

## Prospects Of Use And Processing Of Titanium Blanks Obtained By xBeam 3D Metal Printing Technology

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*Abstract – the article presents the new range of additive technologies called xBeam 3D metal printing that allows the production of titanium alloy parts for the medicine, aeronautical and automotive industries. The new technology opens up essential challenges, such as identifying and analysing the optimal finishing machining strategies for this type of part. The article analyses the production and machining of Ti6Al4V produced by Wire Arc. The research focuses on implementing optimal cutting modes to obtain the required surface quality. This article provides a better understanding of the machining of titanium blanks using this technology. The optimistic results make this method the best alternative to traditional casting technologies and powder metallurgy.*

*Index Terms— Additive Manufacturing (AM), Titan (Ti-6Al-4V) machining, xBeam 3d metal printing, Wire and Arc Machining (WAAM).*

### I. INTRODUCTION

Recently one of the most intriguing and promising advances in the evolution of industrial technology is additive manufacturing (AM). Additive manufacturing is a fast and convenient way to make blanks and prototypes for future products. Layer-by-layer creation of 3D physical objects directly from CAD data without needing tools dies, or human labor is known as additive manufacturing (AM). Using traditional technology, producing prototypes and patterns is labor-intensive and time-consuming. Although additive manufacturing (AM) offers a quick and versatile way to make parts, the technology's general use has historically been constrained by the appropriateness and availability of materials. Using computer-generated 3D model data with additive manufacturing is the technique of combining materials to create items that are almost net-shaped, often layer by layer.

For this reason, additive manufacturing is sometimes referred to as 3D printing, and the tools used to realize it are also known as 3D printers. Materials for layer-by-layer construction of components can be made of polymeric materials and metals in varied beginning states (powder, wire, etc.). Using AM in healthcare, aviation, and other fields is a challenging endeavor requiring a multidisciplinary approach, excellent engineering expertise, a large workforce, and close coordination between engineers and professionals in medicine, aviation, etc. Because AM technology can create models with sophisticated geometrical shapes, it is ideally suited to mimic the complex conditions of the human body, forms of parts for aircraft and rockets, automotive spare parts, etc. The surgeon's ability to see the delicate and hidden features of a patient's injuries is improved by using AM models. It is a significant finding and the first step toward creating other intricate human organs [1], [2]. The industry is particularly interested in using additive manufacturing to create metal components since metals, alloys, and intermetallic

compounds continue to be the primary structural elements used in producing industrial goods with the highest added value.

In many instances, additive manufacturing can offer distinct benefits over conventional metal machining processes, such as:

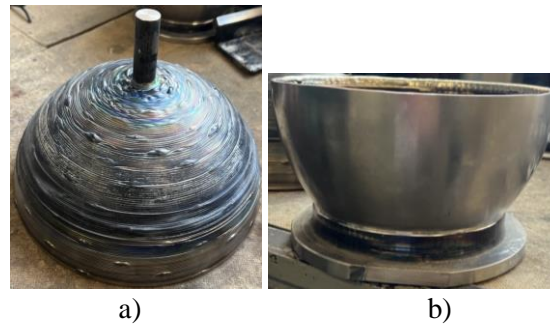
- the production of very complicated components, such as those with overhangs, cavities, bores, bosses, slots, complex curves, etc., especially if the part is made of a material that is difficult to machine, is exceedingly challenging, time-consuming, costly, or even technically impossible;
- when the preparation of specialized manufacturing equipment, molds, or tools is costly and results in a high specific cost of the component, the production of a single part or a small number of batches;
- In remote locations where replacement parts are logistically unavailable, such as aboard spacecraft, offshore platforms, rural areas, etc., spare parts can be manufactured and installed on equipment right away at the location of operation.

The following factors can be used to categorize additive manufacturing (AM) processes for metal objects:

- By feedstock material (powder or wire);
- By heating source (laser, electron beam, or plasma);
- By method of layer formation (selective melting of the prepared layer of powder, "powder bed"; or direct deposition of melt powder or wire on the substrate; "direct deposition") [2].

