МАШИНОЗНАВСТВО ТА ОБРОБКА МАТЕРІАЛІВ В МАШИНОБУДУВАННІ

UDC 621

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MANUFACTURING OF THE SPARE PARTS FOR THE AUTOMOTIVE INDUSTRY USING 3D PRINT WITH SLM METHOD

The main idea of the production process of the spare part was to use such a component, which will have specific characteristics. For instance, resistance against wear out and good mechanical properties. This component is usually not producible by conventional chip machining methods such as turning, milling etc.

Key words: Rapid prototyping, Selective laser melting.

РОБЕРТ САСИК, МАТУС КОВАЛІЧЕК, МИХАЛ ХОЦ, ПЕТР СПИСАК, РУДОЛЬФ МАДАЙ
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ВИГОТОВЛЕННЯ ЗАПАСНИХ ЧАСТИН ДЛЯ АВТОМОБІЛЬНОЇ ПРОМИСЛОВОСТІ З ВИКОРИСТАННЯМ 3D ДРУКУ З МЕТОДОМ SLM

Основна ідея процесу виробництва запасних частин полягає у використанні компонента, який буде мати специфічні характеристики. Наприклад, володіти стійкістю до зносу і хорошими механічними властивостями. Цей компонент, як правило, не вироблений з допомогою традиційних методів обробки стружки, таких як токарна обробка, фрезерування і т. д.

Ключові слова: швидке прототипування, селективна лазерна плавка.

Introduction

Machine AM250 from the company Renishaw belongs to SLM technologies of Rapid Prototyping (www.renishaw.com). University of Žilina uses this device in its laboratory of Rapid Prototyping.

Laser melting belongs to Additive manufacturing technologies that uses very strong Ytterbium threads laser for the melting of very fine metallic powders. The main goal is to create functioning 3D parts.

The production process is based on 3D CAD model that is virtually divided into separate layers. These layers are 2D curves from 20 µm to 100 µm thick. Sequential deposition of different layers of metallic powder and its melting by laser beam in an inert atmosphere produces a three-dimensional metal part. The inert atmosphere is usually filled with argon. The finished work may be removed from the machine. Afterwards, the part can be tooled with heat and surface finishing.

Typical applications for the technology of laser melting:

• Production of prototype parts suitable for functional test,
• Production of implants, or parts with very complex shape,
• Piece and small-batch production of complex parts from specific materials.

AM250 machine allows quick evacuation of the working space, which is immediately filled with a clean argon gas that ensures a clean environment for reactive materials, e.g. titanium. In this case, the content of oxygen in the working area has to be as low as possible. The gas consumption is minimized by the use of perfectly tight and well-welded chamber, which also contributes to the robustness of the machine. AM250 can process non-reactive materials in the nitrogen atmosphere.

AM250 uses the outer powder cartridge with valve closure. This allows the addition of material during the manufacturing process. The powder cartridge can be removed when it is necessary to clean up the machine or exchange cartridges with different materials. Cartridges for the collection of fall over material are located outside the working zone and have their own shut off valves. This allows the re-use the unused material. The cartridge with unused material can be taken out, sifted out and re-used even during the manufacturing process. Manipulation with powder and with the product itself is possible using gloves, which are placed in the doorway into the working area. The filter protects the contact of the user with the emissions that arise during the process.

The device AM250 has been designed for the manufacturing industry with a simple touch screen and rugged construction. Machine AM250 can produce many different parts for the series production. It can create implants, complex grid structures, or detailed geometric shapes for aerospace industry. With the extension of the Z axis, it is possible to produce components up to max 360mm.

The whole process of preparation of data and programming is done offline, so the whole production process is precisely controlled. Software for the pre-processing enables various improvements of the process for advanced users.

Features of AM250:

• Reduction of production time period,
• The production cost reduction of models,
• Production of complex products,

• Ideal for practical use in the medical, aviation and space industries,
• Ability to produce high parts thanks to the extended Z-axis.

Table 1

Technical data of AM250 device (source: renishaw.com)

	AM250
Max. dimensions of a part	250 x 250 x 300 mm (X, Y, Z) Z-axis is extended to 360 mm
Production speed*	5–20 cm³ per hour
Speed of scan	Up to 2000 mm/s
Positioning speed (max.)	7 000 mm/s
Layer thickness	20–100 µm
Laser beam diameter	Diameter 70 µm on the surface of the powder
Laser power	200 or 400 W
Outer dimensions **	1700 x 800 x 2025 mm (D, Š, V)
Mass	gross 1225 kg, netto 1100 kg
Power supply	230 V, single-phase, 16 A
Available materials	Stainless steel 316L a 17-4PH, tool steel H13, aluminium Al-Si-12, titan CP, Ti-6Al-4V a Ti-6Al-7Nb, cobalt-chrome alloy (ASTM75), Inconel 718 a 625

* The speed of production of the part depends on the material, density and shape. The maximum speed of the production of part is not applicable to all materials.
** Dimensions without accessories.

