SHAPE AND SIZE ACCURACY OF 3D-PRINTED AlSi12 PARTS

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Abstract
This paper maps the topic of complex part production using Selective Laser Melting (SLM) technology. During the pre-processing part of the building process, it is crucial to choose the most suitable orientation of the model towards the building plate. It can be said that proper part placement can reduce the amount of support structures and the risk of model bending and following damage due to large thermal gradients. For this purpose, special specimens were printed on SLM280HL machine out of AlSi12 powder under different orientation towards the building plate and with different types of support structures. After finishing the building process, the influence of above described parameters to size and shape of the final product were evaluated. Accuracy of the final products was assessed thanks to contactless 3D scanner ATOS. Results of the work clearly show that if the model is positioned in such a manner that the least energy and thus heat generation is introduced into each layer, the lower the deformation of final part is.

Keywords: aluminium alloys, selective laser melting, rapid prototyping, accuracy

1 Introduction
With use of one of the youngest members of additive technologies, Selective Laser Melting (SLM), it is possible to build functional prototypes [1] out of wide variety of metal materials [2]. Moreover, the designer of the part is not tied with the restrictions of common production technologies such as milling and casting. As a consequence, we are able to produce the parts which contain very complex geometry [3, 4] and any kind of lightweight inner structure [5]. All these facts may lead to introduction of new approaches in designing of the parts which original functionality is maintained yet their weight is considerably lower. On the other hand, successful building of the prototype with use of SLM technology is not an easy and straightforward process [6]. One of the main problems which occur during the building is introduction of large amount of heat when the metal powder is exposed to laser beam. Due to the fact that heat is not distributed uniformly throughout the layer, the part is subjected to large residual stresses [7-9].
In order to catch possible deformation due to above described stresses, proper support structures which connect the model with building platform must be defined. Requirements for these support structures are in direct contradiction. On one side they must be strong enough to fix the model and on the other side they should be brittle enough to be easily removed after the building process is finished. Despite new approaches for designing the supports were introduced recently [10-14], four main groups of support structures remain to be most widely used in selective laser melting approach (**Fig**. **1**). In combination with solid supports in the form of cones and

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cylinders, even the parts with very complex geometry can be reliably fixed to the building plate. This paper focuses on influence of part positioning and supporting on its final accuracy. For this purpose, modern methods for measuring the final part were used.

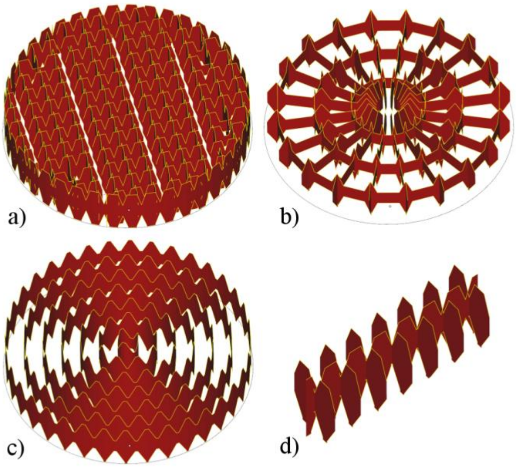

Fig. 1 Standard support structures for SLM technology: a) block, b) web, c) contour, d) line

2 Materials and methods

Testing specimen on which the influence of positioning and support was evaluated is shown in **Fig. 2**. The model was originally developed to verify the boundaries of SLM building process and hence it contains various geometric features. For instance, rectangular holes and protrusions with variable thickness are present on the model. Moreover, set of chamfers and rounds with various angles and radiuses, respectively, are included as well. Overall dimensions of the sample are 100 x 100 x 20 mm.

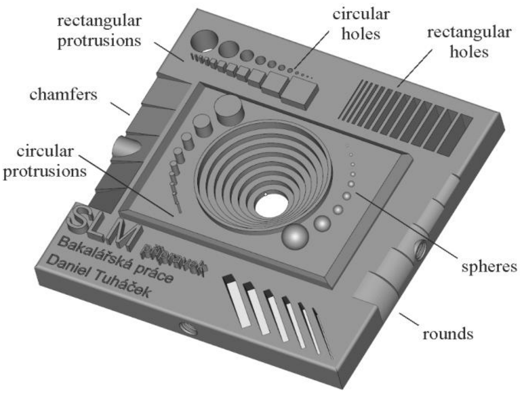

Fig. 2 Testing specimen used for the accuracy evaluation

Pre-processing part of the 3D print was done in Magics 19 (Materialise NV) software. In total, seven different setups of the model were created for 3D print. All the parameters which define model position relatively to building plate and support settings are summarized in **Table 1** and graphically shown in **Fig. 3**. 3D print of the specimens was done using AlSi12 powder [15-18]

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on SLM 280HL machine [19] and with standard scanning parameters provided by the manufacturer.

