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# VERIFICATION OF GEOMETRICAL ACCURACY OF SELECTIVE LASER MELTING (SLM) BUILT MODEL

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S u m m a r y

The article presents individual approach discussion and results of measurements of accuracy of parts built using Selective Laser Melting (SLM) of metal powder. One of the reasons of research was checking the influence of distance from centre of base plate, as well as caused by this phenomena spot deviation on model accuracy. Deformation and deviations of geometry of thin walls was observed and reported. The aim of measurements was to find real accuracy of SLM generated thin walls in order to enable the further research on usage of this technology for production of thin wall elements and micro lattice constructions. Observed phenomena are discussed and used to prepare technological limitations of SLM manufacturing of thin-wall lattice structures.

**Keywords:** SLM, accuracy, generative manufacturing, rapid manufacturing

**Sprawdzanie dokładności modelu wytworzonego metodą selektywnego topienia laserem**

S t r e s z c z e n i e

W pracy podjęto próbę określenia stopnia dokładności modelu wykonanego metodą selektywnego topienia laserem (SLM) proszku stali nierdzewnej. Ustalono wpływ odległości wiązki od środka płaszczyzny roboczej i wywołanego tym zjawiska zniekształcania wiązki na dokładność wytworzenia modelu. Stwierdzono jednocześnie odkształcenie elementów cienkościennych. Określono rzeczywistą do- kładność odtworzenia elementów cienkościennych metodą SLM. Prowadzono analizę uzyskanych wyników w celu zastosowania tej technologii do wytwarzania elementów cienkościennych i konstrukcji mikrokratownicowych. Przedstawiono charakterystykę występujących zjawisk dla ustalenia ograniczeń technologicznych w wytwarzaniu konstrukcji mikrokratownicowych i cienkościennych.

**Słowa kluczowe:** SLM, dokładność, wytwarzanie przyrostowe, szybkie wytwarzanie

## 1. Introduction

More and more importance is presently attached to the product quality, ergonomics and aesthetics [1]. This is simply caused by economical reasons- the nicer product is the more people will want to have one. So the visual design is lately more and more important part of construction process. We can see this effect according to most of the products on the market from consumer electronic

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devices to heavy industrial machines. The best solution for this would be taking into account end-user opinions already in design stage. That is not always possible but nowadays constructors have a tool that enables to show consumers newly designed products or their various alternatives. This tool is called rapid prototyping (RP). Prototyping is an essential part of the product development and manufacturing cycle required for assessing the form, fit and functionality of a design before a significant investment in tooling is made. Until recently, prototypes were still largely handmade by skilled craftsmen, adding weeks or months to the product development time. Because of this, only a few design iterations could be made before tooling went into production, resulting in parts which at best were seldom optimised and at worst did not function properly. Rapid prototyping (RP) is a term which embraces a range of new technologies for producing accurate parts directly from CAD models in a few hours, with little need for human intervention. This means that designers have the freedom to produce physical models of their drawings more frequently, allowing them to check the assembly and function of the design as well as discussing downstream manufacturing issues with an easy-to-interpret, unambiguous prototype [2].

Firstly the idea of generative (additive) processing was to enable creating real touchable geometry basing on computer model. These techniques as 3D printing base on the conclusion that it would be better to have less accurate and less resistant prototypes than none [3-7]. However as different technologies were invented and developed generated samples become more perfectly representing not only geometry, but also physical and functional features of the final product. Some of techniques enables to create metal parts basing on the computer 3D model only, therefore they are called rapid manufacturing(RM). One of such techniques is the selective laser melting (SLM). This process uses high power laser beam to melt metal powder layer by layer to create fully valuable metal products. It enables to create single pieces of individual parts without using or changing of tool or any necessary device. A Man only needs SLM machine and a computer model to create any metal parts that is expected. One of characteristic features of SLM process is that it enables to create thin wall spatial structures what makes it a perfect method for producing micro-grid lattices. As research in this direction are performed in West Pomeranian University of Technology, it has been decided to check firstly how accurate are parts produced using SLM method.

