FAST PROTOTYPING IN THE MANUFACTURING OF COMPLEX ARMAMENT PARTS

БЪРЗО ПРОТОТИПИРАНЕ ПРИ ПРОИЗВОДСТВОТО НА СЛОЖНИ ДЕТАЙЛИ ОТ ВЪОРЪЖЕНИЕТО

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Abstract: *Virtual prototypes or virtual 3D models of complex armament parts reduce costs and production time with minimal risk of hidden flaws, testing and analyzing the construction before creating real physical prototypes or optimizing parameters in parallel with the physical prototypes. The report presents the possibility of rapid prototyping through the virtual 3D model of the SPG-9 breech and using additive manufacturing to obtain a functioning physical prototype.*

Keywords: FAST PROTOTYPING, 3D MODELING, ADDITIVE MANUFACTURING.

1. Introduction

Reduction in cost for the production of complex armament elements (special elements) can be achieved by making prototypes of the needed elements, increasing the quality of the production process and reducing the costs, design and implementation times of the products as a whole.

Prototypes can be both physical and virtual. Virtual prototyping as a technology involves the creation and use of virtual models for presentation, testing and analyzing of particular details before creating the real physical models or optimizing parameters in parallel with physical prototypes. Physical prototyping involves the creation of element models including functional ones in small quantities compared to the manufacturing ones. When a combination of the two technologies is possible significant reduction in costs and production time can be achieved with minimal risk of hidden deficiencies occurring in series production.

Suitable platforms for the creation of virtual models are CAD / CAM systems for designing and manufacturing of special products.

2. Research

2.1. Purpose: Exploring the possibilities for rapid prototyping of special complicated armament components manufacturing.

2.2. Tasks:

- Analyzing types of rapid prototyping;

-Researching the possibilities of rapid prototyping for special manifactured products.

For the purpose of the study the mechanical processing and the equipment necessary for manifactyring the breech of the SPG-9 anti-tank grenade launcher will be reviewed.

Steel with the designation OXN3MFA is used for manufacturing the detail for the SPG-9 breech. Required output dimensions of the material for a single breech are Ø195x230mm at a mass of 51,190 kg.

The manufacturing technological process includes a total of 23 machining operations - 11 mechanical processing, 5 tuning operations, 1 heat treatment, 1 galvanic processing and 5 control operations performed on 7 specialized and universal machines using 10 fittings and over 60 tools.

Different and various questions arise in the implementation of various stages a quick and effective solution is to design a prototype of the product through Virtual Engineering without making a physical prototype. Whereupon design and validation activities are carried out jointly to ensure optimization and testing of products prior to their actual realization.

The virtual prototype is a computer model that allows simulation with a functional realism similar to that of the physical object.

Virtual prototypes allow: research and verification of functionality and performance with the help of specialized software and hardware; Finite Element Analysis; Computational Fluid Dynamics; Kinematic and dynamic analyzes; Reliability Analysis and Failure Mode and Effect Analysis; Planning and simulation of production; Manufacturability; Assembly Analysis; Manufacturing Management; Human Factor Analysis.

The natural environment of the virtual prototype is Virtual Reality. The virtual prototype is the core of the Virtual Reality. Virtual Reality is an artificial computer-generated environment that simulates to a great extent and with extreme credibility the real world around us and gives the user the ability to manipulate and interact with virtual models that behave like real objects. Depending on the degree of human involvement the virtual reality is Desktop VR, Projection VR or Immersive VR.

The advantages of virtual prototypes and models are the reduced cost in initial design stages, increased possibilities for alternative design in the virtual environment and rapid accumulation of design experience.

Physical prototyping involves the creation of a functional product model in small quantities compared to the final product quantitis in its industrialization and commercialization.

Once created physical prototypes are difficult to change. If changes are necessary, this will lead to the development of new models ie. requires extra time and investment.