With an accuracy of up to 20–30 microns, AM techniques, which are based on selective sintering of powders using laser and electron beams, enable the creation of highly intricate and thin components. The primary drawback, however, is the need for additional safety precautions and unique working circumstances, particularly for powders like titanium and aluminum, which are highly combustible and explosive. Complete AM facilities that use powder must build intricate and pricey auxiliary equipment for powder preparation, storage, supply to the AM system, and recycling of leftover powder when the manufactured component is removed from the AM system. New xBeam 3D metal printing technology patented by NVO "Chervona Khvyliya" has substantially greater deposition rates and more readily available, inexpensive raw materials; additive manufacturing technologies based on the use of wire feedstock are seen to be the most promising processes for the mass industrial manufacture of significant components. In addition, using wire material is a competitive advantage, and mechanical tests have confirmed that the resulting blanks are not inferior to standard ones. Therefore, this method is the best solution for manufacturing machine parts of medium complexity and medium-large dimensions. Also, continuous (solid flow) metal transfer from the fused end of the feedstock to the molten pool is one of the most significant and distinguishing characteristics of the xBeam printing technique. It enables efficient control over the deposited layer's breadth and thickness. With xBeam printing, relatively delicate components may be produced quickly and with little need for post-processing. The new configuration of the electron beam gun makes it possible to use powder feedstock effectively since all powder particles fall into the melt zone on the substrate. It offers wire feedstock pre-heating and fusing that is entirely consistent. [3].

Ti6Al-4V titanium blanks increased by 9%, especially in aircraft construction, which is explained by its high corrosion resistance and strength, but machining is tricky due to high cutting forces and a tendency to stick to the cutting tool. One of the problems is that blanks produced by xBeam 3D technology typically have high surface roughness and waviness in the shape of the blanks (Fig. 1) and need to achieve the required tolerance. Due to the geometric and mechanical requirements of the aerospace sector, machining processes are necessary to improve surface smoothness and obtain the required dimensional accuracy. Therefore, the most common approach is to finish additively manufactured parts using a finishing method.



II. Figure 1 – Blanks: a) without post-processing, b) after finishing the process

### III. FUTURE EXPERIMENT

There currently needs to be more input data for an optimal result for future experiments. But describing the future research, method, and tools is relatively easy.

The study aims to develop technology and obtain optimal cutting modes for the operation (turning, milling, etc.), which considers the influence of various factors on the machining process, ensuring the required machining accuracy by controlling the cutting process (vibrations, vibrations, etc.).

Research objectives are

- Investigate existing methods for improving and/or ensuring turning, milling, and finishing accuracy.
- Theoretically develop a blank processing technology with the calculation of cutting parameters.
- Develop a mathematical model of the cutting process using DEFORM 2D/3D, obtain graphs of the distribution of deformations, vibrations, vibrations, pressure on the tool/blank, tool speed, stress, and temperature based on the technological process, develop an optimal algorithm for controlling the cutting process.

- Identify the optimal values of cutting parameters (speed, feed, depth of cut) that determine the optimal machining time, quality, tool life, and required power based on a mathematical model.

- Verify and experimentally confirm the obtained optimal cutting modes on the experimental model.

The experiment:

- Receiving blanks from NVO "Chervona Khvylya"
- Using the parameters obtained in the simulation modeling, the blank is processed according to the information from the customer.

- Performing measurements: shape and dimensional accuracy, surface condition and roughness, and dynamic measurements of the system during machining.

The necessary recommendations for the use of the xBeam 3D technology in combination with cutting processes are not available, so future research requires further experiments and aims to propose various industrial strategies, including describing the manufacturing process, experimenting with cutting modes and procedures to achieve the quality of surface needed and conducting the necessary experiments to determine cutting forces, deformations, and vibrations that affect microstructural results.

