Control system for FDA deposition using a CNC milling machine

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Abstract. This paper presents the command and control part of a 3D printhead, the command and control that is made by combining the PLC of a CNC milling machine with the electrical assembly of an extruded head for FDA(Fusion Deposition Adhesion) processing.
The command and control part of an extruder head is presented. On the same, the paper shows how to connect to the PLC of a CNC and presents the use and operation of an extruder block for FDA machining on CNC

1. Introduction

Regarding the increase in performance, it is expected that the price-performance ratio will improve, in favor of performance, but not as spectacular as it was in previous years. The physical and mechanical properties of the materials used have seen significant improvements and the accuracy has improved from ± 0.25 mm to ± 0.075 mm [1],[2]. . The most important improvements have been, and will be, in rapid prototyping (PR) programming systems, which are easier to use and smarter. The result is a reduction in working time, an improvement in the quality of machined surfaces and finally a reduction in the cost of parts made with the help of these technologies. Thus, if in 1992 a piece cost 15 units of price, today the same piece costs 2 units (fig. 1) [3].

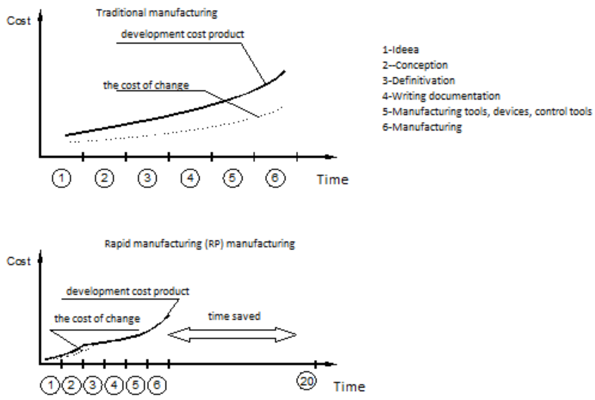


Figure 1 Reduce time by rapid product development [3]

Combining the technique of 3D mechanical design [4], with electrical design [5], or rather the formation of a team containing mechanical engineers and electronic engineers, leads to the manufacture of new equipment and the discovery of new technologies [6],[7] which make it possible to reduce manufacturing costs and increase the performance of the products obtained [1], [8], [9],[10], [11].

2. PLC of CNC and electrical components of FDA system

This paper present the control and command part of the print head assembly has been developed, which will be connected to a TMA-AL-550 CNC (figure 2) [6]. The control panel for FDA filing has several components, starting with the temperature controller that was chosen based on several models, each bringing pluses and minuses, because they were not compatible with either the heating resistance of the extruder block or the correct reading in real time temperature, or with CNC.

For this CNC model, a DELTA DTK 4848 temperature controller was chosen, with the desired reading specifications for the J-cartridge type temperature thermocouple.

During this time, the CNC was also modified on the control side (figure 3), here it was added to the Fanuc PLC to control both start / stop of the filament motor advance, start / stop of the heating resistance, and as input the signal reading temperature when it has reached the temperature set on the controller (figure 4).

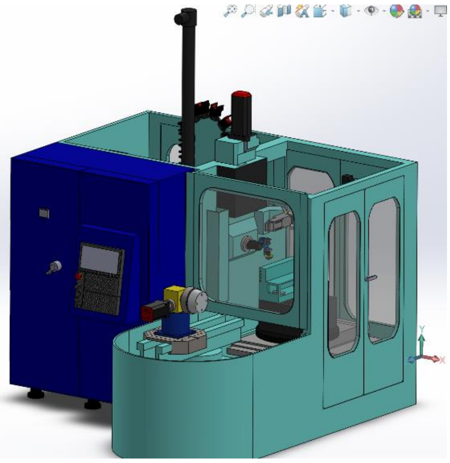


Figure 2 CNC TMA AL 550 SolidWorks3D [6]

Figure 3 CNC TMA AL 550 Printed Block Mounted [6]

The model of electrical resistance is cartridge type electric resistance cartridge Ø6,5x40 mm, 160W, 230V, thermocouple type J, S5435/3, which allows us to supply power it through a semiconductor relay from AC voltage.

The semiconductor relay (figure 5) is a relay without mechanical contact, but performs on / off functions in the same way as an electromechanical relay. The relay used is a Fotek brand SSR, with the possibility of power supply from 34-380V alternating current 10A. The supply voltage for the input control is between 3-32V direct current.

The supply voltage for the input control is between 3-32V direct current. Therefore, for a very high frequency temperature reading, a mechanical relay was not chosen, because SSR (figure 5) are capable of extremely fast operations, and these models are capable of generating the desired frequencies, for the greatest possible possibility of maintaining the temperature. of the extruder block in a well-defined range which helps the flow flow of the filament for a desired deposition.

