23rd International Conference
ENGINEERING MECHANICS 2017
Svratka, Czech Republic, 15 – 18 May 2017

ASSESSMENT OF ROUNDNESS AND WAVINESS DEVIATIONS OF ELEMENTS PRODUCED BY SELECTIVE LASER SINTERING TECHNOLOGY

S. Adamczak*, P. Zmarzły, T. Kozior***, D. Gogolewski******

Abstract: *This paper presents preliminary research results of the influence of process parameters of the selective laser sintering technology (SLS) on the roundness and waviness parameters of cylindrical elements. The excessive values of these deviations impact on the further manufacturing process and reduce the functional properties of final products. The samples were designed in cylindrical shape and it were produced in the Laboratory of Unconventional Manufacturing Technology. The Formiga P100 machine was employed to build samples, using polyamide powder PA2200, which based on polyamide PA12. Due to the heterogeneity of the surface structure which is caused by layered nature of process, the samples were located on the virtual platform in three characteristic orientations. Measurement of the geometric deviations were performed on the Talyrond 365, which is located in the Laboratory for Computer-Based Measurement of Geometrical Quantities at the Department of Manufacturing Engineering and Metrology at Kielce University of Technology. The analysis of the research result showed that the building direction has a significant impact on the above mentioned parameters.*

Keywords: Additive technology, SLS, Roundness deviation, Waviness deviation, Technological heredity.

1. Introduction

Conventional manufacturing technologies which allow to produce precise machine and mechanisms parts have some limitations. One of them is the difficulty of building complex shapes machine parts with both internal and external dimensions. Application of traditional technology also entails large investment of time and work related with the preparation of technological documentation or tools, for example, casting molds and patterns, injection molds or specialized machining tools. Moreover, the production of some types of elements, particularly hollow is often difficult or sometimes even impossible (Kundera, 2014b). An alternative way of production in compare to traditional technologies are becoming the non-conventional manufacturing techniques, among other additive technologies (Błasiak, 2016 and Leu 2013), electro-erosion technology, laser technology (Nowakowski, 2016c), or application the high-pressure water jet cutter (Spadło, 2015). Additive technologies are based on a layered construction of physical models using three-dimensional CAD models. The development of these technologies creates opportunities for their adaptation, among others in: aerospace, foundry or mechanical industry (Kundera, 2014a and Nowakowski, 2016b) or pneumatic muscles (Takosoglu, 2016).

The selective laser sintering technology, which is one of the most complicated additive technologies, was used to build samples in this paper. The mechanical properties, shape and dimensional accuracy of final product depends on the technological parameters, among others, printing direction, layer thickness, laser speed and power, cooling time or even temperature in building chamber (Pilipović, 2010).

* Prof. Stanisław Adamczak: Chair of Mechanical Technology and Metrology, Kielce University of Technology, Al. 1000-lecia P. P. 7, 25-314 Kielce; PL adamczak@tu.kielce.pl

** PhD. Paweł Zmarzły: Chair of Mechanical Technology and Metrology, Kielce University of Technology, Al. 1000-lecia P. P. 7, 25-314 Kielce; PL pzmarzly@tu.kielce.pl

*** MSc. Tomasz Kozior: Chair of Mechanical Technology and Metrology, Kielce University of Technology, Al. 1000-lecia P. P. 7, 25-314 Kielce; PL tkozior@tu.kielce.pl

**** MSc. Damian Gogolewski: Chair of Mechanical Technology and Metrology, Kielce University of Technology, Al. 1000-lecia P. P. 7, 25-314 Kielce; PL dgogolewski@tu.kielce.pl

According to Whitehouse (2010) it can be note that about 70 % of all mechanical parts have a cylindrical shape. One of the basic parameter describing manufacturing accuracy of cylindrical parts is roundness deviation (Stępień, 2014). For cylindrical elements manufactured by rapid technologies, analysis of the roundness profile allow to assess the defects which arising during the operation of sintering. Excessive values of roundness deviation causes difficulties in assembly of components, what is very important in casting technology. In this cases, deviations result from production process of casting patterns or casting molds can be transferred on the final products within phenomena so-called "technological heredity". Moreover, considering the evaluation of production accuracy of high quality mechanical components, the geometrical deviation of cylindrical surface should be examined in range that included surface waviness (Adamczak et al., 2016). The high values of waviness deviation of rotational elements is important source of vibration(Adamczak, 2017 and Nowakowski, 2016a). Therefore, presented research related to assessment the impact of technological parameters of SLS technology on the geometrical accuracy of cylindrical components are reasonable.

