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Bending strength test of specimens printed in FDM technology with hexagonal, concentric and triangle filling

Badanie wytrzymałości na zginanie próbek wydrukowanych metodą FDM z wypełnieniem heksagonalnym, koncentrycznym i trójkątnym

ŁUKASZ MIAZIO *

The fourth stage of works on the study of the impact of technological printing parameters on the strength parameters of the manufactured object is presented in this paper. This step concerned the bending of hexagonal, concentric and triangular samples. Profiles were made of PLA material and printed using FDM (Fused Deposition Modeling) method, with different filling density.

KEYWORDS: materials engineering, rapid prototyping, 3D printing, PLA, FDM

This paper, and supplementing article [5], discusses the research of printed elements with hexagonal, concentric and triangular filling. This is the fourth article presenting research on the durability of components printed on spatial printers in FDM technology (fused deposition modeling), i.e. modeling with liquid material [1,2]. Samples were printed from the same material as before – PLA (polylactic acid, polylactide) – and with different filling density.

Programs for creating machine code for 3D printers enable selection of various types of filling of printed models [3–5]. The type of filling and direction of material application (in the XY plane) have a significant impact on the strength of the produced models, which are additionally very strongly differentiated in layers (in the Z direction). The durability of the inside of the model and the temperature during printing also affect durability. For these reasons, it is necessary to understand the relationship between technological parameters and achieved durability. The presented tests are aimed at determining the strength of samples printed with different density and different type of filling.

Attempt to stretch plastics

It should be recalled that the conditions and manner of conducting a plastic bending test are described in the standard: PN-N ISO 178: 2003 + A1: 2005 Plastics – Determination of bending properties.

The dimensions of the recommended fitting are as follows:

- length $l = 80 \pm 2$ mm,
- width $b = 10 \pm 0.2$ mm,
- thickness $h = 4 \pm 0.2$ mm.

The spacing of supports was assumed as $L = 64$ mm, and the feed speed of the spindle – 2 mm/min. The bending pattern of the sample with concentrated force is shown in fig. 1.

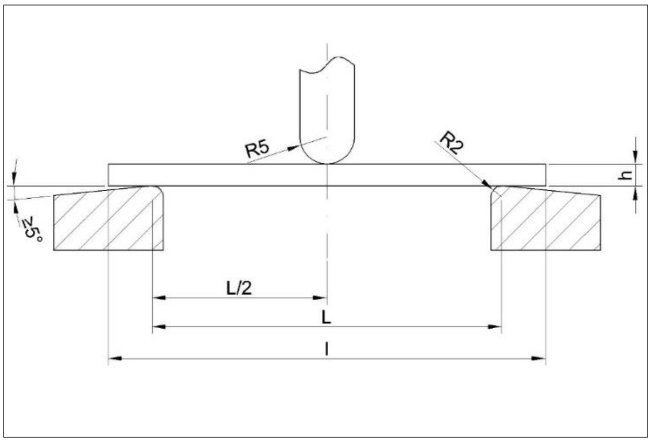

Fig. 1. Location of the test piece at the beginning of the determination

To create a machine code, a molded model was used in the SolidWorks program, whose three-dimensional model was saved to a file in STL format. On its basis, a machine code was created in the MatterControl [6] program, the so-called G-code. In contrast to the previous Cura [5] program, it allows you to choose between hexagonal, concentric and triangular types.

As in previous studies, the samples were printed from PLA's Noviplast material on a BIG Builder DUAL FEED printer by the Dutch company Builder 3D Printers HQ. The fittings were printed flat, along the *Y* axis of the printer, five pieces each. The parameters used were:

- printing speed of the first layer – 20 mm/s,
- printing speed – 60 mm/s,
- head temperature – 215 °C,
- layer height – 0.2 mm,
- thickness of the lower and upper layers – 0.6 mm,
- thickness of side walls – 0.8 mm.

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In addition, a heated table with a temperature of 60 ± 5°C was used.

The fittings were printed with hexagonal fill (fig. 2a), concentric (fig. 2b) and triangular (fig. 2c). The density of the samples was varied from 10 to 100% (every 10%).