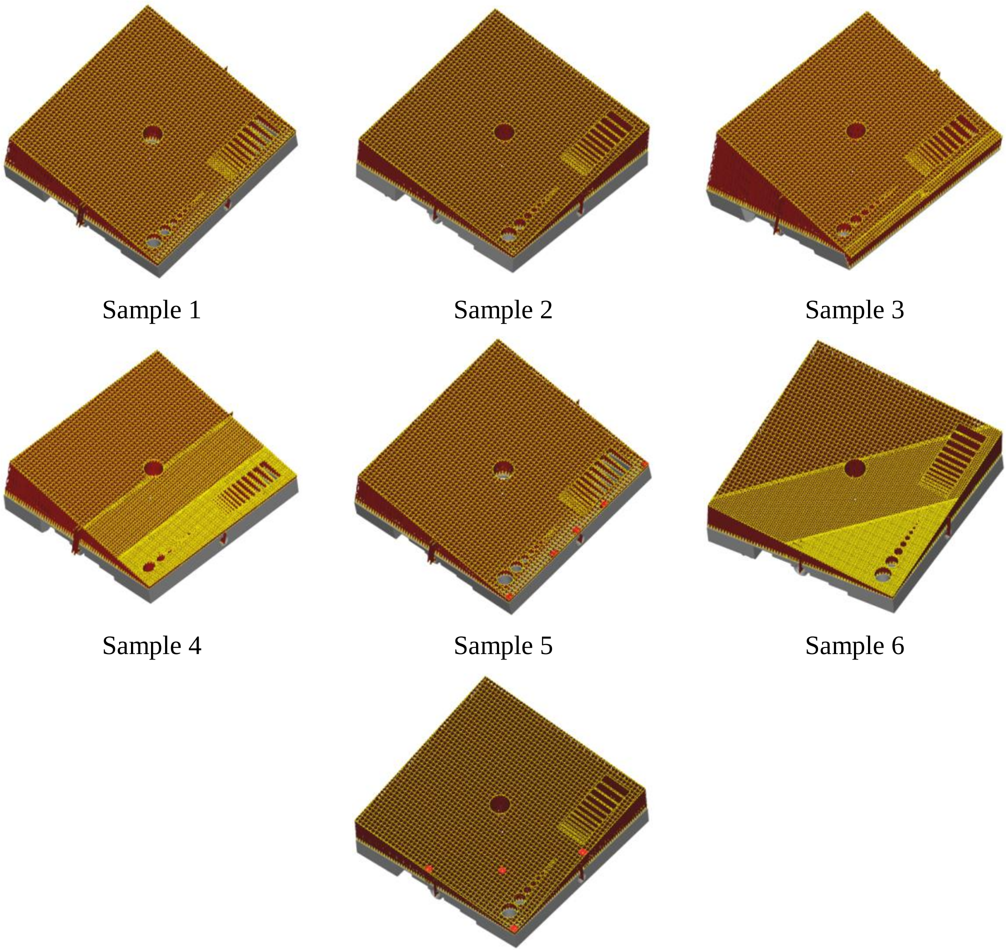

Fig. 3 Bottom part of individual samples with support structure

Table 1 Specimen orientation and support parameters

Sample No.	Orientation angles X, Y, Z [°]	General support structure	Reinforcement with solid support
1	15, 0, 0	Block, uniform 2 mm hatching	No
2	15, 15, 0	Block, uniform 2 mm hatching	No
3	30, 0, 0	Block, uniform 2 mm hatching	No
4	15, 0, 0	Block, variable section hatching	No
5	15, 0, 0	Block, uniform 2 mm hatching	Yes, 5 solid blocks
6	15, 15, 0	Block, variable section hatching	No
7	15, 15, 0	Block, uniform 2 mm hatching	Yes, 4 solid blocks

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2.1 Analysis of geometrical accuracy

After the building process was finished, individual samples were subjected to complex measurement. With regard to preceding experience [20], a contactless optical measuring technology was used. This technology offers several advantages in comparison with conventional methods. For instance, real 3D model can be extracted from the data thanks to very dense set of measured points. While using this method, the deformation of the parts can be evaluated with high precision even for areas with complex geometry.

