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Assessment of mechanical properties of PA 3200 GF polyamide models made by SLS

Ocena właściwości mechanicznych modeli wykonanych z poliamidu PA 3200 GF w technologii SLS

Abstract

The paper presents the results of mechanical properties research of samples made in the Selective Laser Sintering technology. Polyamide powder PA 3200 GF reinforced with glass fiber was the material used to build the model. Samples subjected to a uniaxial tensile test were made in accordance with ASTM D638 – V standard. The printing direction was the technological parameter of the study. The analysis of the results showed that the addition of fiberglass significantly influenced the improvement of mechanical properties, especially the isotropic of mechanical properties with respect to the printing direction.

Keywords: Additive Manufacturing, SLS, Polyamide PA 3200 GF, Formiga P100

Streszczenie

W artykule przedstawiono wyniki badań mechanicznych próbek wykonanych w technologii Selektywnego Spiekania Laserowego. Materiałem wykorzystanym do budowy modeli był poliamid PA 3200 GF wzmacniany włóknem szklanym. Próbki poddane jednoosiowej próbie rozciągania wykonane zostały zgodnie z norma ASTM D638-V. Parametrem technologicznym uwzględnionym podczas badań był kierunek budowy modeli. Analiza wyników badań wykazała, iż dodatek włókna szklanego w znaczny sposób wpływa na poprawę własności mechanicznych, przede wszystkim na izotropię własności mechanicznych w odniesieniu kierunku budowania modeli.

Słowa kluczowe: Technologie Przyrostowe, SLS, Poliamid PA 3200, Formiga P100

1. Introduction

Additive technologies allowing for the construction of physical objects directly from 3D models are increasingly being used not only in the building of prototypes, but also for the production of fully functional machine elements. Currently, layered technologies are used in many areas of industry such as, for example, prototype production [1] or construction of tools used in the production of conventional manufacturing technologies. Mechanical properties of the materials used are so good that they are also used to build components exposed to the wear process [2]. Due to the layered nature of a model construction, most additive technologies using materials based on plastics have anisotropic in both mechanical properties and dimensional-shape accuracy [3–6].

Due to the high degree of complexity in the construction of models using SLS technology, the current state of art describing the impact of technological parameters on mechanical properties does not sufficiently cover the presented topic. Selected manufacturing problems, related to mechanical properties of materials used for construction in SLS technology are described in papers [7–9].

The authors of the research [7] presented in their work the results of strength tests, with particular emphasis on the influence of selected technological parameters on tensile strength. The PA 2200 polyamide powder based on the known construction PA 12 polyamide was used to build the sample models. The research results confirmed that the direction of the models on the building platform directly influences the tensile strength and the Young's modulus.

Another studies related to determining the influence of technological parameters on selected mechanical properties are presented in paper [8]. The authors of the research have tested samples made in SLS technology. A mixture of two polyamide powders based on PA6 and P12 construction polyamides was analyzed. The technological parameters were as follows: laser power, energy density and temperature of the process chamber. The authors also determined basic mechanical properties such as tensile strength and Young's modulus for variable proportions of mixed materials.

This work describes the preliminary tests based on the determination of the impact of the "printing direction" technological parameter on the strength of the models during the uniaxial tensile test. PA 3200 GF material, which is based on pure PA 2200 polyamide, was used in the tests, but it was reinforced with the addition of glass fiber. The analysis of the test results compares the results obtained for polyamide reinforced with glass fiber with the results obtained for pure PA 2200 polyamide presented in work [9].

2. SLS Technology

Selective Laser Sintering SLS is one of the oldest additive technologies. The technology developed in the 1980s is also one of the most complex layered methods. A large number of variable technological parameters that have a direct impact on the manufacturing process and functional properties is one of the largest in relation to other generative technologies, in particular those based on plastics.