2. Study design

The first step of research procedure was designed a cylindrical samples and manufactured it using additive technology, known as Selective Laser Sintering (SLS). This technology based on a layered nature of building physical models. The layer of material in a form of powder is distributed to building platform. Then a selected cross-section of a currently building layer is sintering using CO_2 laser. The polyamide powder PA2200 was used to build the samples. The selected technological parameters used in research were presented in Tab. 1 (EOS COMPANY, 2008). The examinations were carried out for samples placed on the virtual platform with three different positions, i.e. at an angle of 0 ° (No. 1), 45 ° (No. 2), 90 ° (No. 3). The main goal of the presented research was to assess the influence of printing direction on the samples roundness and waviness deviation.

Tab. 1: Selected properties and technological parameters of SLS Technology.

Selected properties of PA2200				Technological parameters		
	Value	Unit	Standard		Value	Unit
Young's modulus	1700	MPa	EN ISO 527	Laser power	21	W
Shore hardness	75	Skala D	ISO 864	Laser velocity	2500	mm/s
Impact strength (23°C)	4.4	kJ/m^2	ISO 180/1A	Energy density	0.056	J/mm^2
Tensile strength	48	MPa	EN ISO 527	Focus beam diameter	0.42	mm
Powdered density	0.45	g/cm^3	EN ISO 60	Printing direction	0/45/90	º
Sintered powder density	0.93	g/cm^3	EOS metod	Layer thickness	0.1	mm

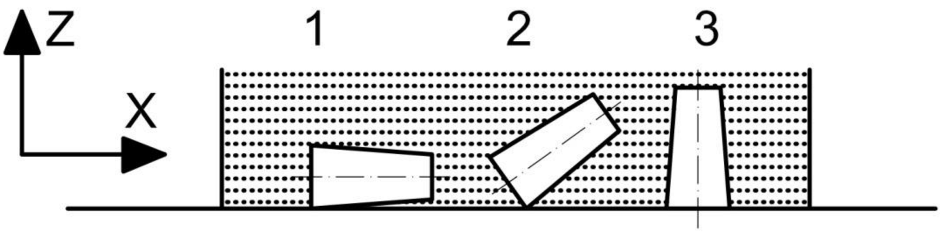

Fig. 1: Samples with support material.

The next step of the research procedure was to measure the roundness and waviness deviations of components manufactured by SLS technology. The examinations were carried out using measuring device Talyrond 365 Taylor Hobson Company. The principle of the device work based on radial method with rotary table. The high accuracy of Talyrond 365 provides a measuring head with resolution of 1.3 nm for measuring range 0.08 mm and Ultra Roundness 5.17 software. The roundness and waviness profiles were measured in a half-way of height of the manufactured samples i.e. 12.5 mm. The parameters used to analyzed were roundness deviation RONt measured in range of 2 – 15 upr (undulation per revolution) as well as a waviness deviation measured in a range of 16 – 50 upr. In order to calculated desired deviations, the primary profile was filtered using Gaussian filter.

3. Analysis of the research results

The research results of the geometrical structure of cylindrical surfaces represented by roundness and waviness deviations were presented in Tab. 2. Symbols a-e indicate the consecutive number of samples manufactured including their different location on the virtual platform.

Tab. 2: Research results.

No. sample		RONt, µm		No. sample		RONt, µm		No. sample		RONt, µm	
		2 – 15, upr	16 – 50, upr			2 – 15, upr	16 – 50, upr			2 – 15, upr	16 – 50, upr
1 (0 º)	a	171.78	50.23	2 (45 º)	a	51.94	29.70	3 (90 º)	a	42.05	20.01
	b	155.49	55.14		b	37.97	28.61		b	51.35	27.09
	c	163.52	71.04		c	47.80	20.47		c	40.65	27.07
	d	169.05	60.09		d	72.83	22.96		d	35.95	20.52
	e	127.20	43.45		e	51.89	27.75		e	40.79	21.56
mean		157.41	55.99	mean		52.49	25.90	mean		42.16	23.25

Analyzing the results presented in Tab. 2 it can be concluded that the roundness and waviness deviations of elements manufactured by SLS technology reach unfavorable high values. The highest mean value of roundness deviation was obtain for samples produced at an angle of 0 °, however the lowest value was measured for samples manufactured at an angle of 90 °. Similar results were obtain for waviness deviation measured in range of 16 – 50 undulation per revolution. Based on research results it can be noted that the cross-section of the samples printed for angle 90 ° have more cylindrical shape. On the other hand for samples produced for angle 0° this shape was elliptical.

