Direct Metal Laser Sintering – Possibility of Application in Production Process

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***Abstract* – The article describes the Direct Metal Laser Sintering technology and its application in production process. In the introduction part, a brief description of DMLS technology is described, its principles with the subsequent advantages and disadvantages. The second part of the article focuses on characterization of the basic materials which are currently most commonly used in DMLS processes. This part aims at describing the basic properties of the individual materials and their demonstration. The final part of the article deals with the possibilities of applying the chosen method in the production process.**

***Keywords* – DMLS technology, DM 20, MS1, GP1, production process.**

1. Introduction

At present, a technological development is observed in all fields of technology. This development is also observed by engineering production through their constant upgrading, by improving the production equipment and by improving new machining methods or production processes. [1] Before launching a new product, the prototype development is one of the longest parts of the whole production process. Today's time requires all manufacturers to respond quickly to customer requirements, and just shortening development time brings considerable cost savings and a competitive advantage. [2]

The DMLS method is one of the current methods that are applied more and more in the engineering industry. Through this method, prototypes and inner shapes can be quickly produced in the developmental phases. They can be reconstructing damaged forms that cannot be produced by conventional methods. [3]

Direct Metal Laser Sintering (DMLS) is a technology that makes it possible to produce fully functional metal parts directly from 3D CAD data. Metal parts manufactured by DMLS technology are completely comparable with the machined and cast parts in terms of mechanical properties. [4]

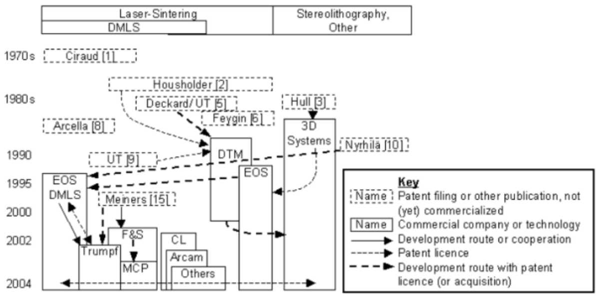

Figure 1. History of DMLS – development and patent [3]

2. DMLS Technology

DMLS technology is based on the gradual melting of very fine layers of metallic powder by a laser beam. The 3D CAD model of the product is first cut into individual layers, the workpiece and then the product is stacked over the layer. The laser beam energy directly melts the metal powder only in the contours of the cut which is defined by the intersection of a given surface by the body (3D CAD model) of the product. During the construction of the product, it is necessary to fix the correct position by means of a support structure which is fixed to the base steel platform. The support elements are layer-

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by-layer created along with the product. The minimum thickness of a layer is 20 microns. The laser thoroughly melts the metal in the form of powder and thus ensures the perfect bonding of the individual layers. [5]

The laser beam is precisely controlled in x and y coordinates, the "z" axis is controlled by a 20 micrometer during changing the layer, allowing for tolerance within the range ± 0.1 mm. The production of small to medium sized parts takes several hours or days. This production takes several days to weeks when using traditional technologies. After running the process, the device works in full automatic mode 24 hours a day. Upon the completion of the production process, the product platform is removed from the workspace of the device and the work is separated from the platform. [6]

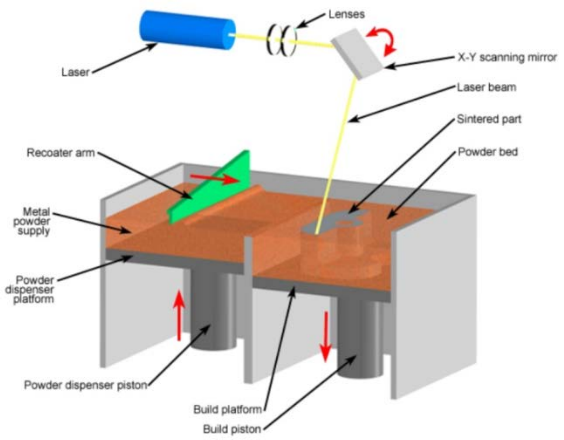

Figure 2. Principle of DMLS technology [6]