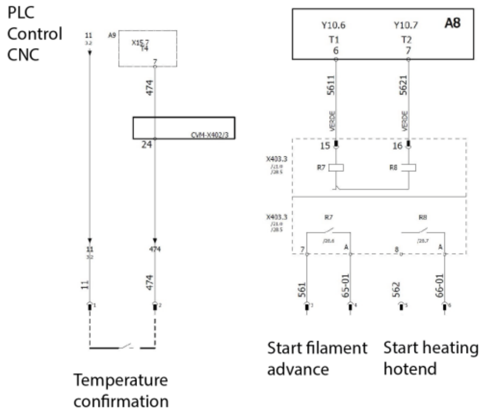


Figure 4 Wiring diagram - connecting the printhead to the CNC

Figure 5 SSR mounted in the control panel

To start and stop the ssr, use the thermocouple (figure 6) located in the extrusion block, which checks the temperature at a certain time set in the controller.

Temperature control can be done at different time intervals, but the PID function of the DELTA DTK (figure 7) controller can also be used, for a precise verification of it. Temperature control via PID mode in the controller by selecting the AT program, which means switching to automatic control, with proportional setting function. Printing is done in the range 210-230℃, depending on the material used, PLA type filaments are printed up to a temperature of 220℃, being an optimal printing temperature up to speeds of 100 mm / s, at higher speeds the temperature must be raised. Printing can be done with PLA starting at 25mm / s at a temperature equal to 190℃, for every 10 mm / s in addition the temperature must be increased by 2.5℃-2.8℃, depending on the ambient temperature or directing the air stream to cool the embossed block, so that the filament passing through the heated block becomes crystallized and can be deposited.

Figure 6 Top-Electric resistant 150W, Bottom-K-type thermocouple probe

Figure 7 Controller temperature DTK

When using the PID function during use, it works on the order of a tenth of a degree, it allows us to use the resistance to heat the extrusion block with great accuracy, because the filament to be extruded is very demanding for fluctuating values.

The high speed sampling of the controller (figure 7) is below 100 ms, which allows us to read at least 10 values per second. The reading of the temperature sensor is very useful to be done as quickly as possible, which allows the output signal regulator to be done automatically to the heating element. To reach the set value, the controller uses the set temperature as the signal point, so each temperature drop is done automatically with a correction for the next output signal for resistance, if set to 210℃, the read temperature is 209.08℃ PID activates the relay for 10ms to reheat the resistance again.

These models of controllers with a hysteresis of the order of a tenth of a degree, help us to keep a lot of the temperature around the set one, these being typical for the temperature adjustment in the case of this model, with a discontinuous output signal. If the unit is left in OUT1Heated mode, it receives values at a longer time interval of 20 seconds, this reading bringing a lot of problems with the heating of the extruder block, because if the set temperature is 210℃, it before reaching this temperature makes a reading, heats up for another 20 seconds and reaches a temperature of 220℃, and in the next cycle the temperature drops below the set one, which causes a continuous flow of filament, blocking it in the nozzle in the extrusion of the filament during cooling or blockage before the corrugated block, or it may even cause the filament to break, and during the heated heating may increase the flow rate of the filament faster. The difference between the operation of a filament extrusion block with a DELTA DTK4848RI controller using PID and mode without using PID.

3. Connect the FDA system to the CNC

The control part of the extruder head was made based on inputs and outputs (sheets 1) from the CNC PLC, connections (figure 8) that make possible different operating characteristics of the machine.

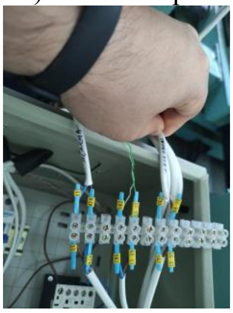


Figure 8 Schneider Contactor LC1D18B5

Figure 9 Driver TB6600

The cnc has as heating output and start filament motor advance on OUTPUT = START HEATING, controll with is made by the DRIVER TB6600 (figure 9)

Alarm 11,474 - FILAMENT ADVANCE START (NEMA stepper motor start-figure 11) Motor advance start 561.65 01;

Input = CONFIRM TEMPERATURE PRINTER HEAD 562, 66 01

In order to be able to control the temperature confirmation input, a Schneider LC1D18B5 (figure 10) contactor was used between the machine and the temperature controller, it keeps the engine feed start control closed.