Digitization of all the tested samples was carried out on GOM - ATOS II 400 3D scanner. The scanner is equipped with the optics which allows measuring in the volume of 250 x 200 x 200 mm (**Fig. 4**). For calculation of resulting cloud of surface points, principles of optical triangulation, photogrammetry and method of fringe projection are used. Overall precision of measuring is ±30 μm.

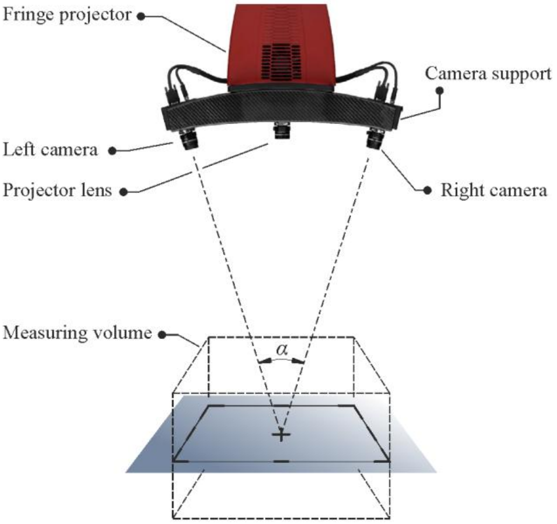

Fig. 4 Principle of measurement on GOM ATOS II 400 3D scanner

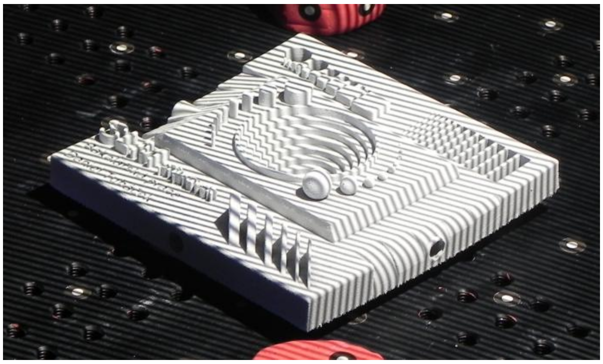

Fig. 5 Process of part digitization

Before the measurement itself was carried out, surface of the sample was treated with chalk powder. This process reduces reflexions during the fringe pattern is projected onto the part