Rapid prototyping technology (RP) is a sophisticated manufacturing technology that creates material models from CAD data through 3D printers. Different types of rapid prototyping systems have different molding principles and system characteristics due to different molding materials. Different systems can directly receive product design (CAD) data without having to prepare tools and tooling and quickly make samples, matrices or new product models. Therefore, applying RP technology can significantly shorten the product development cycle, the cost of developing and improving the quality of development. Most prototypes require three to seventy-two hours depending on the size and complexity of the product which is much faster than a few weeks or months to produce a prototype through machine production.

Adaptive manifacturing (AM) is a technology that allows for three-dimensional layer detail manufacturing by a layer of material based on polymer or metal. The design of the detail in the form of a CAD model file is loaded into the adaptive manufacturing machine (or 3D printer), which then produces the component.

The adaptive manufacturing technology used by most 3D printers is based on modeling by depositing plastic material such as Stereo Lithography-SLA, Digital Light Processing, 3D Printing, Polyjettechnology, Inkjet and Fused Deposition Modeling is not suitable for the creation of the SPG-9 breech.

The main methods for direct 3D production of metal details are: Selective laser melting - SLM (Figure 1) and Laser Engineered Net Shaping - L.E.N.S. (Figure 2) both applicable for manufacturing the SPG-9 breech.

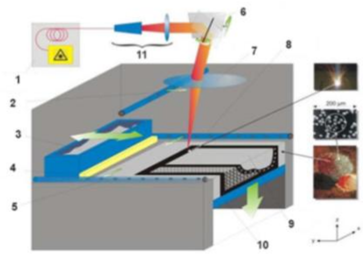

Fig. 1 *Selective laser melting –SLM*
1 - Laser; 2 -Processing gas jet, 3 –Material tank; 4 - Roller; 5 - Inlet of gas; 6 - Mirror; 7 - lentils; 8 - Output gas; 9 - Layer material; 10 - Mass; 11 - Direction of the beam.

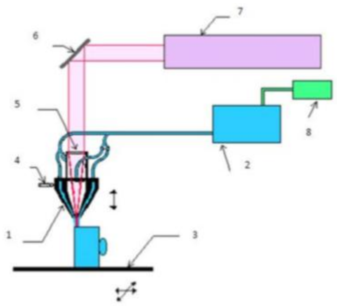

Fig. 2 *Laser Engineered Net Shaping –L.E.N.S.*
1 - Extruding head; 2 -Powder material; 3-table; 4-Inlet shielded gas; 5 - lenses; 6 - Mirror; 7 - Laser; 8 - Transportable gas.

3D models are created with computer aided design (CAD) via a 3D scanner or a simple camera with specialized software to measure the distance and size of the subjects in the picture. Regardless of the object modeling software used the model must be converted to .STL or .OBJ format. In order for the software responsible for printing the model to process the information.

Then the STL file is processed by software that converts the model into very thin layers and creates a G-code file containing specific instructions for the type of 3D printer used and the detail can be printed. In accordance with the instructions given the printer sequentially applies the material layer by layer. In this way, the pattern is created by the overlay of multiple layers. These layers represent the sections of the object from the CAD model connected to each other to form the shape of the final object. Depending on the size and complexity of the object this process may take from minutes to days. The advantage of this way of printing is that almost every possible form can be created.

The resolution of the printer determines how thin each layer and the detail of the object can be. Typically, 1 layer is about 100 μm (250 DPI) although some printers can reach up to 16 μm (1600 DPI). Which is comparable to the resolution of a laser printer.

3D принтирането предлага значителни предимства пред традиционните производствени процеси, като CNC механична обработка и леене, като позволява на производителите да консолидират в един единствен процес различни производствени операции, които преди са изисквали сложни и скъпи производствени процеси.

3D printing offers significant advantages over traditional manufacturing processes such as CNC machining and casting. Allowing manufacturers to consolidate a variety of manufacturing operations in a single process that previously required complex and costly manufacturing processes.

In material-like production unlike traditional production only as much material as it is actually needed for the object itself can be used. With good design and architecture, the loss of material can be reduced to a really negligible minimum often as few as couple of grams.

The new printing materials are far lighter, stronger and more durable than conventional ones. There are high-performance printers that can be used directly for manifacturing details.

