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Influence of FDM printing parameters on the compressive mechanical properties and fracture of ABS material

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Abstract

In this paper, the influence of the infill pattern and infill density on the compressive mechanical properties of additively produced ABS material samples was discussed. The compressive mechanical properties of the material are very important and have a great influence on the behavior of the parts in exploitation. The compressive mechanical properties of the ABS material depending on the printing parameters using FDM technology were determined using the compressive test according to the ASTM D695 standard. In the experiments, two infill patterns (hexagonal and rectangular) and three values of infill density (10%, 40% and 70%) were varied. Based on the results of the research, the influence of the infill pattern and infill density on the compressive properties of the additively produced sample was determined. It was concluded that the parts with rectangular infill pattern have better mechanical properties and that increasing the infill density leads to higher values of mechanical properties.

Keywords: FDM technology, compressive strength, ABS.

1. Introduction

The application and importance of additive manufacturing in modern industry are increasing. According to ISO DIS 17296-1, all additive manufacturing technologies are divided into 7 groups (Gibson et al., 2021): Binder jetting

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processes - BJT, Directed energy deposition - DED, Material extrusion - MEX, Material jetting - MJT, Powder bed fusion – PBF, Sheet lamination – SHL, and Vat photopolymerization – VPP. The most used technology is FDM technology. The reason for its widespread use is the existence of cheap devices and the possibility of making printers according to open source instructions, as shown in the study by (Aleksandrović et al., 2021). Numerous studies have been published on the influence of printing parameters using FDM technology on the mechanical characteristics of parts. Tensile, compression tests, impact toughness tests, etc. are used in the research. The topic of research is the materials most used in FDM technology: ABS, PLA, nylon, PETG and others.

The progress of 3D printers has made it possible to reinforce additively produced parts with glass or carbon fibers. The effect of using glass fibers on the tensile properties of the Onyx material (composite of nylon and short carbon fibers) is shown in the work of (Delić et al., 2023, 2025). It was determined that by using glass fibers it is possible to improve the mechanical properties of the part multiple times and that from the aspect of consumption of glass fibers it is better to increase the number of reinforced layers than to increase the amount of fibers in one layer. Similar results were achieved for ABS material as presented in the work of (Turaka et al., 2024).

The compressive properties of two commonly used materials, ABS and PLA, were investigated in the paper of (Kholil et al., 2022). Samples of both materials were printed with different layer thicknesses: 0.15 mm, 0.25 mm and 0.35 mm. The test results showed that the layer thickness has very little influence on the yield strength and that the maximum and minimum values differ by less than 5%. The influence of layer thickness is somewhat greater on the strain value, with ABS the highest value is for the layer thickness of 0.25 mm and with PLA by 0.35 mm. It was concluded that PLA has significantly better compressive properties than ABS. The mean yield strength of ABS is around 40 MPa and PLA 65-70 MPa.

In a study conducted by (Ahn et al., 2002) the anisotropy of the mechanical properties of the ABS material was determined under the influence of five production parameters: air gap, road width, model temperature, ABS color and orientation of rasters. Based on the results of the experiment, it was concluded that the air gap and raster orientation have a significant influence on the mechanical properties, while the bead width, model temperature and ABS color have a small influence.

2. Experiment plan

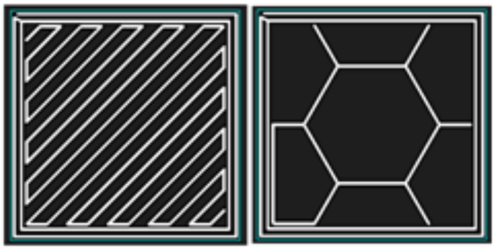
The samples were made according to the dimensions defined in the ASTM D695 standard and are ϕ12.7x25.4 mm. They are printed in an upright position, at the speed recommended by the manufacturer (90 mm/s) and with a standard layer thickness of 0.2 mm. The infill pattern and infill density are varied. According to the recommendations, the nozzle temperature was 230°C and the work table was heated to 110°C. Two commonly used infill patterns were considered: rectangular and hexagonal. Three values of infill densities were considered: 10%, 40% and 70%. The experimental plan is shown in Table 1.

Table 1. Experiment plan

Experiment designation	Infill pattern	Infill density
Rec 10	Rectangular	10%
Rec 40	Rectangular	40%
Rec 70	Rectangular	70%
Hex10	Hexagonal	10%
Hex40	Hexagonal	40%
Hex70	Hexagonal	70%

The samples were printed on a Makerbot replicator 2X 3D printer, made of ABS material from the same manufacturer. When testing the ABS material by tensile test, it was noticed that it is very brittle. Experience has shown that polymer materials rarely crack when tested under pressure and show significant plasticity. Therefore, it was decided to stop the experiment when the height of the part is half of the initial height, i.e. 12.7mm. The test was performed on a Zwick/Roell Z100 universal material testing machine. All the necessary parameters are defined in the software of the testXpert machine.

To check reproducibility, three samples were made for each experiment. The samples after testing is shown in Figure 1b. The used infill patterns are shown in Figure 1a.