Detailed harmonic analysis of measured roundness and waviness profiles indicated that the second harmonic was dominant in all measured samples. This showed that the cylindrical elements manufactured using SLS technology have oval shape. The cool down process in most rapid technologies is very complex. A large temperature gradient and location on the working platform may impact on shrinkage, which results in production an oval shape of elements (Fig. 2).

Furthermore, in order to better illustrate the measurement results, the Fig. 2 shows roundness profile of measured samples, while the Fig. 3 presents the waviness deviations.

a) b) c)

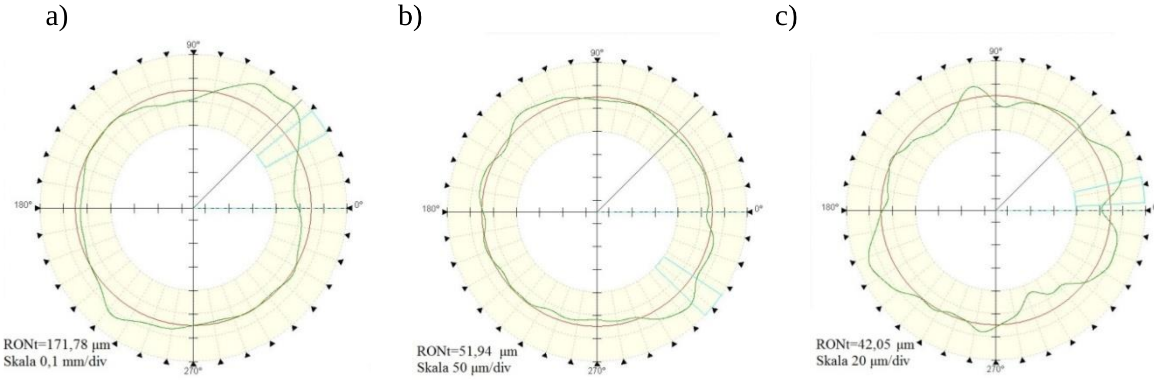

Fig. 2: Roundness profile of samples:a) No. 1a b) No.2a c) No. 3a.

a) b) c)

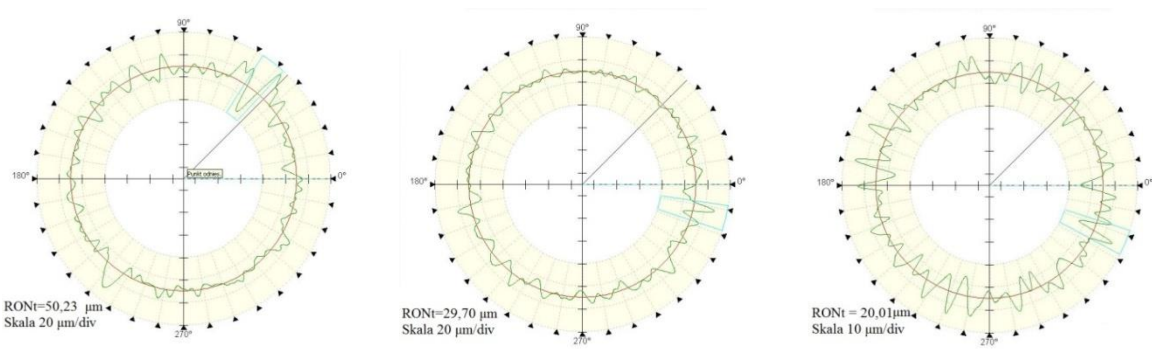

Fig. 3: Waviness profile of samples:a) No. 1a b) No.2a c) No. 3a.

4. Conclusions

1. Based on research results it can be concluded that the values of roundness deviations for all examined cylindrical samples were significantly greater than the values of waviness deviations. Excessive values of roundness deviations effect on the principle of error transferring to the next stage of production as a part of phenomena known as "technological heredity". This kinds of deviations result from layer building nature, which is a characteristic disadvantage of rapid technologies.
2. In order to achieve the smallest values of roundness and waviness deviations of a cylindrical parts produced using SLS technology, the model building axis should be located in parallel direction to main printer axis (axis Z). Therefore the angle of printed direction should be equal 90 °.
3. The results obtained in this paper indicated that application of rapid technology called as Selective Laser Sintering request subjected manufacturing models to further processes.

Acknowledgement

The study was conducted using research facilities purchased with EU funds in the framework of the 2007-2013 Development of Eastern Poland Operational Programme, LABIN Project − Support for Innovative Research Facilities of the Kielce University of Technology in Kielce. Priority 1 – Innovative Economy, Measure 1.3 – Support for R&D Projects.

Therefore, the authors would like to thank to leaders the LABIN program.

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