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ADDITIVE MANUFACTURING OPPORTUNITIES IN THE AVIATION INDUSTRY

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Abstract. Additive manufacturing is a relatively new direction in modern industry and has already taken its place in various industries. The main benefits of the process are well aligned with the main requirements for technology used in aircraft construction. It is for this reason that the technology of additive manufacturing so quickly entered this industry and continues to develop in it.

This article provides a brief introduction to additive technologies and an overview of their possible use in aircraft construction.

Keywords: additive manufacturing; topological optimization; 3D printing; CAD/CAM/CAE systems

1. INTRODUCTION

Additive manufacturing (AM) is an umbrella term for different manufacturing methods that aim to manufacture complex three-dimensional shapes by adding material successively and their sequential connection to each other, see the Fig. 1.

The basic principle of additive manufacturing is that the model is created using a computer system (3D CAD) and then the modeling data is divided into a series of data (layers) of two-dimensional sections of a given thickness, which are then inserted into the 3D printer software and produced in accordance with the developed 3D model.

This principle of layering is incorporated in the design of almost all printer models, which differ only in the type of material used, the method of forming the layers, the type of power supply and the technology of their gluing [1].

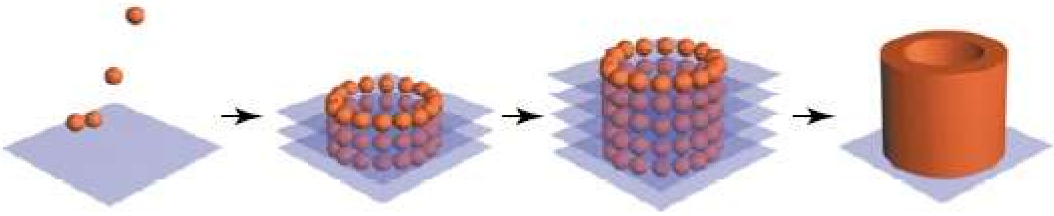

Figure 1 Additive manufacturing process [1]

2. METHODOLOGY

2.1. Classification of additive technologies

Within each method of additive manufacturing, producers of the respective equipment apply different possibilities of working with materials and create their own technologies [2].

A wide variety of additive manufacturing methods are currently available. The main differences lie in the method of application of the layers and the consumables used. Some methods rely on melting or softening materials to create layers: these include selective laser sintering (SLS), selective laser melting (SLM), direct metal laser sintering (DMLS), fused deposition layer printing (FDM or FFF). Another way of solution is the production of solid models by polymerizing liquid materials, known as stereolithography (SLA). Basic methods of gluing materials shown in the table 1 [3].

Table 1 Classification of additive technologies by methods

Method	**Technology**	**Materials used**
Material extrusion	Fused deposition modeling (FDM)	Plastic filament (PLA, ABS, PET, TPU, Nylon, and many more.)
Powder bed fusion	Selective Laser Sintering (SLS) Selective Laser Melting (SLM) Electron Beam Melting (EBM) Direct Metal Laser Sintering (DMLS) Multi Jet Fusion (MJF)	Thermoplastic powders (Nylon 6, Nylon 11, Nylon 12, etc.), metal powders (steel, titanium, aluminium, cobalt, etc.), ceramic powders
VAT Polymerization	Stereolithography (SLA) Masked Stereolithography (MSLA) Microstereolithography (μSLA) and more.	Photopolymer resins (castable, transparent, industrial, biocompatable, etc.)
Material Jetting	Material Jetting (MJ) Drop on Demand (DOD)	Photopolymer resin (Standard, Castable, Transparent, High Temperature)
Binder Jetting	Binder Jetting	Sand, polymer, or metal powder: Stainless / Bronze, Full-color sand, Silicia (sand casting); Ceramic-Metal composites
Direct Energy Deposition	Laser Engineered Net Shaping (LENS) Electron Beam Additive Manufacturing (EBAM)	Metals, in wire and powder form
Sheet Lamination	Laminated Object Manufacturing (LOM) Ultrasonic Consolidation (UC)	Paper, polymer, and metal in sheet forms
Micro 3D Printing	Microstereolithography (μSLA) Projection Microstereolithography (PμSL) Two-Photon Polymerization (2PP or TPP)	Polymer, metal, ceramic

2.2 Benefits of additive manufacturing

Improved properties of finished products

Due to the layered construction, the products have a unique set of properties. For example, parts created on a metal 3D printer, in terms of their mechanical behavior, density, residual stress, and other properties, can have characteristics that cannot be obtained by casting or machining [4].