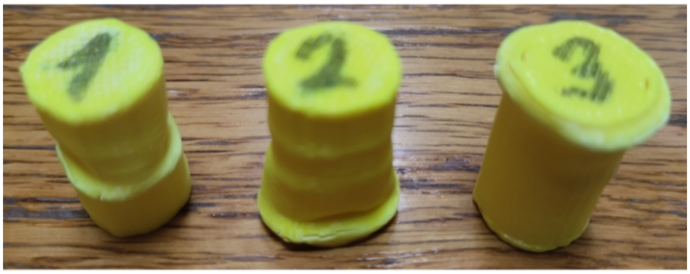


Fig. 1. (a) Used infill patterns – rectangular and hexagonal (b) samples after experiment

3. Results analysis

The results of the experiment are shown in table 2. The table shows the mean values of the obtained results. The S/W ratio was introduced as an additional result indicator. The S/W ratio represents the ratio of the compressive stress value and the mass of the part. The stress – strain diagram are shown in Figure 2. Figure 2a shows the stress – strain diagram for samples printed with rectangular infill pattern, and Figure 2b shows the stress – strain diagram for samples with hexagonal infill pattern. Although the samples were made according to the same standard, i.e. they have the same dimensions and it was possible to show the compression diagram as a compression force - stroke, it was still decided to show the results in the form of compressive stress - strain for easier analysis of the results and comparison with other researches.

Table 2. Experiment results

Experiment designation	Compressive stress, MPa	Strain, mm	Mass, g	S/W ratio
Rec 10	13,95	1,31	1,27	10,98
Rec 40	36,76	12,81	2,1	17,50
Rec 70	74,81	12,71	2,85	26,24
Hex 10	14,17	1,73	1,3	10,9
Hex 40	23,99	2,97	1,87	12,83
Hex 70	41,30	10,29	2,3	17,96

In the case of samples printed with rectangular infill pattern and filling density of 10%, there is a drop in the value of the compressive stress after reaching the maximum force, i.e. compressive strength. This phenomenon is explained by the low value of the infill density, so due to the significant hollow space inside the sample, the internal structure breaks and significant strain occurs. In samples with higher values of infill density, there is a significant increase in compressive strength. Experiments with samples that have infill densities of 40% and 70% showed significantly higher compressive stress values. The results of the experiments unequivocally show that in the case of samples with a rectangular infill pattern, increasing the value of the infill density leads to an increase in the value of compressive stress. The experiments were stopped at approximately 12.7 mm in these two cases because there does not make sense in continuing the experiment because the value of the compressive stress would continuously increase. This assumption is derived from the fact that thermoplastic material is kneading. The compressive strecc value for the sample with a infill density of 10% is 13.95 MPa, with a filling density of 40% it is 36 MPa and with a infill density of 70% even 74.81 MPa.

