Modeling and building a 3D print head

D C Negrau[1,2] , G Grebenișan[1] ,T Vesselenyi[1] ,D M Anton[1] , C I Indre[1]

[1] University of Oradea, Faculty of Managerial and Technological Engineering, Universității Street No. 1, Oradea, Romania

[2] dan.negrau@yahoo.com

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].

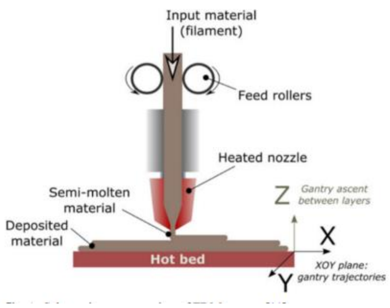


Figure 1 Schematic representation of FDM system [6]

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]

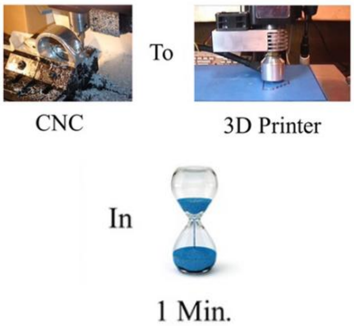


Figure 5. Steps for assambly on the CNC- FASTAX head [9]

- **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]

Figura 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).

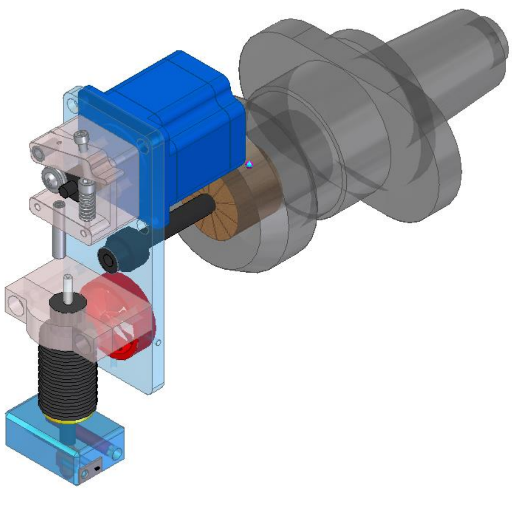
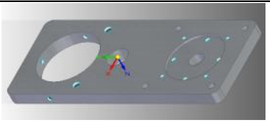
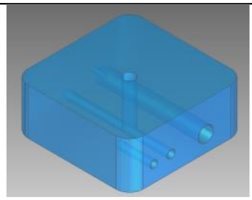
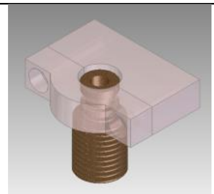
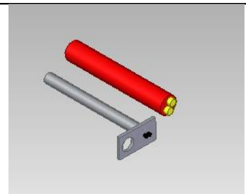
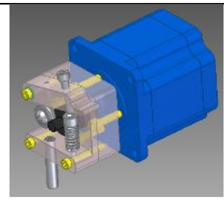
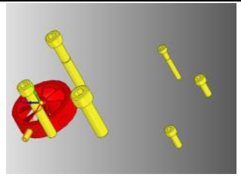


Figure 8 Print head for horizontal CNC machine

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).

Table 1 The parts of print head

Nr. Crt	(a) Support plate	(b) Heater block	(c) Supports heat exchanger	(d) Cartridge electrical resistance Ø6,5x40 mm, 160W, 230V, Thermocouple type J, S5435/3	(e) Stepper motor Nema 23 Filament pull assembly	(f) Screws and cooling cooler
Name picture						
Description	Supports all printhead components and connects to the CNC Made of EN AW-7075 ALZN5 on CNC with an accuracy of 0.02m	In this heater block is mounted the electric resistance cartridge, thermocouple J, printing nozzle, heat exchanger Made of EN AW-7075 ALZN5	They have the role of supporting the heat exchanger, which in turn supports the print head Made by plastic 3D printing: PLA + carbon fiber	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 STAS Parts	The two components assembled together have the role of feeding the extruded head with filament. STAS Parts	The cooler has the role of cooling the heater sink so that the print head temperature can be maintained at the set value and at the same time the heat is not transferred by conduction to the neighboring parts. STAS Parts

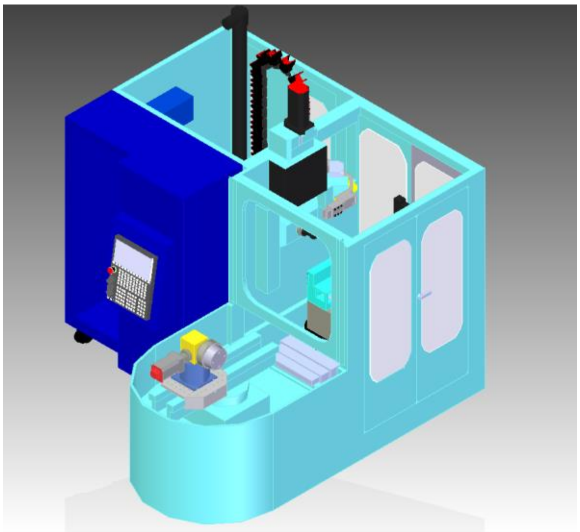
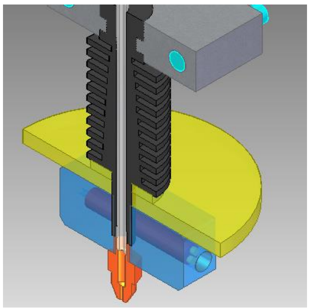


Figure 9 CNC machine TMA-AL-550 [12]

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.