Fig. 2. Sample cross-section with a filling density of 30%. Fill type: a) hexagonal, b) concentric, c) triangular

Results

Tabs. I–III contain the results of bending tests of hexagonal, concentric and triangular shaped fittings. The maximum bending force F_m is given depending on the filling density ρ of the fitting. Additionally, in fig. 3, the curves of the average value of the maximum bending force F_u as a function of the filling density of the sample were plotted – for each type of filling (including cross filling, which was the subject of the research described in paper [2]). In turn, fig. 4 shows the relationship between the maximum stresses when bending σ_f as a function of the fill density ρ of the fitting (a uniform sample cross-section is taken into account for the stress calculation), and fig. 5 shows the mean values of the sag deflection arrow as a function of the filling density ρ fittings for four different types of filling.

TABLE I. List of maximum values of bending forces – hexagonal filling

Density of filling ρ, %	Maximum bending force F_m, N					Average maximum value of bending forces F_u, N
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	
10	60.4	60.1	59.1	59.3	60.2	59.8
20	66.5	66.5	65.7	62.5	67.1	65.7
30	67.8	68.3	68.5	68.1	68.9	68.3
40	69.7	67.3	67.4	70.0	67.1	68.3
50	75.9	76.5	76.9	78.8	77.5	77.1
60	80.3	79.4	80.5	79.2	80.1	79.9
70	86.9	86.1	84.7	87.5	86.8	86.4
80	89.6	90.5	90.1	91.5	89.9	90.3
90	94.1	95.1	96.2	94.2	95.5	95.0
100	99.9	98.9	99.8	98.8	99.5	99.4

TABLE II. List of maximum values of bending forces – concentric fill

Density of filling ρ, %	Maximum bending force F_m, N					Average maximum value of bending forces F_u, N
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	
10	74.9	74.9	74.9	74.9	74.9	74.9
20	89.1	89.1	89.1	89.1	89.1	89.1
30	95.6	95.6	95.6	95.6	95.6	95.6
40	99.0	99.0	99.0	99.0	99.0	99.0
50	104.9	104.9	104.9	104.9	104.9	104.9
60	112.5	112.5	112.5	112.5	112.5	112.5
70	116.2	116.2	116.2	116.2	116.2	116.2
80	124.5	124.5	124.5	124.5	124.5	124.5
90	129.0	129.0	129.0	129.0	129.0	129.0
100	134.6	134.6	134.6	134.6	134.6	134.6

TABLE III. List of maximum values of bending forces – triangular filling

Density of filling ρ, %	Maximum bending force F_m, N					Average maximum value of bending forces F_u, N
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	
10	60.2	60.1	62.2	61.4	59.5	60.7
20	73.5	73.1	74.5	74.1	73.6	73.8
30	73.8	73.4	75.8	76.2	74.2	74.7
40	82.8	83.4	81.2	83.5	82.5	82.7
50	84.1	82.2	81.8	83.6	84.5	83.2
60	86.2	84.9	87.2	86.5	87.5	86.5
70	90.5	89.4	91.7	89.1	89.2	90.0
80	103.3	103.1	103.5	103.9	102.9	103.3
90	110.1	110.4	109.8	111.2	109.5	110.2
100	117.8	116.5	118.8	117.5	116.7	117.5