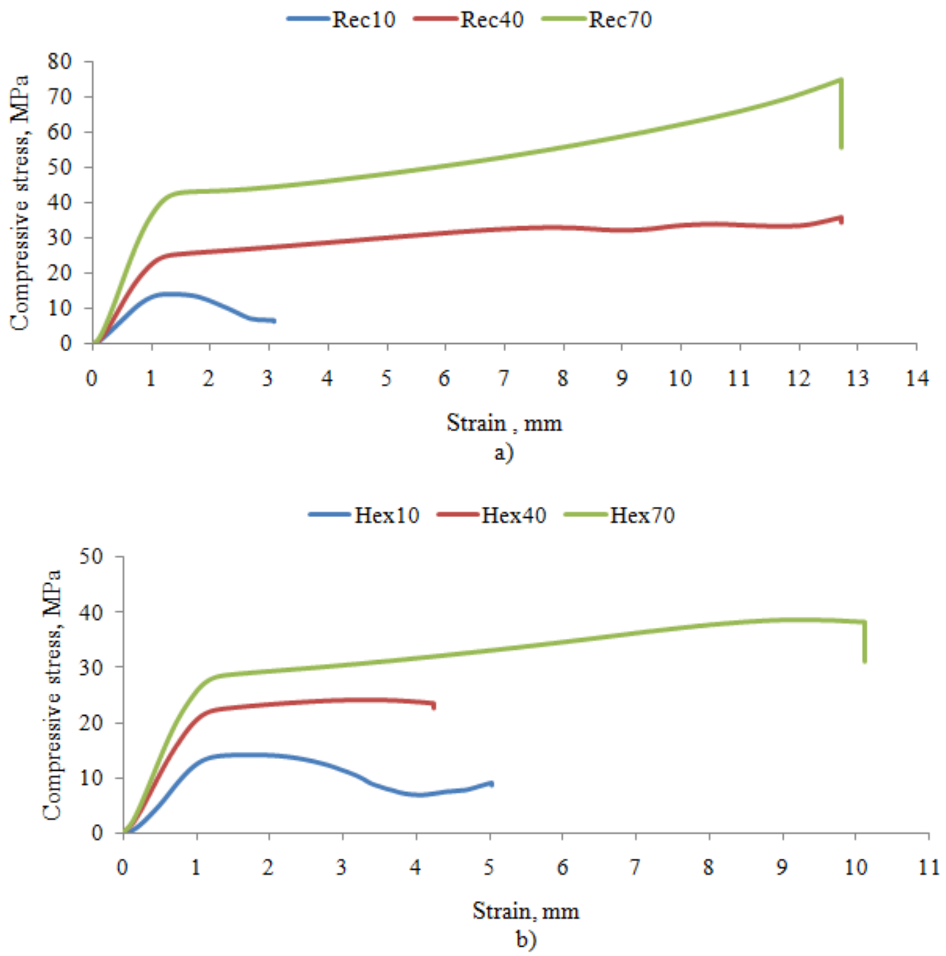


Fig. 2. Stress – strain diagram for (a) samples with rectangular infill pattern; (b) samples with hexagonal infill pattern

In the experiment with samples printed with hexagonal infill pattern, increasing the infill density results in an increase in the value of the compressive stress. For the lowest value of the infill density of 10%, the compressive stress is 14.17 MPa, for samples with a infill density of 40%, the compressive stress is significantly higher and is around 24 MPa, while for the filling percentage of 70% it is the highest and has a value of 41.3 MPa. The reproducibility of the results is satisfactory.

Analyzing the results, it is concluded that the compressive mechanical properties have higher values for samples printed with a rectangular infill pattern. All the above conclusions are shown in Figure 3, where the summarized results are shown in the form of a histogram.

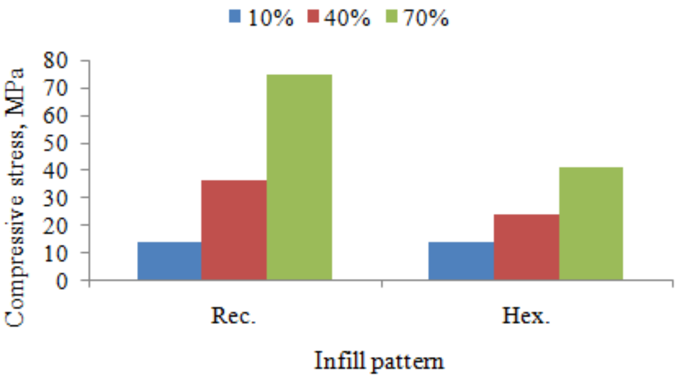


Fig. 3. Histogram with compressive stress results

4. Conclusions

The results of the experiment showed that the compressive properties of the ABS material were significantly better in the case when the samples were printed with rectangular infill pattern than with hexagonal infill pattern. Only in the case when the value of the infill density is 10% when the value of the compressive stress is approximately the same.

An increase in the infill density leads to an increase in the value of the compressive stress for both types of infill pattern. Given that the S/W ratio was introduced as an indicator, it was concluded that increasing the infill density is very good from the point of view of material utilization.

The compressive properties of the material show the behavior of the material when it is loaded with a compressive force, which is the case when the dies for forming thin sheets are made with additive technologies, so it is of significant interest to determine if using the finite element method it is possible to simulate the deformation of polymer hollow structures, which will be one of the directions of further research.

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References

Ahn, S., Montero, M., Odell, D., Roundy, S., Wright, P.K., 2002. Anisotropic material properties of fused deposition modeling ABS. Rapid Prototyping Journal 8, 248–257. https://doi.org/10.1108/13552540210441166

Aleksandrović, M., Ratković Kovačević, N., Kreculj, D., Dihovični, Đ., Jakovljević, P., 2021. Making a 3d printer of delta configuration using open-source project. Structural Integrity and Life 22, pp. 125–130.

Delić, M., Mandić, V., Aleksandrović, S., Arsić, D., 2023. Determination of the influence of infill pattern and fiberglass reinforcement on the tensile properties of additively manufactured material by FDM technology. J Mech Sci Technol 37, 5569–5575. https://doi.org/10.1007/s12206-023-2309-1

Delić, M., Mandić, V., Aleksandrović, S., Arsić, D., Ivković, Dj., 2025. Determination of the influence of FDM printing parameters on tensile strength and fracture occurrence of additively manufactured ABS material, International Journal of Structural Integrity 16, in press, Doi https://doi.org/10.1108/IJSI-03-2024-0040

Gibson, I., Rosen, D., Stucker, B., Khorasani, M., 2021. Additive Manufacturing Technologies. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-030-56127-7

Kholil, A., Asyaefudin, E., Pinto, N., Syaripuddin, S., 2022. Compression Strength Characteristics of ABS and PLA Materials Affected by Layer Thickness on FDM. J. Phys.: Conf. Ser. 2377, 012008. https://doi.org/10.1088/1742-6596/2377/1/012008

Turaka, S., Jagannati, V., Pappula, B., Makgato, S., 2024. Impact of infill density on morphology and mechanical properties of 3D printed ABS/CF-ABS composites using design of experiments. Heliyon 10, e29920. https://doi.org/10.1016/j.heliyon.2024.e29920