Figure 10 Schneider Contactor LC1D18B5

Figure 11 Nema 23 stepper engine

Filament extrusion is done with a Nema 23 motor (figure 11), it is controlled by a TB6600 driver, which has an Arduino Nano controller connected to tell it the speed and direction of rotation on the pins D2-Dir +, D3-Pul +, D5-En +, and the pins EN-, Dir-, Pul + are grounded on arduino nano. The Arduino controller has the D12 pin connected to the 561 CNC output, which controls starting / stopping the Nema 23 motor.

The contactor and the temperature controller are supplied directly to AC 230V, and the Arduino Nano microcontroller is supplied with a 5V, 2A SMPS source, as well as the filament feed motor driver is supplied with a 24V SMPS source. Their power supply was made separately, because on the 230V AC power outputs of the Cnc we did not have the necessary current for their power supply (figure 12,13).

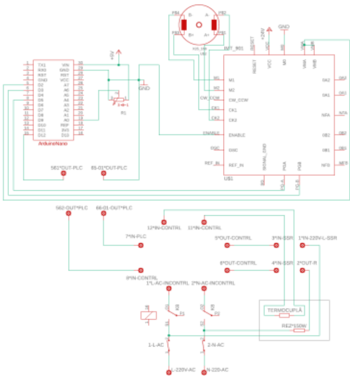
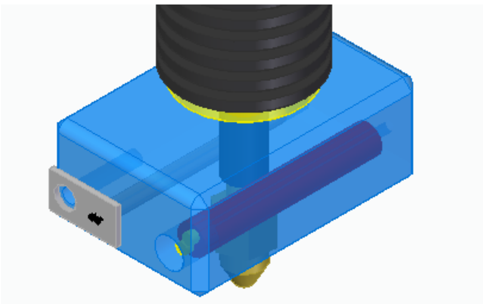


Figure 12 Control panel mounting **Figure 13** Wiring diagram of the 3D printing board

The extruder block assembly (figure 14) was designed to be easy to heat, with the threaded bore for the extrusion head or nozzle. The nozzle was made of CW617N brass (figure 15) with a lathe, its inner hole was ground on the inside to reach the inside diameter of 1mm + -0.01. It helps us to extrude the filament without blocking the carbon fiber particles that are in the composition of PLA filaments, which can have up to 30% insertion of carbon fibers inside them. For the use of these filaments it is very useful to grind the extruder on the inside so as not to create the blockage of carbon fiber particles inside the extruder. When observing a brass nozzle, which printed about 1 kg of PLA filament with carbon fiber insert, after milling it, fine internal scratches are observed under the microscope. These internal scratches occur after the brass is continuously attacked by the carbon fiber insertion flow, leading to internal irregularities in this nozzle.



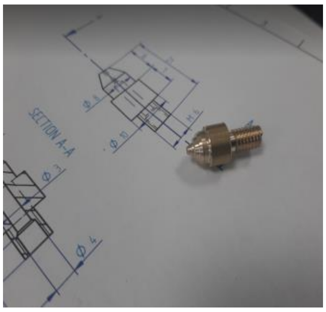
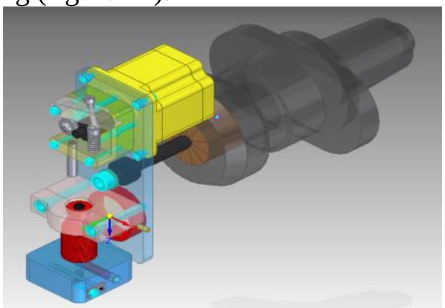


Figure 14 Hot End **Figure 15** Nozzle brass

Following the electrical design of this printhead (figure 16), I generated the G [12] codes for printing, codes involving movements, printing advances, heating of the filaments, we switched to the actual printing (figure 17).



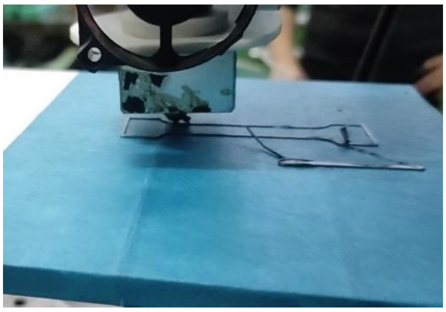


Figure 16 Extruder block assembly **Figure 17** Test Print

4. Conclusion

In conclusion, by combining the knowledge of the mechanical engineer with that of the electronic engineer, such systems as the one presented in this paper can be constructed.

After assembling the mechanical elements with the electronic ones, the CNC machine TMA-AL-550 can print 3D.

In the future we intend to create a post processor for the creation of printing programs.

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