided.

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