Fig. 1. AM250 machine

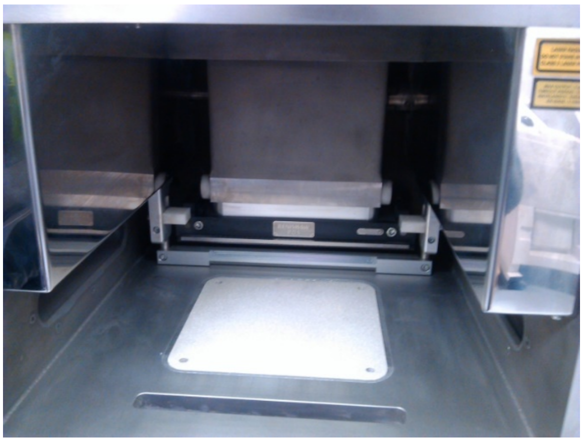

Fig. 2. Work zone of AM250

The evaluation of manufacturability of components using Rapid Prototyping method and Selective Laser Melting (SLM) technology

The main idea of the production process of the spare part was to use such a component, which will have specific characteristics. For instance, resistance against wear out and good mechanical properties. This component is usually not producible by conventional chip machining methods such as turning, milling etc.

Fig.3 shows a component that is not producible via chip machining methods because it contains a hole that has a square cross-section.

The second indicator was a bad accessibility of the component in the market, since the part comes from older version of an automobile. The ideal substitution part was a spare part for speedometer for an automobile VW LT 28 year 1997. Main dimensions of the component are 85 x 23 x 23 mm.

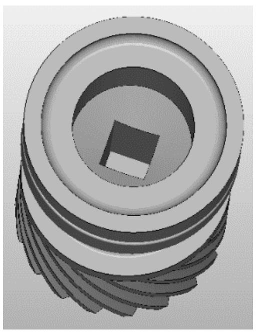

Fig. 3.

Fig. 4.

The original parts of this type are produced from a plastic material, most probably by casting, eventually by injection molding. The original part was worn out on the cogwheel section Fig. 4.

Phases of technological process of Rapid Prototyping method

Pre-processing

The working procedure of the production of part was a standard rapid prototyping process. During the first step it was necessary to construct component according to all dimensions of the original part. The model was constructed in a suitable CAD program. It is also possible to produce a reference digital model of the 3D scan of the damaged part, which can be repaired in the CAD program. Thus, a new useable and fully functional component is created.

After construction of a digital model was the component ready for production. There has been Renishaw Autofab v1.8 used for data processing. There were designed manufacturing layers, all parameters of the production as well as support structures, which prevent the deformation of the parts during the production process and ensure the connection of the parts with the base plate.

Fig. 5. Damaged part

Fig. 6. Reference model scan

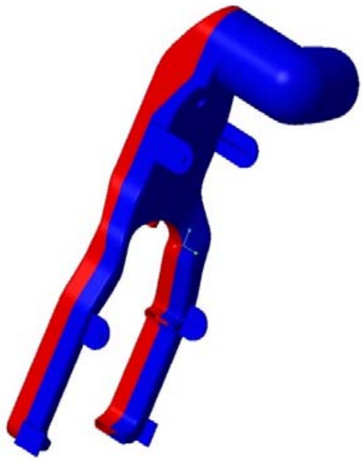

Fig. 7. Model constructed in CAD

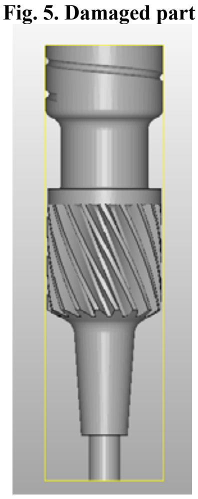

Fig. 8. STL file ready for processing

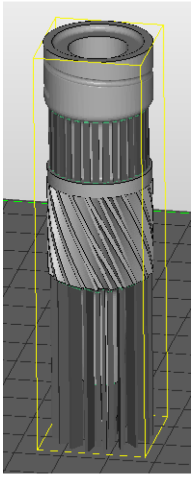

Fig. 9. The design of the supporting structures

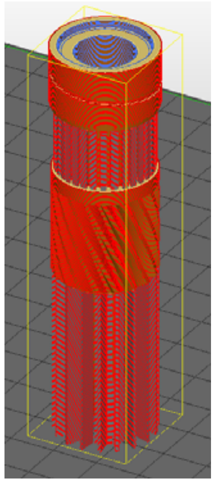

Fig. 10. Software cut-off of the model into layers

Parameters of the production were set into the following values on the AM250 machine:

