RESEARCH ON OBTAINING METALLIC PARTS USING ADDITIVE MANUFACTURING TECHNOLOGIES

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ABSTRACT: Additive manufacturing technology (AM), also known as "3D printing", "additive production" or "additive process", is based on the idea that a model generated using a three-dimensional computer-aided design (CAD 3D) system can be manufactured directly. AM significantly simplifies the process of producing complex 3D objects from CAD data. In the additive manufacturing process, parts are made by adding material in thin layers, each layer being a cross-sectional section of the original part derived from CAD data. This paper presents data on the main types of additive technologies that can be used for additive manufacturing of metallic parts, as well as a case study on the use of additive technology to produce a non-return valve seat from a valve support.

KEYWORDS: additive manufacturing, 3D printing, metallic additive technologies, dimensional control

1. Introduction

Additive manufacturing technology (AM), also known as "3D printing," "additive production," or "additive process," is based on the idea that a model generated using a three-dimensional computer-aided design (CAD 3D) system can be manufactured directly, without the need for process planning. Although not a simple task, AM technology significantly simplifies the process of producing complex 3D objects from CAD data. In contrast to other manufacturing processes, which require careful and detailed analysis of the part geometry, AM requires only a few dimensional details and an understanding of how the additive manufacturing machine and materials used work [1-2].

In the additive manufacturing process, parts are made by adding material in thin layers, each layer being a cross-sectional slice of the original part, derived from the CAD data. Each layer must have a finite thickness, and the resulting part will be an approximation of the original data [3]. The thinner each layer, the closer the final part will be to the original. All commercially available AM machines use a layer-based approach, and the differences between them are determined by the materials used, the method of layer creation, and the method of bonding between layers. These differences determine the precision of the final part, the properties of the materials, the mechanical properties of the part, the production speed, the need for post-processing, the size of the machine, and the total cost of the process.

In the production of additively manufactured parts, dimensional verification and control operations play an essential role in ensuring their quality and conformity with the designed specifications. These operations involve the use of specialized equipment, such as 3D scanners and coordinate measuring machines, to evaluate the dimensions and geometry of the manufactured parts. By comparing the measured data with the designed specifications, production errors can be detected and corrected in a timely manner, ensuring a high quality and precision of the additively manufactured parts. [4]

This paper aims to present data on the main types of additive technologies that can be used for the additive manufacturing of metal parts, as well as a case study on the additive manufacturing of an anti-return valve seat using AM technology in a valve support.

2. Metallic additive technologies

Direct Energy Deposition (DED) is an additive manufacturing technology that involves melting and depositing material directly onto a substrate, using an electron beam or a powerful laser. There are two main DED technologies: LENS (Laser Engineered Net Shaping) and EBAM (Electron Beam Additive Manufacturing). LENS uses a laser to melt metal, while EBAM uses an electron beam. This technology is commonly used for repairing or remanufacturing metallic components, but it can also be used for producing complete large-sized parts such as structural elements for aircraft or spacecraft. One of the main advantages of DED is the ability to print with heavy and specific materials, such as titanium or nickel alloys, which are used in aerospace and medical applications.

Powder Bed Fusion (PBF) is an additive manufacturing technology used to produce three-dimensional parts, using a powder bed as the base material. It is one of the most common 3D printing techniques used for industrial additive manufacturing. Generally, powder bed fusion works by applying a source of energy to fuse the material in powder form. A leveler or roller spreads a thin layer of powder onto a build surface, the energy source selectively melts or sinters the material based on the cross-section of the 3D model. After the layer is melted, the build plate lowers by a distance equal to the set thickness of a layer, and the leveling and selective melting (based on the next section of the part) of the powder process repeats.

Laser Powder Bed Fusion (LPBF) is a process in which a leveler or roller spreads metal powder onto a substrate and a laser beam is used to melt the powder required for each layer. Due to the combustible nature of metal powders, an LPBF process is usually carried out under an inert gas, such as argon, or under vacuum because of the flammability hazard. The unmelted powder can often be reused in the process, but it can degrade over time due to oxidation.