The 3D CAD data of the manufactured part is imported into the process software. This data is preferably uploaded to the workstation in the format of the stack. The other formats may be added using additional modules for processing. It is also necessary to realize a verification of the created data file, due to the closure of the part volume by means of a network of planar triangular faces. Then, the optimal manufacturing position of the part is proposed and the appropriate thickness of the sintered layers is selected. The correct choice of layer thickness (0.020 mm or 0.040 mm) is especially important with respect to accuracy and speed of production - thinner layer means higher accuracy but extends production time. Finally, the software, according to the type of material selected, assigns the right technological parameters of the construction and "cuts" 3D data into the individual layers. These data are sent to the DMLS device. Further, a steel platform is attached to the working chamber of the device. [7]

All the necessary data are set up and the production process can begin. The batching device adjusts the quantity of powder for one layer and the arm with the ceramic cutting edge spreads a uniform layer of powder to the surface of the steel platform according to the chosen thickness. During the construction of the part it is necessary to fix the correct position of the part by means of a support structure which is anchored to the basic steel platform. The support structure is built with the product. At the same time, the steel platform conveys the heat generated by sintering, so the molten metal solidifies very quickly. For most used materials, the working chamber of the machine is filled with nitrogen to protect the manufactured parts from oxidation. Nitrogen is not used for the reason that integrated generator is supplied with compressed air. It only separates the nitrogen molecules. In the case of application of titanium as building material argon is used to create a protective atmosphere. [7]

After the completion of the production process, the platform with products is removed from the workspace of the device and the parts are separated from the platform. The unused powder is transported into the container. An indispensable part of the DMLS production of metal parts is finishing operations. First of all, it is necessary to remove the supporting structures from the surface of the product and then the surface can be further grinded, polished or machined in the same way as the classic metal material. An important advantage of direct production of metal parts through DMLS technology is to eliminate the need for the tool. The production process is both economic and ecological, because 98% of the powder is reused for production. This technology makes it possible to create both outer and inner shapes of a component (however complex) at the same time, which results in the possibility of direct production of complex parts that would previously have to be made from several components for technological reasons. All the advantages and disadvantages of this technology are given in the following table. [4]

Table 1. Advantages and disadvantages of DMLS technology

Advantages of DMLS technology	**Disadvantages of DMLS technology**
High strength and toughness of manufactured parts	Machine is energy-intensive
Reduction of costs and production time	Higher input costs for production facilities
Automatic operation of the machine	Need for finishing operations
Production of the part directly from 3D CAD data from the customer	Part size is limited by production equipment
low material consumption (non-molten powder can be reused)	

3. Metal powders for DMLS technology

The material selection is quite large - from light alloys through steel to super-alloys and composites. At present, there are various specific alloys for the DMLS process as well as standard industrial materials such as e.g. stainless steel. In this part of the article will be described the three most commonly used powder materials that meet the requirements of the demanding customer. The following table presents a summary of the basic properties of selected materials for DMLS technology. [8]

Table 2. The basic properties of selected materials for DMLS technology

Material	Young's modulus [GPa]	Minimum recommended layer thickness [µm]	Tensile strength [MPa]	Yield strength [MPa]	Hardness
GP1	190	20	1 100	500	23-33 HRC
MS1	200	40	1 100 (1950)*	1 000 (1 900)*	33 – 37 HRC (50-54 HRC)*
DM20	80	20	400	200	115 HV

*presented values are stated for heat treated material

Direct Metal 20 (DM 20)

The material is a very fine powder based on bronze which is referred to as DM 20. It was specially developed for metal melting using DMLS technology. The advantage of this material is the higher speed of construction and the easy completion of the manufactured component surface. The resulting parts offer good mechanical properties with excellent detail and surface quality. The surface of the product can be easily finished by machining or can be easily polished. This material is ideal for the production of functional metal prototypes, and is also suitable for the production of prototype or small-series injection molds. [8]

Stainless Steel (GP1)

This type of steel is characterized by high corrosion resistance and good mechanical parameters. Composition of steel corresponds to US classification 17-4 and European 1.4542. It meets the AMS 5643 requirements for chemical elements - Mn, Mo, Ni, Si, C, Cr, Cu. The manufactured parts can be machined, polished or welded. This material is ideal for the production of functional metal prototypes or spare parts. [8]