3D printers printing with metal offer direct production for details with great complexity removing costly tooling and shortening the time required for preparation and subsequent processing.

The main advantages of 3D printed metal models are: freedom in details design, fewer joints, reduction of workpiece weight by merging, greatly shortened production time, reduction in the cost of prototypes and small detail series, high metal density of the parts - 96-100%, a great variety of metals and alloys, high repeatability and precision of workmanship and handling of biocompatible materials - cobalt / chromium and titanium.

The creation of a physical prototype of the SPG-9 breech can be achieved by the use of additive manufacturing for metal parts.

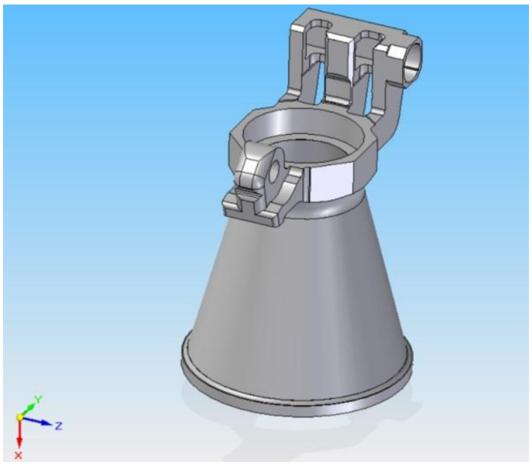

Fig. 3 *Model of the SPG-9 breech.*

Continuous technology development for additive manufacturing allows for the creation of finished details (including almost 100% dense fully functional constructions) through a one-step process. Additive manufacturing systems are becoming more and more reliable and efficient and the range of suitable materials has grown considerably compared to the first truly applicable manufacturing practices in the field.

Powder bed and direct powder-like layer processing technologies, known as laser melting systems are commercially available under varius trade names such as: systems for selective laser melting (SLM), laser mixing and direct metal laser sintering (DMLS). The only exception from this principle is the electron-beam melting process (EBM), during which an electron beam is used under a vacuum.

The variety of available materials for additive metal manufacturing is constantly expanding. Stainless steels, aluminum, nickel, cobalt-chromium and titanium alloys are most often used, and a number of AM manufacturers also offer their own proprietary materials.

Research institutes, universities and AM systems manufacturers are already developing and offering customized materials tailored to the needs of client applications. Not all existing metal materials can be used for the additive production of parts but in most cases, and in the presence of suitable equipment, a metal powder can be created for each model - a raw material for manufacturing the necessary products.

The wide variety of materials offers users a great deal of choice for the right material to meet the desired product specifications.

Common properties of metal powders suitable for AM are the spherical geometry of particles obtained from gas atomization and particle size distribution depending on the thickness of the layer, typically between 10-50 μm.

Material properties such as tensile strength, hardness, and elongation coefficient are used as reference points for deciding the suitability of the material.

In order to achieve the required specifications or to improve the properties of the manufactured parts, such as surface quality, geometrical accuracy and mechanical properties, additional processing is often required after the additive process.

The high quality of the metal products produced by additive manufacturing allows the application of different finishing technologies for metal surfaces to meet the surface quality and geometry requirements.

After removing the supporting structures and separating the obtained parts from the construction platform they can be milled, perforated, polished, etc. Heat treatment is often included in the process chain as well as the "shot peening" technology (a high-tech adhesion process carried out by a stream of solid particles). These techniques are used to improve the mechanical and tactile properties of the surfaces of the additively manufactured parts.

Electropolishing significantly improves the surface quality of AM produced parts during the finishing treatments. Its main purpose is to minimize the micro roughness thereby reducing the risk of them retaining dirt and debris and material leftovers on the surface of the detail and improving its cleanliness.

Electroplating can also be used for degreasing, coloring and passivation, especially for surfaces exposed to abrasion. Since electroplating does not involve mechanical, thermal or chemical action, small and mechanically fragile parts can be processed.

The process of designing metal parts produced through AM typically involves the use of topology optimization software to determine the place of deposition of the material and the areas from which it can be removed. From the low stress areas, material is removed until the finalized construction is created and optimized for load-bearing parts.