- Thickness of the layer 25 μm
- Speed of the laser during the burning of the boundary contours 0,25 m/s
- Speed of laser during the burning of the filling structures of the component 0,57 m/s
- The power of laser 400W

The calculated parameters that were estimated for our specific model by the Autofab software:

3650 layers – 1 layer 0,025 mm (25 μm)– the height of model together with supporting structures 89 mm.
Time required for the 3D print of a single prototype 12h 50min, for mini-batch of 10 pieces 40h 30min.

Processing

Processing is the mere production of part using the machine AM250. The production procedure belongs to category of additive technologies. Here the material is gradually added. Each material layer is deposited on the top of the part and afterwards it is sintered by high-performance laser. This method is called SLM – Selective laser melting.

Powdery aluminium material of the thickness of the grains 25 µm with a designation of AlSi10Mg-0403 has been used as a material for the manufacturing of the part. The chemical composition of the material is in the Table 2. Custom chemical analysis was carried out by manual digital spectrometer ED-XRF Delta.

This technology provides heat treatment of metal powder at a temperature lower than the melting point of the main constituent. The main goal of this technology is increasing of the strength of bonding of the individual particles. SLM is one of the additive production techniques that uses a high power laser (e.g. a carbon dioxide laser) for the fusion of small particles of the metal powder material. The capture and the movement of the laser is predefined according to the pattern, which is generated according to characteristic features of a 3D CAD designed part, or according to capture of digital image. After creating one layer of the powder bed moves in the direction of the Z-axis by the value of the thickness of one layer and the new layer of material is applied on top of the original layer and the process is repeated until the part is complete (Kopeliovich, 2006). The metal powder is progressively melted in the microscopic layers using a laser beam, which does not leave large porous structure. (Osakada, Shiomi, 2006, p.1188).

Table 2

AlSi10Mg-0403 characteristics

	Data provided by producer / supplier Renishaw	Own chemical analysis – measurement 1,2,3			
Chemical element	Percentual content in %	1	2	3	Arithmetic mean
Al	Balance	90,00	89,60	89,30	89,63
Si	9-10	9,60	9,90	10,00	9,83
Mg	0.25-0.45	0,70	1,00	0,93	0,88
Fe	<0.25	0,23	0,40	0,43	0,35
N	<0.20	-	-	-	-
O	<0.20	-	-	-	-
Ti	<0.15	-	-	-	-
Zn	<0.10	-	-	-	-
Mn	<0.10	-	-	-	-
Ni	<0.05	-	-	-	-
Cu	<0.05	-	-	-	-
Pb	<0.02	-	-	-	-
Sn	<0.02	0,10	0,10	0,10	0,10
Sb	-	0,10	0,13	0,13	0,12

Fig. 11. Without surface treatment

Fig. 12. Sandblasting finishing

Fig. 13. Polishing finish

Post-processing

The post-processing is based on the removal of the support material. Support consists of the material, which is appended to the building of the model, in order to build the overhanging parts of the model, cavities, and parts with complex shapes. It is important to note that post-processing is an integral part of the production of the prototype therefore it can significantly affect the final price and time of production of the prototype.

The basic steps of post-processing during the SLM are:

- Clean-up of the model from residual powder material. Tail powdery material can be used for further construction of the models.
- Removing the model from the base plate
- Removing the support structures from the produced parts
- Grinding, application of sanding or polishing of the produced parts.

The produced part had been blast cleaned, and polished, in order to remove the roughness, since the part without surface treatment have unsatisfactory roughness for this type of component.

Summary

The tested component is currently still in the car and it has fulfilled its function without damage since May 2015. Therefore, we can evaluate this test as a successful. Although the production is more expensive than conventional technologies, there is an advantage that such a component made of a material AL10SiMg has extended durability compared to the plastic original that has been produced by casting or injection moulding machinery. The production of the spare part is relatively quick, since the market does not provide spare parts for this type of car any longer. This production is also possible for repairs and recovery of automotive veterans. In the future, these technologies will not be used solely for prototyping of new parts, but also for smaller or larger series production of new parts.

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