Electron Beam Melting (EBM) is another powder bed fusion process for metals. An EBM printer functions like a small-scale particle accelerator, pulling electrons into the powder bed under vacuum to melt the metal material, instead of using a laser. [5]

Selective Laser Melting (SLM) technology is an additive manufacturing method primarily used for producing complex metal parts. It involves selectively melting a thin layer of metal powder, using a laser to build the object in successive thin layers. The melting process is based on detailed information about the final object, obtained from a CAD model. After the first layer is melted, the build platform lowers and a new layer of metal powder is applied over the previous one, and the process is repeated until the object is fully built. SLM technology is used in various fields, such as prototyping, production of parts for the aerospace and medical industries, and production of components for the automotive industry. [6]

Binder Jetting (BJ) technology is an additive manufacturing process that uses a liquid binder to bind the powder material in a layer-by-layer model. By spraying powder material with a spray head, a liquid binder is applied to bind the powder material in that layer, and this process is repeated for each layer until the model is complete. Afterward, the part is baked in an oven to solidify and harden. This technology can be used to create colored parts and to combine multiple materials. The advantages include short processing times, low cost, and high throughput. [5]

The subject of the case study is the production of an Anti-Reverse Valve Seat Piece using SLM technology. The function of this piece is to prevent the backflow of fluid in a hydraulic or pneumatic system. This valve allows the fluid to flow in one direction but blocks the reverse flow by automatically closing the valve when the pressure drops below the set value. This ensures that the hydraulic or pneumatic system functions properly, without allowing the fluid to flow back and cause damage or malfunction. The Anti-Reverse Valve Seat can be made from different materials depending on the working environment, such as stainless steel or bronze.

3. Case study - Designing an anti-reverse valve seat

3.1. Initial data

The initial data used for the case study consists of the detailed drawing of the product, partially presented in figure 1, the functions, and the characteristics of the surfaces related to the piece surfaces (see figure 2 and table 1).

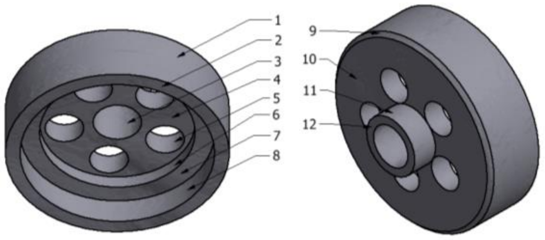

Fig. 2 Surfaces of the Anti-Reverse Valve Seat Piece

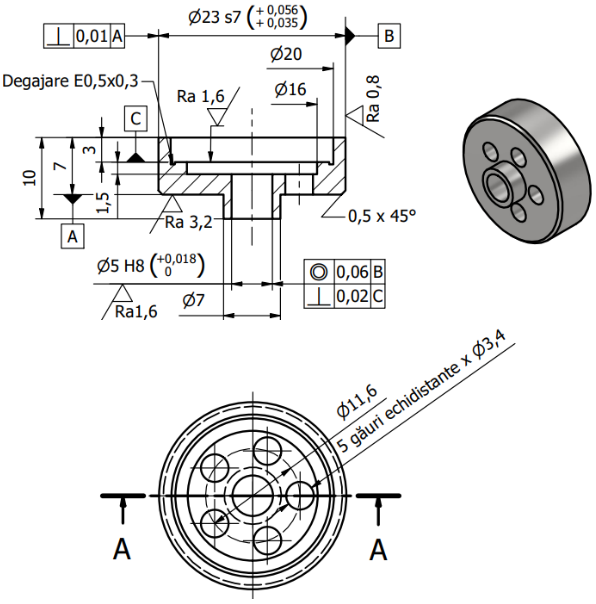

Fig. 1 Detail drawing of the Anti-Reverse Valve Seat Piece

Table 1. Surface Functions and Characteristics

Surface, S_k	Function	Nominal shape	Dimensions and tolerances [mm]	Roughness, Ra [μm]	Position tolerance(s) [mm]	Other data
S_1	Positioning and orientation within the assembly	cylindrical	Ø23s7	0,8	⊥ 0,01 A Reference base B	d g e s
S_2	Bordering	planar	Ø20/ Ø23s7	6,3	-	
S_3	Assembly function with the check valve	cylindrical	Ø5H8	1,6	◎ 0,06 B ⊥ 0,02 C	
S_4	Contact with a conjugate part	planar	Ø5H8/Ø16	6,3	-	
(5x) S_5	Function of allowing fluid to flow in only one direction through the valve	cylindrical	Ø3,4	6,3	-	
S_6	Bordering	cylindrical	Ø16	6,3	-	
S_7	Valve contact	planar	Ø20/Ø23s7	1,6		
S_8	Bordering	cylindrical	Ø20	6,3	-	
S_9	Prevents edge degradation and operator injury	conical	0,5x45° ±0,1	6,3	-	
S_{10}	Contact with the check valve reference	planar	Ø7/ Ø23s7	3,2	Reference base A	
S_{11}	Assembly function with the check valve	cylindrical	Ø7	6,3	-	
S_{12}	Contact with the check valve reference	planar	Ø5H8/Ø7	6,3	-	

3.2. Model preparation and code generation for printing

The part was made using the Autodesk Inventor 2023 software. By virtual testing of several manufacturing platform orientations in a dedicated software, the optimal orientation was chosen to be the one with the least support, as supports can hinder the printing and post-processing of the part, with the shortest print time and the least stress. Thus, we arrived at the optimal orientation presented in figures 3 and 4, where the part was positioned at an inclination angle of 40°.