## 2. Sample model for accuracy verification

The process of selective laser melting of metal powder is performed using laser beam which is located over central horizontal position of work area. Melting of required sections is achieved by deviating of laser beam by system of two prisms (one for each X and Y direction) that, with application of sophisticated optics can move beam focus in a specified distance from the centre of work table. That is why model sample should include elements that allow to compare dimensions in dependence on their distance from the table centre in maximum operational distance. Change of beam focus can especially cause a problem by manufacturing of extremely small elements sensitive to the change of their dimensions. As presented research is a part of wider research for building of thin grid lattice constructions, it became necessary to check if position of elements in the work area can have significant influence on accuracy of small elements dimentions.

The model for accuracy verification was created of six thin wall square and round prisms that were located in the possible distances from the work area centre and one of each prisms located in centre of table. Dimensions of created samples are shown in Fig. 1.

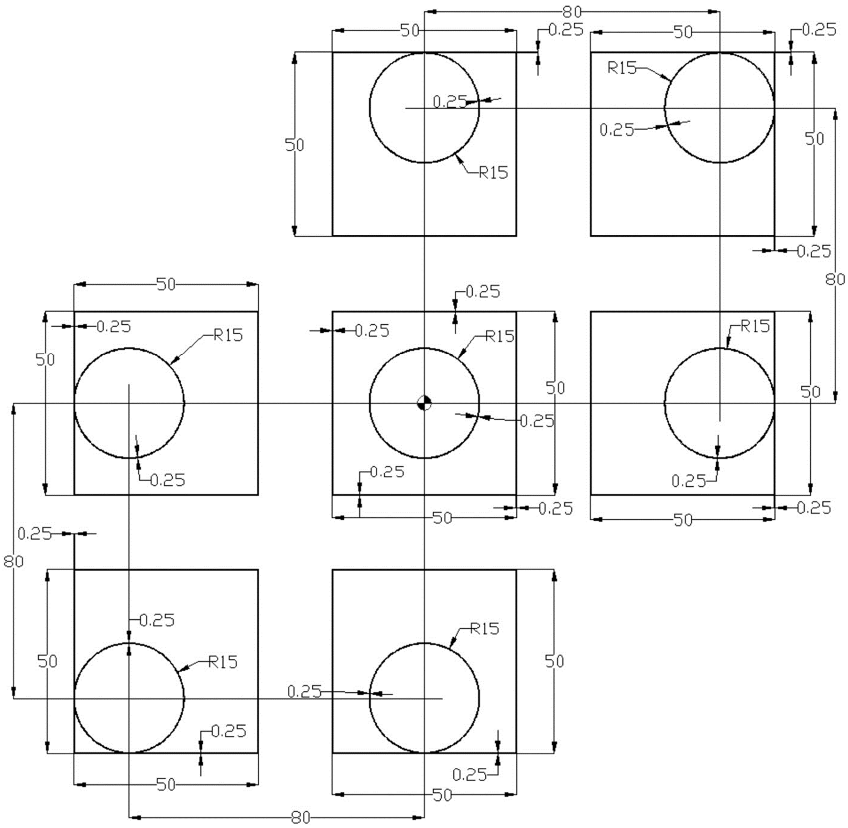


Fig. 1. Dimmensions of created samples

Such a sample enables to measure the wall thickness and such dimensions as large linear dimensions (square lengths and widths), inner and outer radius and wheel centres positions in dependence on distance from the work area centre. In the former research, it was observed, that large flat thin walls can bend after building due to the thermal stress related to local heating of material with laser beam. That is why samples were 5 millimetres high which is enough to enable freely measuring of required dimensions and not too high, so the walls do not bend due to the thermal stress. To obtain reliable results of measurement there was a series of 3 pieces built using the same model and building plate material and with the same process parameters. Produced samples are show in Fig. 2

