

## PRINTING WITH THE METAL X PRINTER IN THE UNIVERSITY ENVIRONMENT

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**ABSTRACT:** Currently, the creation of complex structures that cannot be produced by conventional production methods can be easily achieved through 3D Printing. Highly complex models have the advantage of being 3D printed as a single piece, thus eliminating the costly use of several work stages in classical production. In this paper, we present the system purchased by Aurel Vlaicu University of Arad. This system offered by the Markforged company is intended to be used by students of the Faculty of Engineering in the learning process. At the same time, in this paper, we also make a comparison between filament printing systems, a comparison that aims to present the efficiency of the system we opted for.

**KEYWORDS:** 3D printing, filament, sintering, CAD/CAM, education

### 1. INTRODUCTION

Today's societies are concerned with finding economical solutions for production, and 3D printing has become a reliable option. 3D printing, also known as additive manufacturing, is a three-dimensional manufacturing process that provides spare parts or prototypes obtained through the layering process.

Physical objects are produced based on digital models, and their geometry varies depending on the role they will play after printing.

The main advantage of this system is the reduced production time and significantly lower costs compared to traditional methods. Currently, several technologies and materials are used for 3D printing, the offer being very varied and addressable both to the industrial environment and for home or educational use. Currently, the creation of complex structures that cannot be produced by conventional production methods can be easily achieved through 3D printing.

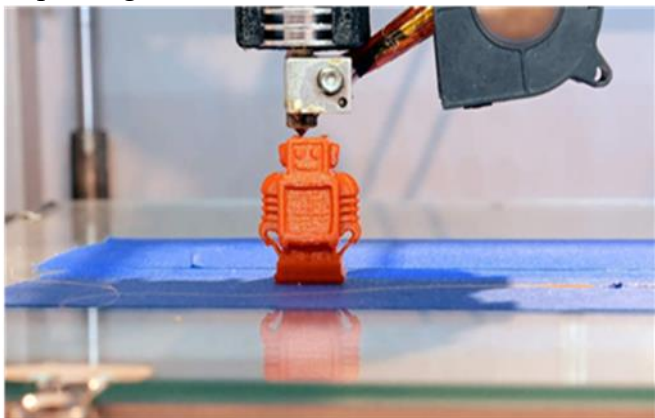
Models with a high degree of complexity have the advantage that they can be printed 3D as a single piece, thus eliminating the costly use of several work stages in classic production. Another advantage that should not be overlooked is the possibility of easily customizing a reference without additional costs.

Modifying an object can be easily done in the digital environment without involving production processes or additional devices. 3D printing is also environmentally friendly, so it easily aligns with current general policies.

Being an additive process, by superimposing layers, the printing uses only the material necessary to obtain the product, the residues are very low and can usually be recycled, returning to the process.

As fascinating as the area of 3D printing is, we must admit that there are also limitations:

- Such printing is not suitable for large-scale production;
- The price of printers and raw materials is high for high-performance printers;
- The range of materials that can be used is still quite limited, as is the palette of colours and finishes;
- The resistance and durability of the products obtained is limited. Not all additive technologies ensure durability of the resulting products;
- The precision of the printed products is not very high; there are situations when deviations occur that cannot be neglected;
- There are size limitations of 3D printers; despite existing limitations, the 3D printing is continuously expanding, with increasing development in the industrial area, especially in car production.



**Figure 1.** Additive printer [1]

## 2. INTRODUCTION

Taking into account what is happening in the industrial area and wanting to prepare our students for what awaits them in production after completing their studies, at Aurel Vlaicu University of Arad, we wanted to offer a wide range of printing systems, so that Engineering students are familiar with such systems and can wisely choose the appropriate system to the needs of the company where they will work.

One of the systems purchased by our university is the Metal X sintering printing system. The purchased printer is produced by the Markforged Company, which through the solutions it offers has revolutionized 3D printing. It is an industrial printer designed to obtain metal parts, such as: spare parts for industrial machinery, injection moulding tools or functional prototypes.

