Modeling and building a 3D print head

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Abstract. The paper presents 3D modeling and the construction of a printing head for plastic, a head that will be used on a CNC milling machine. The component parts were modeled with Solid Edge software, and for manufacturing the parts we use a CNC milling machine and one conventional lathe. Following the manufacture of the parts, they were mounted together. After that, the mechanical parts was connected together with the electrical components and the result is a functional head that uses fused deposition modeling (FDM) technology.

1. Introduction
Additive manufacturing (AM) is a fast and efficient method of manufacturing parts [1], manufacturing based on technologies (figure 1) such as fused deposition modeling (FDM) [2], a technology that is widely used in the production of parts in various fields. [3], of high complexity and technical quality [4],[5], parts that are built layer by layer [6], based on a 3D model saved in stl format.

The generated STL file is loaded into the machine's built-in software, which divides it into individual slices and as sign attributes, such as fill percentage and wall thickness, and as basic printing materials using plastic filaments, such as be PLA, carbon fiber, ABS and other plastics [7].

Figure 1 Schematic representation of FDM system [6]

There are also other companies that during this period do research and produce additive printheads such as: HURCO, FASTRAX, MELTIO ENGINE, 3D HERNDON.

- HURCO in 2014 he began to explore ways to combine subtractive and additive technologies thus managing to produce a printhead (figure 2) to be used on the same CNC machine together with cutting tools without the need for repeated configurations of the CNC machine (setting print head such as a cutting tool-offset tool)[8], concluding that such operation is much
cheaper than purchasing a complete system, and at the same time the manufacturing process is much shorter and cheaper (figure 3).

**Figure 2.** Print head HURCO [8]

**Figure 3.** Part obtained by printing + milling in 3 weeks compared to 52 weeks with another method [8]

- **FASTRAX** also a print head (figure 4), which was designed and built by Dante Dudy for personal use, and later being produced as an industrial product. This printhead can be adapted to any CNC machine (figure 5), having the control part separately from the CNC PLC, having as control panel a touch screen [9].

**Figure 4.** Print head FASTAX [9]

**Figure 5.** Steps for assembly on the CNC-FASTAX head [9]

- **MELTIO ENGINE** manufacture a 3D laser deposition print head that can be adapted to almost any CNC machine (figure 6). This head is precise and suitable for 5-axis milling machines and also suitable for mounting it on robots (figure 7), to produce a part from "zero" or to load with material a part that has wear and then milling it [10].
Figure 6. Meltio Engine print head fixed on a CNC [10]

Figure 7. Mounting the Melted Engine head on an ABB robot [10]

As a price it is around 90.000 EURO, a relatively low price compared to a mixed car that reaches 1.000.00 EURO. Such processes are used to repair large and expensive parts, such as injection molds, car assembly stations and in the aeronautical industry [1].

2. 3D modelling and Finit Element Analysis (FEA) print head
Starting from the idea of “TRANSFORM” the CNC + TMA-AL-550, in a mixed machine, we mechanically designed the extruder head using the software Solid Edge ST7[11], software that allows both 3D modeling of parts and the creation of 2D models based on 3D ones, which will later be used in the production area for the manufacture of 3D printhead parts.

The printhead is made of both standardized elements (electrical resistance, thermocouple, stepper motor…) and parts that are not stas (cooler, heater block, mounting bracket, adapter for CNC mounting), elements that can be changed very quickly and easily, so that this head (figure 8) can be dimensionally modified, as well as its parameters (melting power mounting a higher electrical resistance, filament supply + change of filament supply motor) depending on the requirements of a possible customer, who has a certain milling CNC (vertical, horizontal) (table 1).

Figure 8 Print head for horizontal CNC machine

The machine on which we mounted the printhead is a 5-axis CNC milling machine (TMA-AL-550)[12], and the printhead (figure 8) has been designed so that it can be mounted on this horizontal CNC, and also can operate in the mode of working with 5 consecutive axes of the machine (figure 9).
| Nr. | Crt | Description |
|-----|-----|-------------|
| (a) | Support plate | Supports all printhead components and connects to the CNC. Made of EN AW-7075 ALZN5 on CNC with an accuracy of 0.02 mm. |
| (b) | Heater block | In this heater block is mounted the electric resistance cartridge, thermocouple J, printing nozzle, heat exchanger. Made by plastic 3D printing: PLA + carbon fiber. |
| (c) | Support heat exchanger | They have the role of supporting the heat exchanger, which in turn supports the printhead. Made of EN AW-7075 ALZN5. |
| (d) | Cartridge electrical resistance 0.5x40 mm, 160W, 230V, Thermocouple type J, S5435/3 | The resistor has the role of heating the heater block, and the thermocouple J monitors temperatures and transmits the information to the temperature controller Delta DT3. |
| (e) | Stepper motor Nema 23 | The two components assembled together have the role of feeding the extruded head with filament. STAS Parts. |
| (f) | Screws and cooling cooler | The cooler has the role of cooling the heater sink so that the printhead temperature can be at the same value and at the same time the heat is not transferred by conduction to the neighboring parts. STAS Parts. |
For the dimensioning of the heater block, of the cooler, the choice of the materials from which to build the components of the printhead, we used the analysis with finite element [13], [14], and based on the obtained results we found that the filament melts before it enters the heater block. In this analysis (figure 11) is presented the section of the 3D model of the extruder assembly (figure 10) with its components and the temperature of each component. With the help of FEA we modified both the design of the printhead and the addition of new components (teflon spacer) to prevent heat transfer from the hot end to the cooler, so that the temperature of the cooler is maintained at 50 degrees.

Teflon tube from the inside of cooler, hot end an nozzle, plays a double role, it is used primarily to direct the filament to the nozzle, because if it were transferred directly through the metal, due to the high roughness, the filament could become blocked.

3. Conclusion
Additive manufacturing (AM) is a new industrial revolution, and the main machine tool manufacturers are developing this technology and with the help of finite element design and analysis software, an optimized print head can be built.

Using the printhead presented in this paper, he transformed the TMA-AL-550 CNC milling machine into a hybrid CNC machine. The electrical design of its printhead, as well as its control and programming, will be presented in other papers.
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