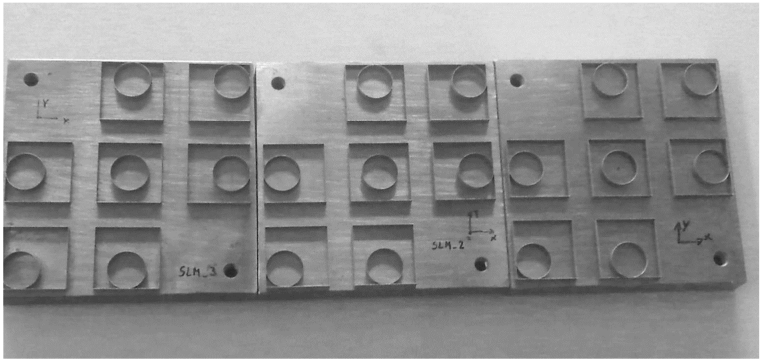

Fig. 2. Selective Laser Melting samples

## 3. Measurements

Measurements were performed using 3D coordinate measuring machine Zeiss Eclipse which is the property of Laboratory of Metrology located in Faculty of Mechanical Engineering and Mechatronics, West Pomeranian University of Technology, Szczecin. As a reference centre point of coordinate system, geometrical centre of inner circle was used, which is consistent with model and SLM machine coordinate system. Figure 3 shows a sample on a table of measuring machine during measurements. As the surface of an object built using SLM method has characteristic rough structure, which is caused by characteristics of SLM method, i.e. metal powders as initial material, there was a necessity to use a proper measuring probe and a large number of measurements for each sample, according to the measurement plan. As a result, there were 28 series of measurement results for each feature multiplied in three samples. It was made a series of diagrams showing deviations of various dimensions of each samples depending on their location on work table after the statistic processing.