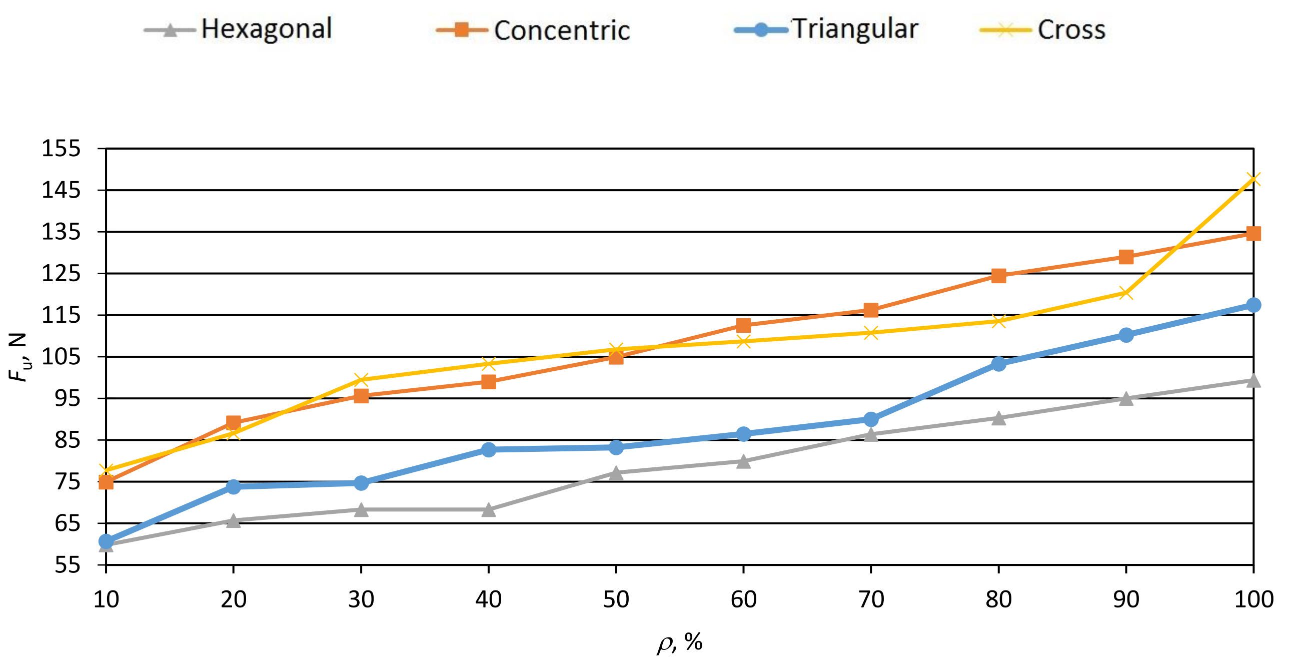

Fig. 3. Graph of the average value of the maximum bending force as a function of the density of the sample filling