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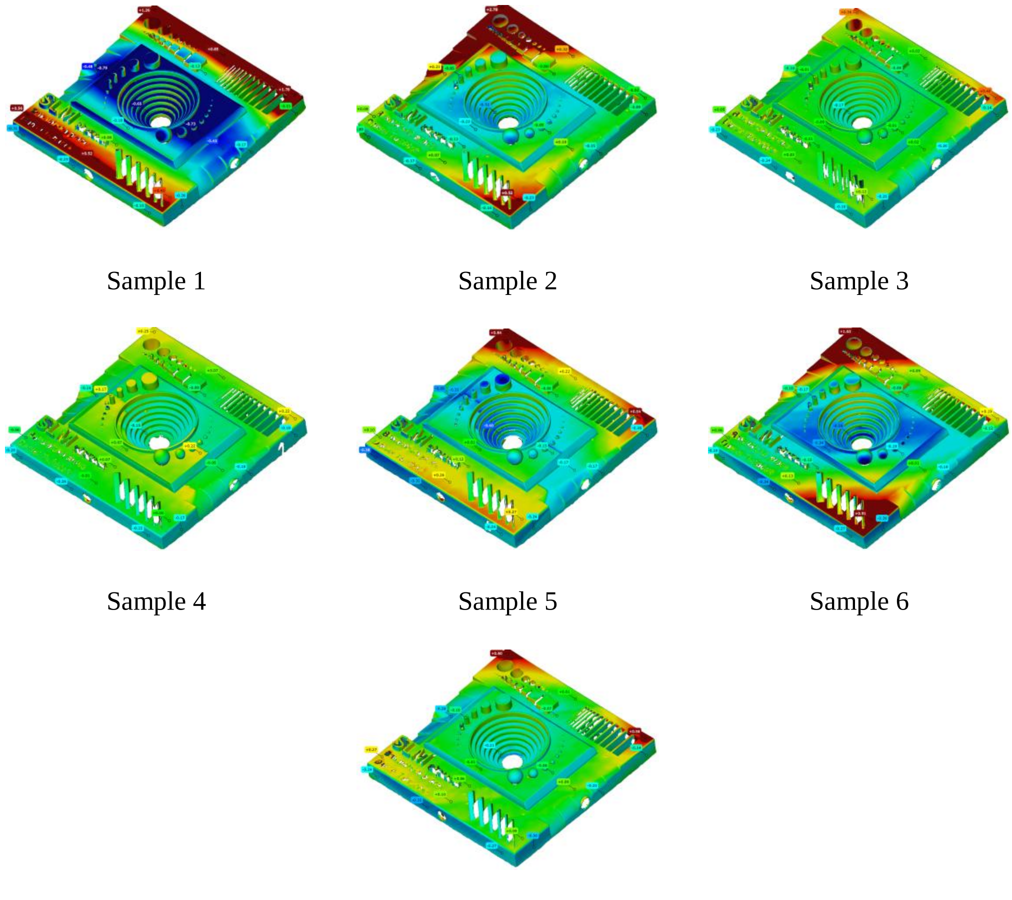
surface. After the surface was treated, the part was fixed to revolving platform of 3D scanner. Digitization of the model was done in such a way that 30 scans were taken from various positions and angles in order to obtain the whole contour of the specimen (**Fig. 5**). Individual snapshots were then transformed to one mutual coordinate system thanks to reference points and high resolution polygonal map of part surface was calculated. Finally, resulting data were compared with original CAD model of the specimen using GOM Inspect Professional v8 software.

3 Results and Discussion

In **Fig. 6**, colour map which shows how much the sample dimensions differ from original data is shown. Darker colour refers to a place with high deviation from the original data and vice-versa. For clarity, maximal differences in shape are summarized in **Table 2**.



Sample 1 Sample 2 Sample 3

Sample 4 Sample 5 Sample 6

Sample 7

Fig. 6 Colour map of sample size deviations from original CAD model.

As it was mentioned in the introduction of this article, large amount of heat is introduced into the model during the process of sintering. As a consequence of this fact, high deviations from desired shape are likely to occur. If the final part was measured using conventional methods

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such as determination of dimensions on coordinate measuring machine, some of the major deviations might be easily omitted. Thanks to precise 3D scanning of the part, the deviations can be calculated in fast and reliable way.

Table 2 List of maximal deformations

Sample No.	**Maximal positive deformation [mm]**	**Maximal negative deformation [mm]**	**Maximal absolute deformation [mm]**
1	1,78	-1,02	2,8
2	2,78	-0,50	3,28
3	0,40	- 0,43	0,83
4	0,25	- 0,31	0,56
5	0,84	- 0,53	1,37
6	1,63	- 0,72	2,35
7	0,60	- 0,82	1,42

Final results show that the highest deviation from original data occurs on sample 2 which was a specimen tilted in the angle of 15° around both X and Y axis and supported using block structure with 2 mm hatching. Moreover, sample 6 which was oriented in the same way as sample 2 and supported with variable section hatching shows insufficient accuracy as well. On the other side, the best results can be found for sample 4 which was tilted in the angle of 15° around X axis only and support structure is composed of three areas with hatching varying from 0,5 to 2 mm.

4 Conclusions

Positioning and appropriate supporting of the model are crucial for the selective laser melting technology. This pre-processing step highly influences overall shape and size precision of the final product. For the sample which was tested in this study, tilting around both X and Y axes show worse results in shape accuracy than if the model was tilted around one of the axis only. Main focus should be also aimed to fixation of first layers. Variable hatching which uses more dense supports for initial layers leads to more convenient connection with building plate and thus to more precise output. Best results are achieved for the setup in which the model was tilted 15° around the X axis and supported with the hatch which hatching distance varies from 0.5 mm to 2 mm.

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