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The Influence of Technological Parameters of 3d Printing with PLA-Plastic on the Mechanical Characteristics of Products

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The main problem of modern engineering is to increase the reliability and durability of parts and components of mechanisms, along with a constant decrease in metal consumption of structures. The relevance of the problem is constantly growing due to the increased requirements for the manufacture of products, the need to save scarce expensive metals and alloys and, as a result, replace them with economically more profitable options. One of the promising replacement options is the use of plastic structures, in particular, polylactic acid (PLA) in the structures. PLA is a biodegradable thermoplastic used in 3D printing.

However, despite the widespread use of 3D printing with PLA-plastic, there is practically no data on the mechanical characteristics of manufactured products in open access. The nature of the influence of a temperature range, printing speed, layer height, the speed of movement of a print head on the properties of products are not described, which does not allow to predict the mechanical properties of a final product. Therefore, the study of 3D modes of PLA printing with plastic affecting the mechanical characteristics of products is of serious scientific and practical interest [1].

To establish the mechanical characteristics of a product with various technological parameters, it must be subjected to a series of tests, tensile tests are among the main ones. Testing the sample is necessary to establish strength, which is a particularly important parameter in its further use. These tests were carried out on a hydraulic tensile testing machine with a measuring software package in the Kason WAW-300 kit, where the sample was subjected to tensile forces until destructure. The device installed on the machine determines the scale of stretching in the form of a diagram. The more plastic the sample, the longer its resistance to fracture is and vice versa [2].

The determination of tensile strength of a sample is carried out according to State Standard 11262, and the determination of an elasticity modulus – according to State Standard 9550-81. The 3D model designed in the SOLIDWORK program and printed on a 3D printer corresponds to the type and size specified in State Standard [3].

Four types of filling forms were used in the work: triangular, honeycomb, line and edge printing. The optimal percentage of filling was selected. It determines how much plastic will be inside the sample. The choice was stopped at 20% [4].

Tensile tests were carried out at a temperature of 23 ± 2° C in accordance with State Standard 11262–80 and State Standard 9550–81. Before the tests, the width and thickness of the samples in the working part was measured with an accuracy of 0.01 mm in three places and the cross-sectional area was calculated. The smallest cross-sectional area was taken into account.

Before testing, the necessary marks were applied to the sample (without damaging the samples), which limited its base and the position of grips edges. The samples were fixed in the clamps of a testing machine according to the marks that determine the position of clamps edges, so that the longitudinal axis of clamps and axis of the sample match each other and follow the direction of movement of a movable clamp. The clamps were tightened evenly so that there was no slipping of the sample during the test and it did not break at the place of fixation. Then the samples were loaded with an increasing load, the speed of clamps expansion was 5 mm / min while determining the strength and relative residual elongation. During the destruction time, the force was fixed. The samples were printed at a constant nozzle temperature of 215 ° C and a heating stage of 55 ° C. The printing speed was 60 mm / s.

According to the test results, the following data were obtained:

Table 1 – Strength characteristics of the samples

Sample / Repeat No.		Load	Tension	Ductility zone	Elastic limit	Elastic modulus	Load	Tension	Ductility zone	Elastic limit
		Fm (Max Farce), Kn		Fp, MPa		E, MPa	Fm (Max Farce) Kn		Fp, MPa	
							Mean			
Triangle	1	1,09	27,25	0,71	17,75	0,41				
	2	1,11	27,75	0,74	18,5	0,46	1,11	27,75	0,74	18,42
	3	1,13	28,25	0,76	19	0,33				
Honeycombs	1	1,17	29,25	0,76	19	0,47				
	2	1,12	28	0,71	17,75	0,48	1,15	28,67	0,73	18,25
	3	1,15	28,75	0,72	18	0,36				
Line	1	1,02	25,5	0,67	16,75	0,46				
	2	1,1	27,5	0,7	17,5	0,32	1,08	26,92	0,68	16,5
	3	1,11	27,75	0,67	15,25	0,38				
Edge	1	1,62	40,5	0,96	24	0,53				
	2	1,35	33,75	0,77	19,25	0,41	1,53	38,25	0,90	22,42
	3	1,62	40,5	0,96	24	0,53				

During a tensile test, the longitudinal arrangement of fibers (edge) showed the best results, due to the fact that it is much close to the initial characteristics of the material and the parameters affecting the bonding of the layers have less impact.

Nevertheless, it should be noted that the results shown in Table 1 are valid only for the load applied perpendicular to the direction of the fibers, in the case of loading along the fiber, the strength characteristics are significantly reduced, that is, there is a strong correlation of the characteristics between the direction of the load and the fiber.

The experimental and theoretical data obtained can be used to deepen the existing theoretical models that describe 3D printing processes. In addition, the results of the work can be applied in the educational process while giving lectures, conducting laboratory and practical classes etc. In the future, the results of this study can be used in industry while designing commercial equipment, finished products produced by 3D printing in large enterprises of the country, such as MAZ OJSC, MTZ OJSC, AMKODOR OJSC.

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