DIMENSIONAL ACCURACY OF MODELS MANUFACTURED BY SELECTIVE LASER SINTERING TECHNOLOGY

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Abstract

The paper presents the results of the metrological research of models manufactured by additive manufacturing technology, selective laser sintering (SLS). Three type of placement of the cylindrical geometrical features of the model on the building platform during manufacturing where chose. Samples were prepared with polyamide powder PA 3200 GF (with addition of glass fibres). Coordinate measuring machine (Prismo Navigator, Zeiss) were employed to obtain measurements. Research results proved that location of geometrical features on the build tray (printing direction) has a major impact on their dimension accuracy. Both, the most and the least favourable location variants were determined.

Keywords: SLS; PA 3200 GF; CMM; Additive Manufacturing Technology; Polyamide.

1. Introduction

Additive technologies date back to the early 1980s. A turning point in the development of the above mentioned technologies was the year 2000, followed by the rapid commercialization of additive technologies and a significant drop in machine prices (3D printers). Originally, these technologies were used only to build individual prototype models of small size. With time, however, thanks to the development of technology, especially the increase in the precision of the manufactured of machine components (3D printers), the quality (accuracy) of models manufactured by additive technologies has improved. Currently produced machines have construction chambers of much larger dimensions, and model materials have both high mechanical properties and such operational features as, for example, bio-compatibility (SLS - PA 2200, according to EN ISO 10993-1) or high wear resistance. Elements manufactured by layered technologies become a kind of everyday life, in particular in the case of industrial applications. Currently, there are technologies that use materials based on plastics or even a metal materials [6], [7], [12], [19]. With the development of machines construction, there has been a progress in the technological capabilities of the manufacturing process. Currently, research is being carried out related to the possibilities of producing (printing) on existing models [3], [4], for example using FDM technology and ABS material. The mechanical properties of the models are good enough to allow the construction of

prototype models for real functional tests, e.g. technical sealing elements [5] [16], [17], [18] bearings components [1] or pneumatic muscles [13].

Research related to determination of selected mechanical properties and dimensional-shape tolerance of models manufactured using SLS technology have been described in many research papers, among others [2], [9], [14]. The presented works related to both topics, the impact of technological parameters on the above-mentioned properties as well as innovative research related to the analysis of the properties of mixtures of polyamide powders [10], [11], also reinforced with, for example, the addition of aluminium. The analysis of the volumetric and anisotropic parameters of the geometrical structure of the surface, which analysis was presented in the work [15] is important in case of layered structure of model. In the case of conventional production technologies, e.g. milling process, the minimum value of the machined layer thickness is an important technological parameter [8], [20]. Additive manufacturing technologies have similar parameter, the minimum layer thickness, which has a direct impact on the accuracy and mechanical properties of models. In the presented research were analyse the influence of the technological parameter which is the direction of the location of geometrical features relative to the building platform on their accuracy.

2. Methods

The aim of the research was to determine the influence of placement the geometrical features (diameters and planes) of the models on the building platform on the dimensional and shape accuracy of the produced models (measurement of diameters, angles and flatness of the surface). The material used to build the sample was polyamide PA 3200 GF, which is additionally reinforced with fiberglass. The layer thickness was set as 0.1 mm and the temperature of the process chamber was 176 °C. The dimensions of the test sample along with a model approximated by triangles are shown in Figure 1. The STL model was saved with approximation parameters, i.e. deviation tolerance (TO) 0.01, angle tolerance (TK) of 5°. Using the coordinate measuring machine Prismo Navigator, Zeiss, the diameters of holes made in three variants of location in relation to the building platform marked with numbering 1-3 were measured, and then by the point determination of the plane of the tested surfaces, both the inclination angles A1-E1, A2-E2 and 45° (for diameter number 2) were calculated. In addition, the flatness of the tested surfaces was determined, A-E. The samples along with the supporting material, and then during the measurements process are shown in Figure 2. Three measurements of the tested values were made during the tests, and in Table 1 the mean value of the measurements were presented.

Fig. 1. Samples: Dimensions and STL approximation

Fig. 2. Samples: cleaning process and measurements

3. Results

Research results obtained by using coordinate measurement machine (angles and surface flatness deviation) have been presented in the table 1. Moreover in table 2 diameter deviation for three type of the orientation samples on the building platform have been shown.

Angle, °			Surface flatness, mm		
Feature	Measure	Deviation	Feature	Measure	
45°	36°12'18"	-8°47'42"	A	0.1117	
A	0°24'26"	0°24'26"	B1	0.0608	
B1	30°50'39"	0°50'39"	C1	0.0752	
C1	45°31'48"	0°31'48"	D1	0.1163	
D1	59°46'27"	-0°13'33"	E1	0.0671	
E1	89°10'8"	-0°49'52"	B2	0.0707	
B2	30°40'21"	0°40'21"	C2	0.0781	
C2	45°16'35"	0°16'35"	D2	0.0802	
D2	59°54'23"	-0°5'38"	E2	0.0864	
E2	89°20'21"	-0°39'39"			

Table 1. Metrological research results

Feature		Measure	Deviation	Tolerance class
Ø, mm	1	9.4535	-0.5465	15
	2	7.7163	-2.2837	18
	3	9.6324	-0.3676	14

Table 2. Diameter deviation

Analyzing quantitatively the results of measurements of geometrical features of the examined surfaces, it can be stated that depending on the direction of their location relative to the construction platform, they are characterized by a certain degree of accuracy. For diameter measurements, the accuracy is in class respectively 15 and 14 for angles 0° and 90°, and in class 18 for 45°. Analyzing the results of side wall inclination measurements, it can be stated that the mean values of angular deviations are for SLS technology: 0°30'28". This deviation is caused by large internal stresses resulting from the material cooling process. This problem concerns many additive technologies such as SLS or SLM, where the high temperature of the building chamber (more than 170 °C) generate unfavorable temperature gradients at the interface between the model and the support material. The measurement of flatness deviation of the tested surfaces presents similar deviations values, the average values in SLS technology is equal - 0.083 mm. It is also related to the high temperature of the building chamber and difficulties in cooling process.

4. Conclusions

These studies clearly show that the direction of the models' location and their geometrical features fundamentally affects the accuracy. The most favourable variant of the location of geometric features in the case of internal cylindrical surfaces is 90°. The least advantageous variant is the position of features at an angle of 45°, where the so-called "collapse" of the material under the influence of the change in material density in the sintered state is strongly visible. The flatness measurement of the tested surfaces clearly indicates that the direction of their inclination affects shape tolerance deviations. It is clearly visible that variants B1-E1 show much larger deviations of flatness in comparison to the second variant i.e. B2-E2. The flatness value is an about 0.1 mm what is equal to the layer thickness.

In the future it is plan to include additional technological parameters (energy density, layer thickness and laser parameters) and their influence on the accuracy of manufacturing models.

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6. References

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