In this method, a polyamide powder with a grain diameter of only 0.056 mm is spread on the machine working platform over the shoulder, and then a focused CO_2 laser beam scanning the selected cross section sinter the currently built layer, combining it with the previously created and thus creating the model. During the tests, a Formiga P100 (3D printer, machine from EOS) was used to make the sample models. The mechanical properties of materials used in the construction of samples are shown in Table 1.

Table 1. Mechanical properties of materials: PA 2200/PA3200 GF [10]

Mechanical properties	Value	Unit	Standard
Young's modulus	1700/3200	MPa	EN ISO 527
Impact strength	4.4/5.4	kJ/m^2	ISO 180/1A
Shore'a hardness(15s)	75/80	–	ISO 868/Scale D
Denisty	0.930/1.22	g/cm^3	EOS method

3. Research

Tensile strength tests of samples made in SLS technology were carried out using an Inspekt Mini 3kN strength testing machine. The samples were made in accordance with ASTM D638-V. The initial strength tests presented in [9] indicated large differences in the strength of the sample models made with the variable parameter of the orientation of the models on the building platform (printing direction). In connection therewith, technological parameter included in the presented research was the direction of the models on the building platform. Three directional were chosen, i.e. 0°, 45° and 90°, shown in Figure 1.

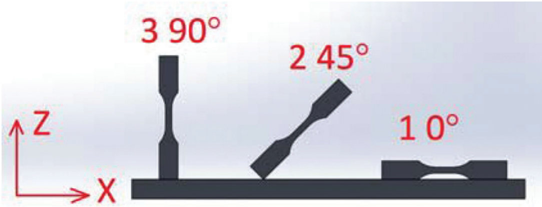

Fig. 1. Samples on the platform

Each type of samples was made in the amount of 5 pieces to perform statistical calculations. For each direction, tensile strength was determined experimentally in the form of the parameter – *Rm*, Young modulus – *E*, and relative elongation of the samples – *A*, whose results are shown in Table 2. The table also shows the calculated values of standard deviation. A graphical representation of the test results is presented in Figures 2–4, where the tensile results of the samples are compared, depending on the printing direction.