Built around a 5th generation extrusion and motion system, Metal X is desktop-friendly, easy to use, and has a small footprint. It features advanced error detection and can be monitored from the cloud.[2]

The purchased system consists of:

- Printer (fig2)



Figure 2. Metal X Printer [2]

-The Wash-1 washing tank (fig3) has integrated stations for chemical dissolution of bonding agents and for drying. Various parts can be washed in parallel, which allows maximizing production efficiency. [2]

-The Sinter-1 (fig4) is a high-performance, high-value furnace, ideal for smaller parts. With an active hot zone of 4,760 cm<sup>3</sup> (290 cubic inches), it can process any of Markforged's materials in just 26 hours. [2]



Figure 3. Wash-1[2]



Figure 4. Sinter-1[2]

The printing technology used is Metal FFF (Fused Filament Fabrication), a technology similar to fused deposition modelling/fused filament fabrication (FDM/FFF). [3]

The filament it uses is a filament composed of metal powder bound with a polymer.

To obtain a part using this system, the following steps are taken [4]:

-Creating the drawing in a 3D environment that allows saving the file as stl (stereolithography);

-Entering the drawing into the printer software and making positioning adjustments;

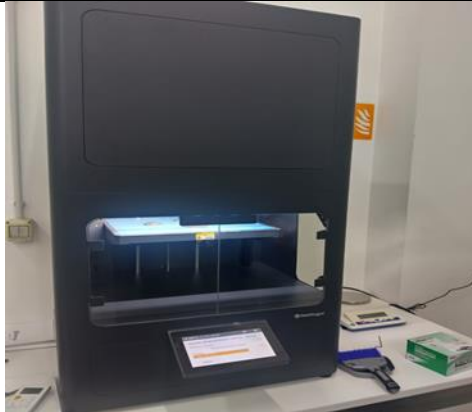







-Obtaining information related to the time required for production, the amount of material required and the costs resulting from the analysis of the drawing;

-Printing – the part is made layer by layer from composite metal filament;

-Binder liquefaction (wash) – the part is placed in a solvent bath that removes the polymer binder and then dried inside the same washing machine, only in different areas; [11]

-Sintering – the part is heated in a special oven, where the metal powder dandifies to 96–99% of the density of the bulk material

**Table 1.** The stages a landmark goes through from design to physical production with the Markforged system

<p style="text-align: center;"><b>3D printing</b></p>		
<p style="text-align: center;"><b>Washing - drying</b></p>		
		
<p style="text-align: center;"><b>Sintering</b></p>		

**Metal X production process flow**



The system software tracks everything that happens online, from the printing simulation (with the necessary information related to time, material consumption, costs) to the washing, drying, sintering operations. All the information necessary for a complete process can be found on the Eiger company website. The Faculty of Engineering has a monitoring account for the operations performed on the Metal X printing system.