Because of the limited size of modern AM systems, the production of large-dimensional structural elements with them is also somewhat limited. The dimensions of the chambers of the typical industrial AM metal machines are approximately 630 x 400 x 500 mm.

A suitable equipment for the manufacture of a SPG-9 breech using the additive manufacturing method of metal details is the 3D Systems ProX Direct Metal – printers for direct printing of metal models.

Fig. 4 *3D Systems ProX Direct Metal.*

The 3D printers ProX Direct Metal of 3D Systems produce metal parts and high density metal casts from a wide range of materials with proven mechanical properties.

The ProX DMP 100, 200 and 300 printers include flexible settings for parameter control. These open systems offer users the ability to develop parameters and are able to use any material in addition to the ready-to-use alloys of 3D Systems. The ProX DMP 320 printer, with replaceable production modules, allows for fast material change according to the printer configuration.

	DMP Flex 100	ProX DMP 200	ProX DMP 300	ProX DMP 320
Build volume (W x D x H)[1]	3.94 x 3.94 x 3.15 in (100 x 100 x 80 mm)	5.51 x 5.51 x 3.94 in (140 x 140 x 100 mm)	9.84 x 9.84 x 12.01 in (250 x 250 x 305 mm)	10.82 x 10.82 x 14.96 in (275 x 275 x 380 mm)
Metal alloy choices with developed print parameters	LaserForm CoCr (B) LaserForm 17-4PH (B) LaserForm CoCr (C)	LaserForm CoCr (B) LaserForm 17-4PH (B) LaserForm Maraging Steel (B) LaserForm AlSi12 (B)	LaserForm CoCr (B) LaserForm 17-4PH (B) LaserForm Maraging Steel (B) LaserForm AlSi12 (B)	LaserForm Ti Gr1 (A)[2] LaserForm Ti Gr5 (A)[2] LaserForm Ti Gr23 (A)[2] LaserForm AlSi10Mg (A)[2] LaserForm Ni625 (A)[3] LaserForm Ni718 (A)[3] LaserForm 17-4PH (A)[3] LaserForm CoCrF75 (A)[3] LaserForm 316L (A)[3] NEW LaserForm Maraging Steel (A)[3]
Layer thickness	10 μm - 100 μm Preset: 30 μm		Preset: 40 μm	10 μm - 100 μm Preset: 30 and 60 μm
Repeatability	x=20 μm, y=20 μm, z=20 μm			
Min. feature size	x=100 μm, y=100 μm, z=20 μm			100 μm
Min. wall thickness	150 μm	150 μm	150 μm	150 μm
Typical accuracy	± 0.1-0.2% with ± 50 μm minimum	± 0.1-0.2% with ± 50 μm minimum	± 0.1-0.2% with ± 50 μm minimum	± 0.1-0.2% with ± 50 μm minimum
Material loading	Manual	Semiautomatic	Automatic	Manual
Recycling system	Optional external system	Optional external system	Automatic	Optional external system
Interchangeable build modules	No	No	No	Yes
Real-time monitoring	No	No	No	DMP Monitoring

[1]Maximum available part size using standard build plate [2]Set up A [3]Set up B Complete specifications available at www.3dsystems.com

Fig. 5 *Specifications of the 3D Systems ProX Direct Metal.*

3. Conclusions

The methods of virtual prototyping in the CAD / CAM / CAE environment are applied in the design of a special device - a SPG-9 breech, to improve the production technology and reduce the cost of manufacturing the part. The designed virtual 3D model gives a better idea of the part design and is easier to correct than conventional 2D drafts.

The machining process used to create the part requires 7 machines in 23 processing stages and over 10 devices as well as over 60 tools to be used which are reduced to one machine for additive manufacturing - 3D Systems ProX Direct Metal for the production of high-density metal parts from a large wide range of materials with proven mechanical properties.

Using 3D prototyping in the design a special SPG-9 breech reduces costs, whether it is used for the creation of a prototype or in serial production.

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