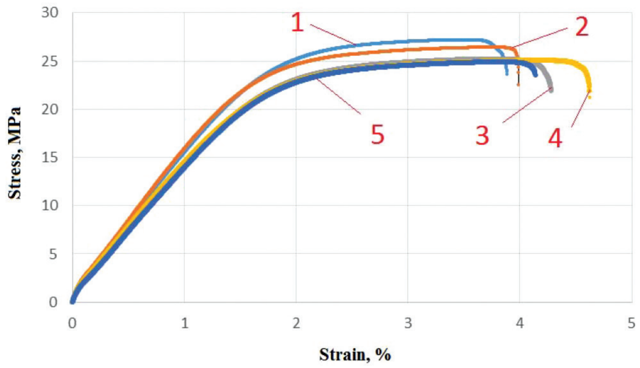

Fig. 2. Tensile test result for the first type of placement

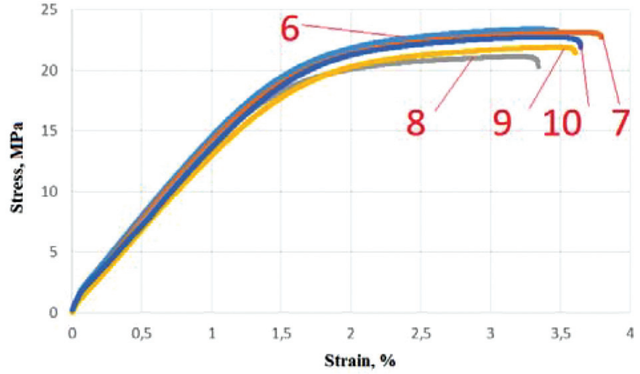

Fig. 3. Tensile test result for the second type of placement

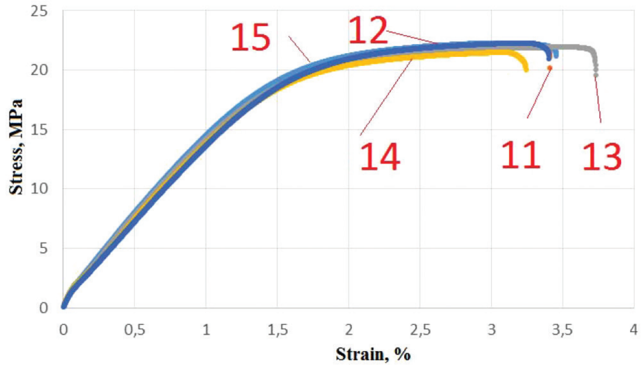

Fig. 4. Tensile test result for the third type of placement

Analyzing quantitatively the results of the research, it can be concluded that with the increase of the angle of placing the models on the building platform, the tensile strength of polyamide decreases. In the case of samples made with a given angle of 0°, the average tensile strength value is 22.05 MPa. In the case of samples made with a given angle of 45°, the average strength value is 21.05 MPa. The least advantageous variant of placing the models relative to the building platform is the angle of 90°, where the average value of the strength is 20.75 MPa. Comparing the test results for those obtained for pure polyamide PA 2200 [9], it can be concluded that the addition of glass fiber clearly affects the improvement of the strength of the samples, in particular the phenomenon of anisotropy. In the case of pure PA 2200 polyamide, the average measurement results for the same location and the same type of test varied by up to 50% depending on the direction of the models on the building platform. At the same time, pure polyamide was characterized by very different elongation of samples during the test ranging from 1% to 15%. The presented test results for glass fiber reinforced polyamide clearly indicate that the addition of glass fiber minimizes the influence of printing direction on the strength of the samples. The test results presented in Table 2 indicate that the highest elongation value was recorded for samples made at an angle of 0°, however, the results obtained for 45° and 90° differ slightly. After analyzing the data on the percentage elongation of the tested samples, it can be stated that the addition of glass fiber reduces anisotropic in mechanical properties also in this aspect.

Fig. 5.

Table 2. Research results for polyamide PA 3200 GF

No.	*Rm*, MPa	*E*, MPa	*A*, %
1	22.59	0.59	9.40
2	21.96	0.60	9.01
3	20.98	0.49	9.78
4	22.1	0.58	10.78
5	22.65	0.53	9.76
$\bar{x}$	**22.05**	**0.56**	**9.75**
s	**0.6**	**0.04**	**0.59**
6	19.44	0.57	7.96
7	21.62	0.56	8.33
8	19.16	0.51	7.72
9	21.76	0.52	8.48
10	23.3	0.63	8.73
$\bar{x}$	**21.05**	**0.56**	**8.24**
s	**1.55**	**0.04**	**0.36**
11	18.53	0.54	7.84
12	19.91	0.55	8.07
13	21.81	0.61	8.88
14	21.35	0.59	7.49
15	22.13	0.58	7.46
$\bar{x}$	**20.75**	**0.57**	**7.94**
s	**1.34**	**0.02**	**0.52**

4. Conclusion

After analyzing the results of tensile tests of polyamide reinforced with glass fiber samples, and comparing the results with previously performed tests for pure polyamide, the following general conclusions can be formulated:

The tensile strength expressed by the Rm parameter is the highest for samples made with a given angle of 0°. As the value of the angle increases, the tensile strength decreases. Statical analysis allows us to state that the standard deviation of the test results is also the smallest for the above-mentioned positioning of the models, which positively affects the reproducibility of the test results.

Samples made at an angle of 90° are characterized by almost 20% lower elongation compared to samples with a given angle of 0°.

The value of the Young's modulus for all the made models of samples remains at a similar level regardless of the direction of the models' location on the building platform.

The results of the presented tests in comparison to those obtained for pure PA 2200 polyamide are characterized by a very high degree of isotropy.

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