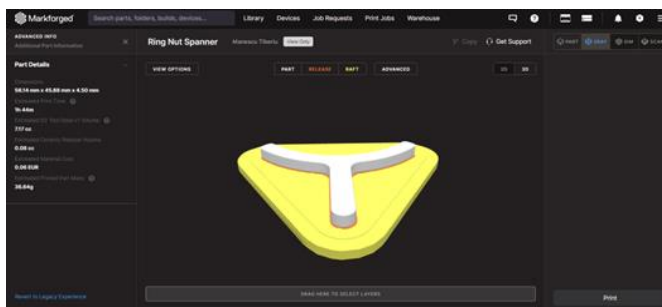
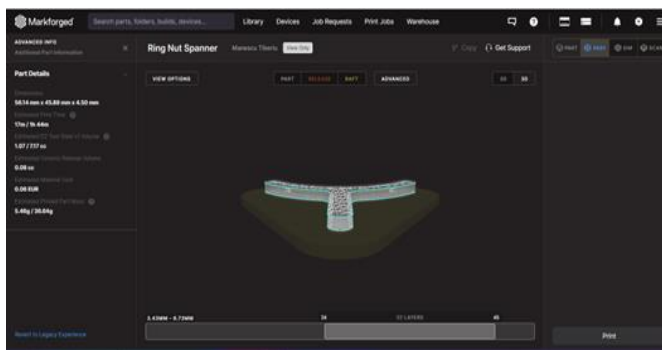
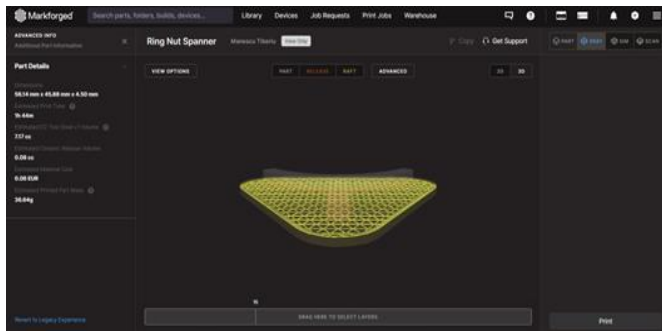
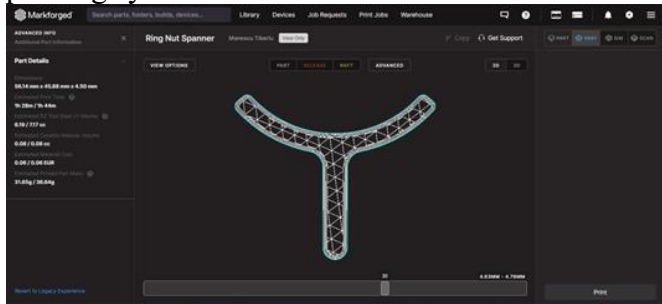


Figure 5. Print tracking on the Eiger website [12]

The materials compatible with this system are:

- Stainless steel (17-4 PH, 316L)
- Inconel 625 (nickel-based superalloy)

- Copper
- Tool steel (A2, D2, H13)

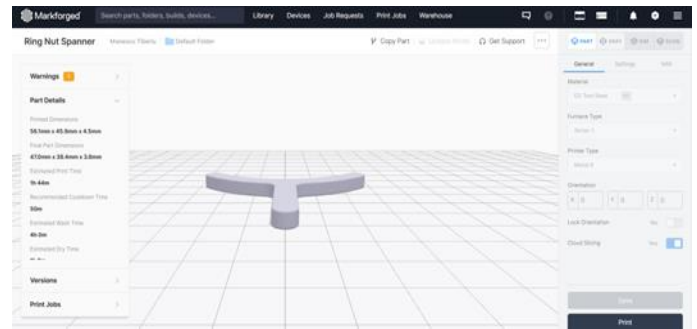


Figure 6. The landmark you want to print [12]

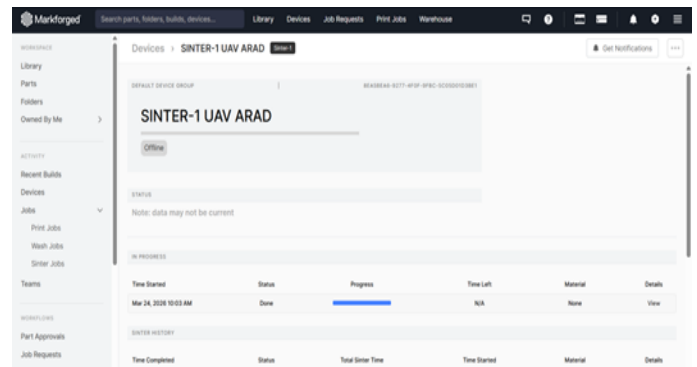


Figure 7. Example of sintering tracking [12]

The advantages of this system are [5]:

- Lower cost than the traditional SLM/DMLS printers (Selective Laser Melting/Direct Metal Laser Sintering).
- Increased safety – does not use loose powders, but solid filament.
- Easy to operate and integrate into a typical industrial environment.
- Possibility of rapid manufacturing of functional prototypes and end-use parts.