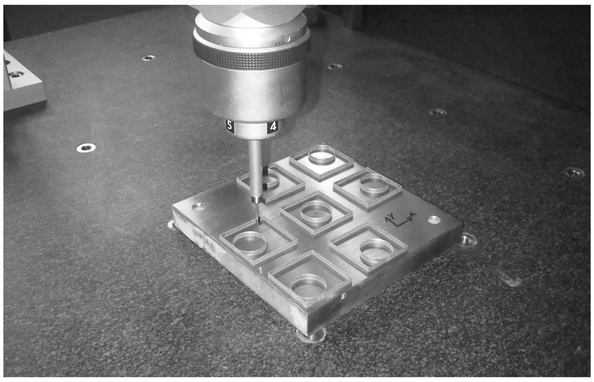

Fig. 3. Samples measurement

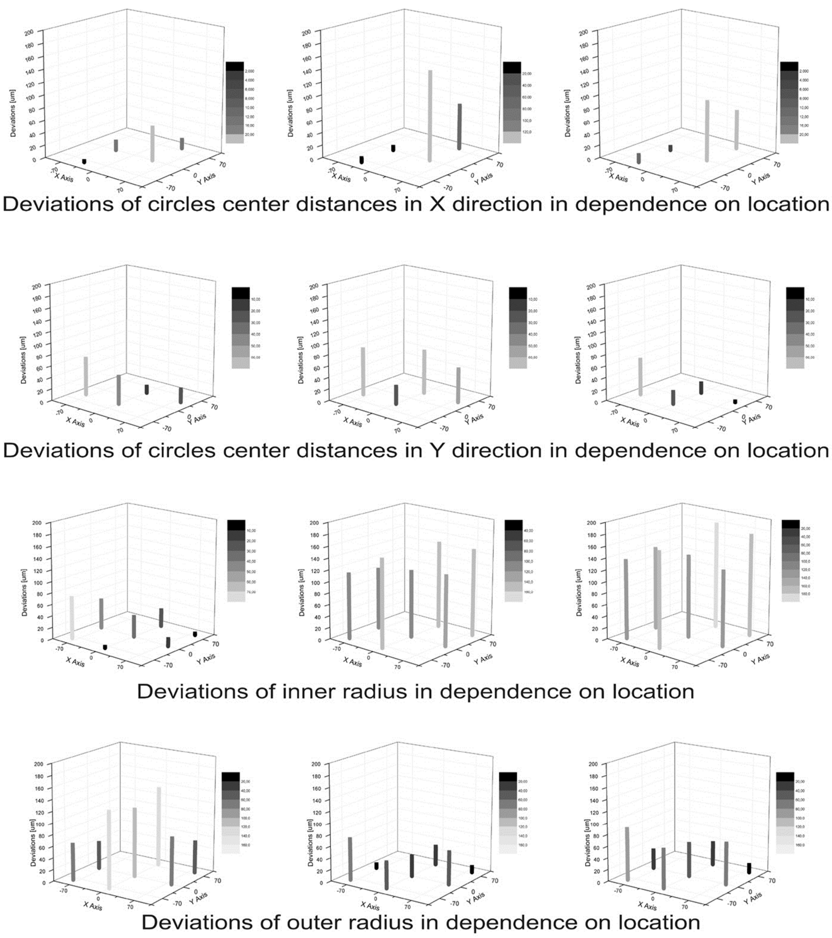


Fig. 4. Comparsion of measured deviation values for a pattern of circles

Sample diagrams of measured values of deviations are shown in Figs. 4 and 5. Figure 4 shows diagrams of deviations for circles dimensions for each of three samples and deviations of measured dimensions of rectangles are shown in Fig. 5. Rows of the diagrams show sets of the deviations values measured on three samples according to CAD model. The highest measured deviation was observed on rectangle size and it was 0.202 mm. The smallest measured value of deviation was 0.002 mm and it was the deviation of circle centre position. In conclusion, range of measured deviations is very high, but their distribution is not related to the position and kind of measured dimension.

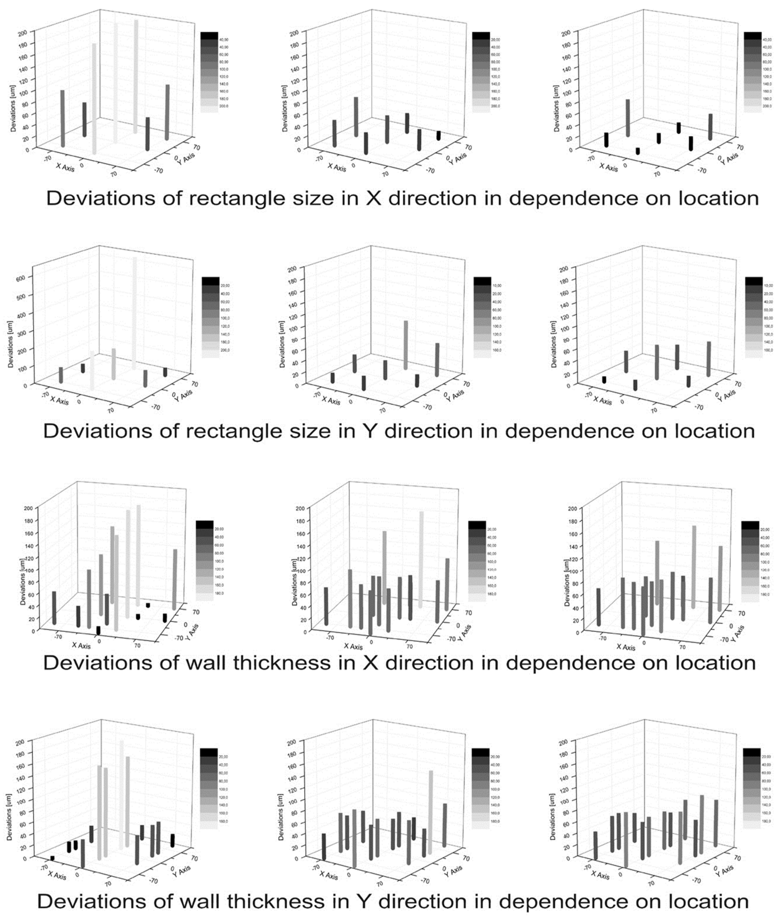


Fig. 5. Comparsion of measured deviation values for pattern of rectangles

## Conclusions

Despite the fact that some of the values of the measured deviations are similar in produced samples, it is impossible to determine repeatable values of measurements for all series of samples. It is also impossible to identify relations between values of measured deviations and localisation of dimension in machine coordinates system.

One can notice a dependences of obtained deviations values on measuring directions or on dimension values in some samples but this dependence is not significant. The change of this dependence in a case of some samples indicates that it cannot be treated as a rule.

Values of recorded deviations are significant. In some cases, these values are similar to measured dimensions so it is probable that though large count of measurements and high carefulness of measuring procedure, the results of measurements may occur not proper. It is probably caused by significant influence of surface roughness on produced samples. Neglecting of this influence was the most significant issue during the measurements as they were realised by ball shaped tool tip. Achieving complete and reliable results requires further research.

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