Saving raw materials

Additive technology uses just about the amount of material needed to manufacture your product. The loss of raw materials can be up to 80-85% with traditional manufacturing methods.

The ability to manufacture products with complex geometry

Equipment for additive technologies allows the production of items that cannot be obtained in any other way. For example, a part inside a part, very complex cooling systems based on mesh structures (this cannot be obtained either by casting or stamping) [5].

Manufacturing mobility and data exchange acceleration

The process of creating technical documentation for 3D printing is much easier and faster. This means that fewer people are involved in the pre-production process [6].

3. USE OF TOPOLOGICAL OPTIMIZATION IN RELATION TO ADDITIVE MANUFACTURING IN AIRCRAFT CONSTRUCTION

From its inception, additive manufacturing has been used in the aerospace industry. It not only plays the role of rapid prototyping technology to save capital and time during the product development period, but also has a profound impact on product design, direct part fabrication, assembly and repair in the aerospace industry. With recent developments, AM has rapidly evolved into a strategic technology that will generate revenue throughout the aerospace supply chain [7].

Topological optimization is a new technology that is beginning to change the way people think about aircraft construction. Topology optimization is a mathematical method that optimizes material layout within a given design space, for a given set of loads, boundary conditions and constraints with the goal of maximizing the performance of the system.

Figure 2 Example of using topological optimization [7]

3.1. Topological optimization software

Modern design tools allow not only to predict the degree of deformation of a part, but also to optimize it, in accordance with the specified limits of mass and strength. In general, a blank model is prepared, from which excess material is subsequently removed. The result of topological optimization is a complex structure, on the basis of which a model of a part is formed for production. Such a part has the required strength with a minimum weight, but is difficult to manufacture using traditional methods. Optimal would be additive manufacturing to create these models [8].

Now topological optimization tools are mainly components of large CAD / CAM / CAE development packages from Siemens, Dassault Systèmes, Autodesk. This technology is used mainly in 3D printing with metal alloys. Generative design, combined with strength analysis, solves the problem of reducing product weight while maintaining strength, which is important not only in the aerospace industry. In any production, material savings will lead to lower costs, especially when it is related to expensive metal powders [9].

There is a significant number of software products on the market that can be used to perform topological optimization calculations. Typically, this functionality is provided by packages that produce deformation modeling and strength calculations.

Topological optimization can be done in such programs as: Siemens NX, Siemens Solid Edge, CATIA 3DEXPERIENCE, SOLIDWORKS, ANSYS Mechanical, PTC Creo.

Apart to be optimized is placed in the workspace, others are attached to it, which will not be affected by the process, but participate in the interaction. The specification of the fasteners and the applied loads is done within the framework of the assembly. In other programs, modeling the entire assembly is not necessary, it is enough to create only touch points. But in this case, the accuracy of the calculations may turn out to be lower [10].

3.2. Example of technological data for additive manufacturing

We will deal with two parts that perform the same function with certain loads and have a certain source. In fact, it is one and the same detail, but with a different geometry. The geometry of the first part is optimized for production by standard production methods: milling machine, lathe and other metal processing technologies. It is a simple and flat geometry, easy to achieve when machining on a machine. The second part has a more complex geometry [11,12].

Figure 3 Comparing the same products with different design solutions [11]

According to the data, the second part has less tension, less movement under load and, most importantly, the weight decreased by 1 kg. It's not much for one piece, but if they are made a hundred thousand a year, then we can save a hundred tons of metal with just one piece. In addition, each kilogram of weight increases the load per aircraft. (Figure 3, Table 2)

Table 2 Same detail with different design solutions

	Traditional construction	New construction
Weight [kg]	3,703	2,670
Maximum stress [MPa]	1045	897
Deformation under load [mm]	2,29	1,72

4. CONCLUSION

The aerospace industry has shown an increased interest in additive manufacturing since its inception. The ability to remove many of the constraints from design to production enables solutions that increase efficiency and reduce parts weight. The aerospace market, by its very nature, requires small batch production of high quality parts. Additive technologies replace some of the tooling that is often unique and expensive.

However, the main problem of introducing these technologies into the production process of manufacturing products for aviation and rocket and space technology is their certification, since strict requirements are imposed on the physical and mechanical characteristics, stability and surface quality of parts manufactured using additive technologies, which are not always possible to fulfil.

Nevertheless, this problem is gradually being solved by large world manufacturers of aviation and rocket and space technology, and parts created using additive technologies are already used in serial products of aircraft.

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