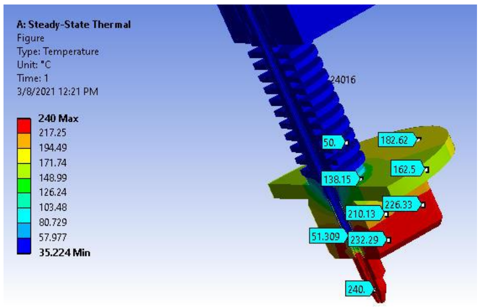


Figure 10 Print head modify after FEA **Figure 11** Analysis FEA

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.

4. References

[1] J. Gausemeier, N. Echterhoff, and M. Wall, "*Thinking ahead the Future of Additive Manufacturing – Innovation Roadmapping of Required Advancements*," Univ. Paderborn Direct Manufacuring Res. Cent., p. 110, 2013, [Online]. Available: http://www.hni.uni-paderborn.de/en/pe.

[2] V. Shanmugam et al., "*Fatigue behaviour of FDM-3D printed polymers, polymeric composites and architected cellular materials,*" Int. J. Fatigue, vol. 143, no. October 2020, p. 106007, 2021, doi: 10.1016/j.ijfatigue.2020.106007.

[3] L. Suárez and M. Domínguez, "*Sustainability and environmental impact of fused deposition modelling (FDM) technologies,*" Int. J. Adv. Manuf. Technol., vol. 106, no. 3–4, pp. 1267–1279, 2020, doi: 10.1007/s00170-019-04676-0.

[4] F. Rayegani and G. C. Onwubolu, "*Fused deposition modelling (fdm) process parameter prediction and optimization using group method for data handling (gmdh) and differential evolution (de),*" Int. J. Adv. Manuf. Technol., vol. 73, no. 1–4, pp. 509–519, 2014, doi: 10.1007/s00170-014-5835-2.

[5] D. C. Negrau, G. Grebenian, and C. Gherghea, "*A brief overview of Additive Manufacturing,*" IOP Conf. Ser. Mater. Sci. Eng., vol. 898, no. 1, 2020, doi: 10.1088/1757-899X/898/1/012029.

[6] U. K. uz Zaman, E. Boesch, A. Siadat, M. Rivette, and A. A. Baqai, "*Impact of fused deposition modeling (FDM) process parameters on strength of built parts using Taguchi's design of experiments,*" Int. J. Adv. Manuf. Technol., vol. 101, no. 5–8, pp. 1215–1226, 2019, doi: 10.1007/s00170-018-3014-6.

[7] Y. Hu, R. B. Ladani, M. Brandt, Y. Li, and A. P. Mouritz, "*Carbon fibre damage during 3D printing of polymer matrix laminates using the FDM process*," Mater. Des., vol. 205, p. 109679, 2021, doi: 10.1016/j.matdes.2021.109679.

[8] "Adding and Subtracting to Make the Next Generation of Hybrid 3DCNC Machines - ASME." https://www.asme.org/topics-resources/content/adding-subtracting-make-next-generation-hybrid (accessed May 04, 2021).

[9] "CNC Mill into a Hybrid 3D Printer - 3D Printing Industry." https://3dprintingindustry.com/news/turn-your-cnc-mill-into-a-hybrid-3d-printer-57755/ (accessed May 04, 2021).

[10] "Meltio Engine transforms any CNC machine into a hybrid 3D print system." https://newatlas.com/3d-printing/meltio-engine-hybrid-manufacturing-system/ (accessed May 04, 2021).

[11] D. Santoro, "Solid Edge 2021 | Siemens Digital Industries Software - Ingenuity for Life," Accessed: Apr. 26, 2021. [Online]. Available: https://solidedge.siemens.com/en/solutions/products/complete-product-development-portfolio/whats-new-in-solid-edge-2021/ (accesed in May 04, 2021)

[12] T. D. E. Doctorat, "*Contributions to the Concept of Processing Applications in 5 Axis CNC Rotary Tipper Table with 2 Removable Axle DOMENIUL : INGINERIE INDUSTRIALĂ LA CONCEPTUL DE PRELUCRARE IN 5*," 2014.

[13] "*An optimization approach by Finite Element Analysis, using Design of-*Negrău_2019_IOP_Conf._Ser.__Mater._Sci._Eng._568_012065.pdf." .

[14] "*A neural networks approach of process fault diagnosis using time series-*Grebenişan_2019_IOP_Conf._Ser.__Mater._Sci._Eng._568_012079.pdf." .

Acknowledgments

Published with the support of the University of Oradea because it provided me with scientific resources and with the support of the ID 123008 - POCU/380/6/13 project, - SMARTDOCT – Programe de înaltă calitate pentru doctoranzii și cercetătorii postdoctorat ai Universității din Oradea pentru creșterea relevanței cercetării și inovarii în contextul economiei regionale.