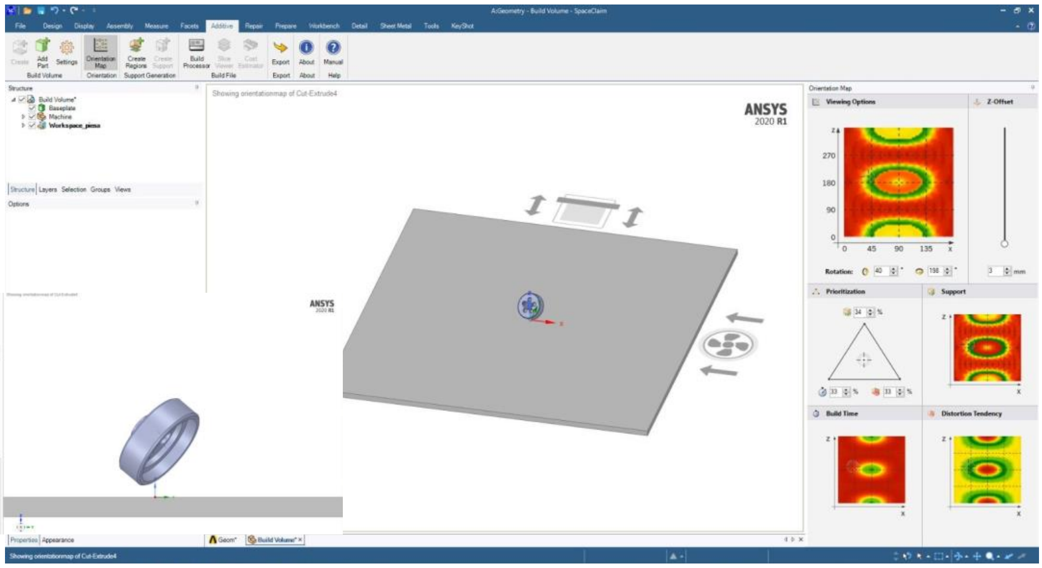

Fig. 3 Identifying the optimal orientation on the manufacturing platform

The following process parameters were selected for printing the part:

- Layer thickness: 0.05 mm
- Support vector:
  - Speed: 1.032 m/s
  - Laser power: 270 watts
  - Focusing diameter: 0 μm
- Support point:
  - Speed: 0.1 m/s
  - Laser power: 270 watts
  - Focusing diameter: 0 μm
- Part hatch:
  - Speed: 1.117 m/s
  - Laser power: 270 watts
  - Focusing diameter: 0 μm
- Part contour:
  - Speed: 0.614 m/s
  - Laser power: 154 watts
  - Focusing diameter: 0 μm

The 3D CAD model in .STL format was processed in the printer software, where support was added, and then when transferred to the printer, a manufacturing time was given according to the aforementioned process parameters.

The manufacturing time of the part given by the DMG MORI program was 6 hours, 6 minutes, and 46 seconds.

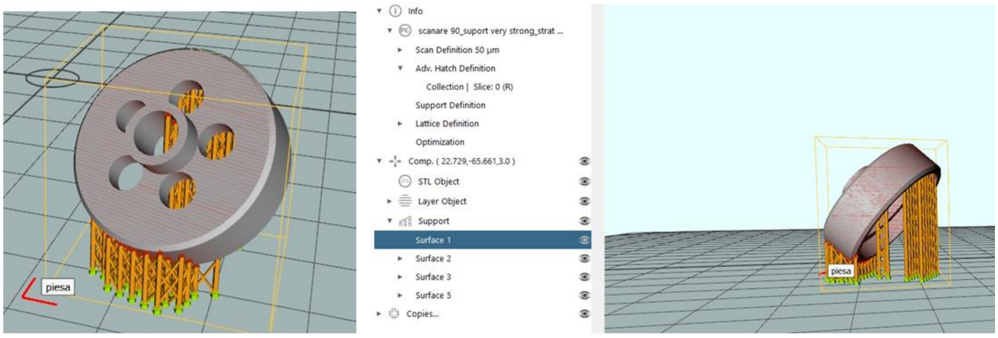

Fig. 4 Part processed in the printer software

3.3. Equipment Preparation and Manufacturing Process

The equipment used in the manufacturing process was a DMG MORI LASERTEC 30 SLM printer. It printed the part with titanium powder (Ti-6Al-4V). Ti-6Al-4V is an alpha-beta titanium alloy with high specific strength and excellent corrosion resistance. It is one of the most commonly used titanium alloys and is applied in a wide range of applications where low density and excellent corrosion resistance are required, such as in the aerospace industry and biomechanical applications (implants and prosthetics).