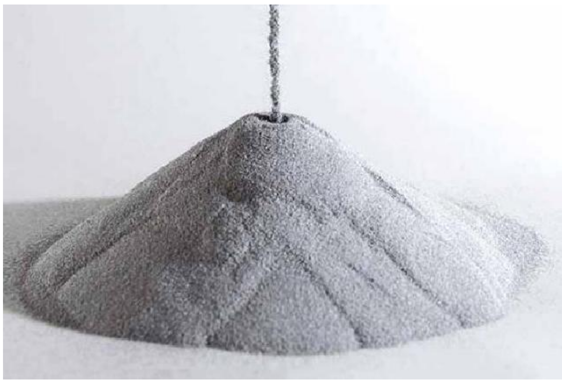

Figure 3. Stainless Steel (GP1) [9]

Maraging steel (MS1)

Maraging Steel is a metallic powder which is optimized primarily for work on EOSINT M systems. The steel composition corresponds to European classification 1.2709. This type of steel is characterized by very high strength and hardness of the surface. Components made from this material have a homogeneous structure with a hardness of 36-39 HRC and may be further heat-treated up to 54 HRC (6 hours at 490 ° C). Parts can be further machined, eroded, polished, as well as the conventional tool steels. The material is commonly used for tools and high load industrial components. [8]

Figure 4. Maraging Steel (MS1) [8]

4. Application of DMLs technology in the production process

DMLS technology gradually takes on the position of the production method for the quick and accurate production of fully functional prototype parts or final products. The 3D printing process produces highly durable components that are used in many industries such as the aviation, automotive, electronics, medicine, consumer goods, architecture, and so on. The broad field of application is in the field of molds and tools for the production of plastic or metal products - prototype molds, small-lot molds, shape-like inserts and cores with cooling channels for faster heat removal.

Figure 5. Flange of exhaust pipe produced by DMLS technology[10]

Rapid injection molding methods are one of the important areas of DMLS technology utilization in the engineering industry. Especially in the mold making, the main advantage is that production time is not greatly affected by the complexity of mold cavity geometry as opposed to production by conventional technologies. In the case of prototype or small-lot molds, the production of molded inserts is generally used in universal frames. As the material of the mold, a bronze alloy (Direct Metal 20) is chosen with respect to the speed of construction and simple finishing of the surface of the cavity. The lifetime of this type of mold depends on the kind of injected material but roughly approximates 2000 pieces of moldings. Prototype forms are suitable for customers who need to obtain prototypes from serial materials and directly check the injection process, functionality and mechanical properties of the moldings, and so on. Small-scale forms are designed for a series of thousands of moldings in a row. The design and mold mechanics match this specification. In the case of more complicated moldings, the mold is cut manually.

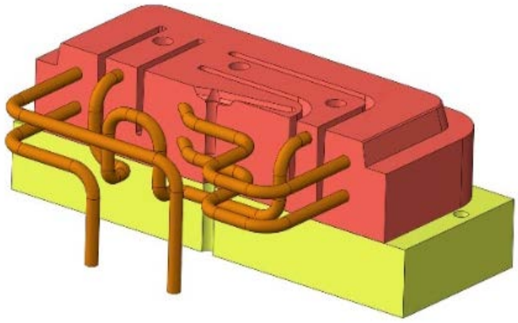

Figure 6. Cross - section model of form with conformal cooling [11]

The DMLS technology is one of a number of Rapid prototyping methods that are used for the development and manufacture of components in the engineering industry, specifically in the automotive industry. Except for this application, it is possible to apply the DMLS technology in the production of components for crash tests, parts for functional verification and assembling (hood suspension, locking systems) or also for the production of high load components in racing cars. Applying the method is also possible in the production of more luxurious automobile models, where it is used to make shape-complicated design elements. In given industries, the main reason for applying the DMLS method is the speed associated with the geometric complexity of the produced parts.

5. Conclusion

Components manufactured by DMLS technology are highly resistant and they are used in many manufacturing and non-production sectors. [12] The DMLS method also has several advantages and disadvantages. The basic advantages include reduction of production times, high strength and toughness of manufactured parts, fully automatic operation of the equipment, high geometric flexibility, production of parts directly from 3D CAD data from the customer, low material consumption (non-melted powder is reused) and compatibility with other processes. [13] However, on the other hand, technology requires higher purchasing costs for manufacturing facilities, the equipment is spatially and energy-intensive, it is necessary to apply finishing operations and the size of the parts produced is partially limited by the production equipment. In view of the above drawbacks of DMLS technology, it can be concluded that it is widely applicable in the engineering industry, whether for molds, tools, prototypes of spare parts, and where there is no need to produce large quantities of the same parts, but the necessary flexible response to market demands or customer wishes.

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