The limitations of this printer are [6]:

- The resolution and complexity of the parts do not reach the level of laser printers (SLM, DMLS).
- Requires additional equipment (wash & sinter).
- The total production time is longer, due to the post-processing steps.

Basically, Metal X is an "entry-level" solution for metal 3D printing, intended for companies that want to quickly go from prototypes to functional parts, without the very high costs of powder and laser technologies. [10]

### 3. COMPARISON BETWEEN METAL X (MARKFORGED) AND CLASSIC METAL 3D PRINTERS BASED ON SLM/DMLS

Following an analysis of 3D printing systems, we can make the following compare

- functional prototypes,
- auxiliary tools and fixtures,
- low-cost small batch production.

However, it is not the best choice for applications where high precision, perfect density and a wide range of materials are critical—areas where SLM/DMLS printers remain the industry standard. [9]

For student training, the existence of this printer in the university environment is welcome.

Even if the costs are quite high for education, with funding being scarce, the benefits of student training are compensating, offering a higher quality of teaching. Compared to SLM/DMLS systems, Metal X has lower acquisition and maintenance costs, integrating more easily into university laboratories.

The acquisition of such a system by universities opens up avenues for collaboration with industry, through the establishment of industry-university partnerships.

The role of Metal X in universities, as an educational tool, is important because:

- It provides accessibility and safety for the learning process,
- It allows students to practically learn the principles of metal additive manufacturing.
- It stimulates interdisciplinary research (mechanics, materials and robotics),
- Compared to SLM/DMLS, it is safer (does not work with loose powders) and can be used in university laboratories without special infrastructure.
- It supports the formation of practical skills in students in metal additive manufacturing.

For applied research Metal X in universities is:

- Useful in research projects related to design for additive manufacturing, topological optimization, development of functional parts and testing of material behaviour.
- It allows the rapid creation of metal prototypes for scientific and industrial experiments.

**Table 2.**

Feature	Metal X (Markforged)	SLM / DMLS (traditional)
Technology	Composite filament extrusion + wash + sinter	Selective laser melting of metal powder
Materials	Limited: stainless steel (17-4 PH, 316L), copper, Inconel 625, tool steels (A2, D2, H13)	Very varied: aluminium, titanium, cobalt-chromium, special steels, superalloys, magnesium, etc.
Final Density	96–99% solid	>99.5% (equivalent to solid)
Layer Resolution	50–125 µm	20–50 µm
Dimensional Accuracy	±0.1 mm	±0.05 mm or better
Surface Quality	Higher roughness, requires mechanical post-processing for fine applications	Better finish, but still requires post-processing
Equipment Cost	~€100,000–€150,000 (+ Wash & Sinter €70,000–€100,000)	400,000–1,000,000 €+
Material Cost	~€150–€250/kg	~300–600 €/kg
Operation Complexity	Easy to use, safe (no loose powder)	Complex, requires skilled personnel and special powder chambers
Production Time	Slower (sintering can take hours)	Faster in printing, but with mechanical/thermal post-processing
Applications	Functional prototypes, tools, fixtures, spare parts	Critical parts in aerospace, medical, automotive high-performance, complex topologically optimized structures

If we were to draw a conclusion, based on the comparison made, we can say that:

Metal X is an entry-level, affordable, safe system, good for functional prototyping and common industrial parts. [7]

SLM/DMLS is a high-end, expensive system, necessary for critical applications where density, precision and range of materials are essential

#### 4. CONCLUSIONS

The Metal X printer is an effective entry-level solution for metal additive manufacturing, especially for companies that need:

- customized parts,

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