To start and operate the printer, a temperature of about 20°C is required in the room. Thus, air conditioning needs to be turned on and kept on throughout the entire process. Also, the humidity needs to be reduced, and air conditioning is used for this purpose as well.

When the outside environment has optimal levels, the operations continue at the interior level. The process starts with leveling the plate on which the part will be printed, followed by the elimination of oxygen inside the printer. The oxygen level is lowered from 21% to 0.2% by increasing the level of argon. Also, the plate temperature is increased, as the material used for printing needs to be at 80°C. Finally, the powder level is checked to be sufficient to print the part. Specifically, for the part that is the subject of this study, a volume of titanium powder of 300x300x50 mm^3 was needed for printing. Images of the printing process and the obtained result are shown in figure 5.

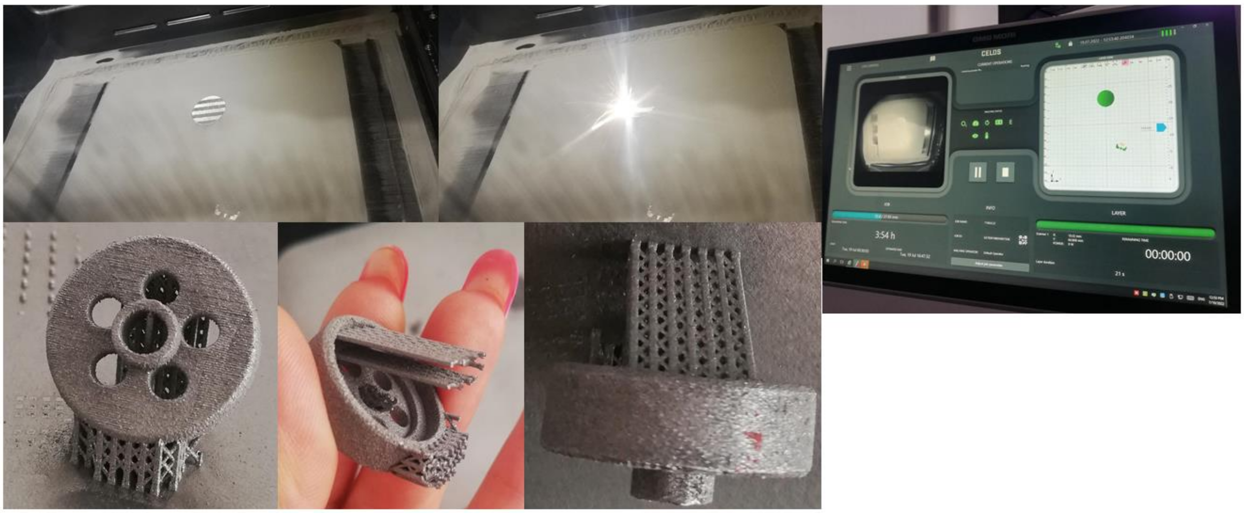

Fig. 5 The printing process and the obtained result

3.4. Post-Processing and Part Verification

The post-processing of the part was performed using pliers, thus removing the supports placed to support the structure of the part. Images of the post-processing and the final part after post-processing are presented in figure 6.

Fig. 6 Removing supports and final part

After the post-processing stage, the dimensional check of the part was carried out using a digital caliper to see if the dimensions of the part were respected and it fits within the dimensions and tolerances in Table 1, as well as verifying the surface roughness of the part, which was obtained as Ra=10.6µm. The entire checking process was photographed, as shown in figure 7.

Fig. 7 Dimensional verification of the part

4. Conclusions and perspectives

Based on the findings presented in this research paper, the following conclusions can be drawn:

→ In the case of additive manufacturing, a Computer Aided Design (CAD) model is loaded into the software of a 3D printer, which then builds the object by depositing successive layers of material. This technology is very versatile, allowing the production of objects with complex shapes and geometries, including internal components or winding structures.

→ In comparison to machining, additive manufacturing can be more efficient and economical for the production of customized or small-batch parts. Additionally, it can be faster, more precise, and more flexible in the production of objects with complex geometries. On the other hand, machining may be preferred for the production of parts from stronger materials or when strict tolerances are required. Furthermore, machining may be faster and more efficient for the production of large-batch parts.

→ The case study conducted shows that a metal part obtained through additive manufacturing can successfully meet the prescribed dimensional characteristics, but not always the prescribed roughness characteristics, in the case of small roughness's on certain surfaces. However, additive manufacturing can be helpful for the production of unique or small-batch parts because it can be used to create blanks with very small machining allowance, thus greatly reducing the waste resulting from machining.

5. References

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