Overcoming the limited tool life that generally stops people from employing high cutting rates is the main problem when machining titanium. Cutting speeds for Ti-6Al-4V are frequently capped at 60 m/min to guarantee adequate tool life. There are several techniques to make titanium more machinable. The basic guidelines for machining titanium blanks produced by additive manufacturing methods using metal wire, such as turning and milling, and meeting aviation standards, demonstrate that the impact of machining strategies and changes in tool paths affect the quality of the final surface. The main challenge in titanium machining is overcoming tool stability, which usually does not allow for high cutting speeds. In order to ensure good tool life, cutting speeds for Ti-6Al-4V are often limited. There are several ways to improve the machinability of titanium. These include using standard cutting fluids and

alternative cutting tool materials, such as coated carbide cutting tools (Al, Si, Ti, N), which double the tool life compared to uncoated carbide tools [4].

Milling titanium is a more complex operation than turning. The cutter only mills part of each revolution, and chips tend to stick to the teeth during the part of the revolution that each tooth is not milling. On the next contact, the tooth can be damaged when the chips are knocked off. This problem can be significantly alleviated using lift milling instead of conventional milling. In this type of milling, the cutter comes into contact with the thinnest part of the chip as it exits the cut, which minimizes chip sticking. When milling titanium, when the cutting edge fails, it is usually due to chipping. The 20-30% increase in cutting speed possible when using carbide tools compared to HSS tools only sometimes compensates for the additional costs of tool sharpening. Therefore, it is recommended to try both HSS and carbide tools to determine the best tool for each milling application. It is recommended to use water-based coolants. Turning titanium can be used without any difficulty. Carbide tools should be used for turning and boring as they provide higher performance and longer service life. Ultra-high speeds are recommended for machining high-speed steels. Tool deflection should be avoided, and a solid and constant flow of cutting fluid should be supplied to the cutting surface [4], [5].

The most detailed milling experiments that can be relied upon for future research with wire arc [6] with recommended machining and tools parameters for cutting speed ( $V_c$ ) 55 m/min, feed ( $V_f$ ) 88 mm/min, radial engagement ( $A_e$ ) 1 mm, with tool using cutting material as solid carbide and using flood coolant, and cutting length approximately 30 mm, showed two challenges were identified from the experimental results: forced vibrations brought on by the cutting forces' modulating frequency and form mistakes brought on by erroneous defections. In addition, the researchers [6] developed the following guidelines for the milling process to reduce the impact of the geometry of the blank (Fig. 1a):

- Maintain the feed direction in the direction of the lesser waviness to maintain the mean cutting forces as steady as feasible.
- Make that the spindle's rotational and modulating frequencies are different. It happens when spindle speeds are low.
- The modulating frequency and its harmonics can produce possible forced vibrations. Design the setup and clamping accordingly so that no natural and modulating frequencies are in phase.
- Changes in defections are caused by force modulation. Design the milling procedure to produce the surface-defining cut with the least force fluctuation possible.

#### **IV. SCIENCE NOVELTY**

Therefore, several developments will help to perform future work based on the recommendations identified by other researchers. Also, it should be developed suitable cad model for visualization of all post-processing machining using DEFORM 3D to determine the optimal cutting modes, forces, vibrations, and deformations, as well as pressure on the tool, and at the end, conduct an experiment on an accurate model. Therefore, it should be investigated to see if the following guidelines and theory hold for the procedure and if it may result in financial advantages for the machining process. It is also necessary to develop lathe machining strategies, which must be explored.

The science novelty for conducting the research:

- Significant economic effect from obtaining a blank using xBeam 3D metal printing technology.
- Recommendations for the rational choice of cutting modes and tooling for the cutting process.
- A methodology for combining simulation CAD modeling and experimental research will be proposed, which involves the primary simulation of machining a blank with different parameters of cutting modes, analysis of these results, and only then a proposal for achieving the most effective cutting conditions from both technological and economic points of view.
- Further development of research on dynamic processes of machining titanium alloys.

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