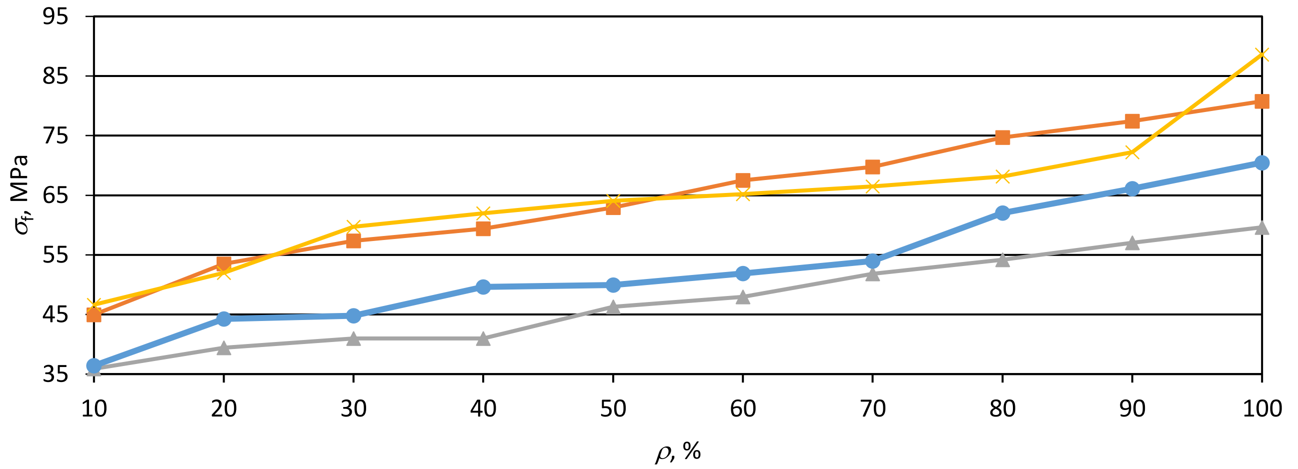

Fig. 4. Stress diagram as a function of sample filling density

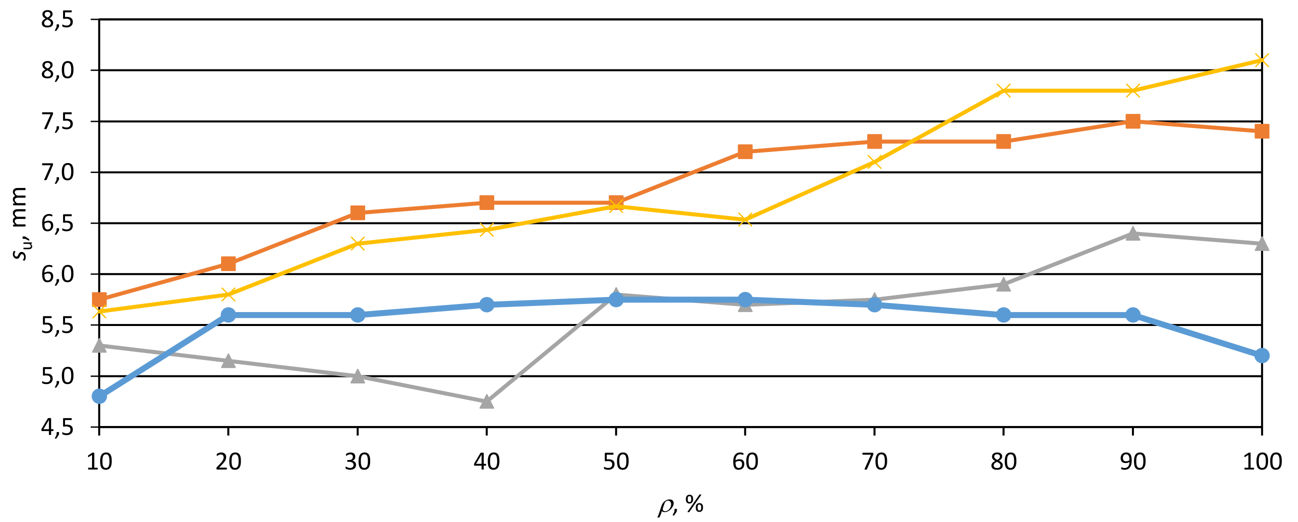

Fig. 5. Diagram of the average value of the deflection arrow as a function of the density of the sample filling

Conclusions

Presented tests show that in the case of bending, higher bending strength was exhibited by concentric and cross-fill samples (mesh) described in the previous article [2]. These results are consistent with the static testing of samples [1,3]. In addition, in the case of concentric filling, the value of the maximum breaking force increases in proportion to the density of the sample filling. In the case of this kind of fillings, a higher value of the deflection arrow was also obtained.

The smallest values of the maximum bending force were noted for the hexagonal fill. This type of filling was also the worst in the tensile test [3], which probably results from the printing method (in the case of this filling, short sections, forming a hexagonal shape, are printed, not long ones – as in the case of concentric filling). Little better results were obtained for triangular filling.

It can be concluded that a sufficient type of filling is a cross filling (mesh) that occurs in all programs for creating machine code for 3D printers. On the other hand, the filling ρ = 30% is optimal in terms of strength and material consumption, and thus the printing time of the model.

REFERENCES

1. Miazio Ł. „Badanie wytrzymałości na rozciąganie próbek wydrukowanych w technologii FDM z różną gęstością wypełnienia”. *Mechanik.* 88 (2015) (7CD): pp. 533–538.
2. Miazio Ł. „Badanie wytrzymałości na zginanie próbek wydrukowanych w technologii FDM z różną gęstością wypełnienia”. *Mechanik.* 89, 7 (2016): pp. 758–759.
3. Miazio Ł. „Badanie wytrzymałości na rozciąganie próbek wydrukowanych w technologii FDM z różną gęstością wypełnienia – wypełnienie heksagonalne i koncentryczne”. *Przegląd Mechaniczny.* 6 (2017): pp. 51–53.
4. www.mattercontrol.com.
5. https://ultimaker.com/en/products/ultimaker-cura-software.

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