Investigation on hardness Shore D of 3D printed parts of Acrylonitrile butadiene styrene

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Abstract: *In this article, hardness Shore D of 3D printed ABS samples were investigated. The experimental results were analytical and statistically processed.*
Keywords*: 3D PRINTING, SHORE D HARDNESS, ACRYLONITRILE BUTADIENE STYRENE*

1. Introduction

3D printing technologies are constantly improving. Much research is being done on the production of machine elements using the basic 3D printing technology- FDM material deposition. In this regard, it is necessary to study the mechanical properties of 3D printing materials. One of the main materials used in FDM technology is Acrylonitrile butadiene styrene ABS. The advantages of this thermopolymer include excellent strength, good dimensional stability, good processability and chemical resistance. Figure 1 shows the technology for printing ABS using the technology FDM[1],[2].[3].

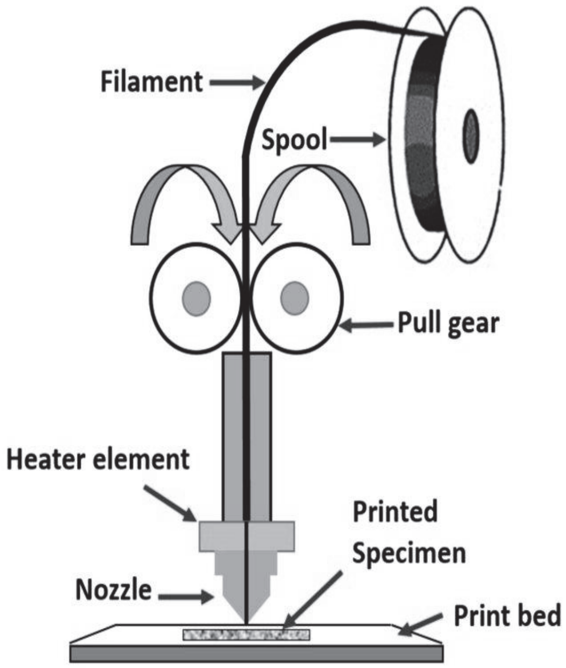

Fig. 1 Schematic of a FDM 3D printing.

In it, the material, which is in the form of a thread, also called filament, is extruded from a special extruder. It has a built-in drive, as well as a heater through which a melt is created. With the help of mechanisms driven by stepper motors, 3D printing is carried out.

Hardness is understood as the ability of the surface layer to resist elastic and plastic deformation when impacted by a harder body[4]. The method is widely used in engineering practice because the test is fast, easy and non-destructive. According to the principle of operation, hardness testing methods are classified into the following[5]:

- Scratching methods
- Indentation methods
- Rebound methods

According to the loading rate, the methods are divided into static and dynamic. For many materials, the ratio of the hardness value to that of the maximum tensile strength is known, i.e. the method can be used to obtain indirect data for other mechanical characteristics such as fatigue tests. As a mechanical characteristic, hardness depends on a number of properties of the materials - elastic properties, plastic properties, etc. Hardness is an important mechanical characteristic because it characterizes the wear resistance of the parts

.2. Materials and methods

4 samples measuring 40x40x6mm were printed from ABS polymer with the following modes:

- Material- Acrylonitrile butadiene styrene
- 3d printing speed- 350mm/s
- Extruding temperature- 235-240^{o} C
- Bed temperature- 105^{o} C
- Layer height- 0,2mm
- Infill- 100%
- 3D printing duration: 10 min

There are a number of standardized methods for measuring hardness - Brinell, Rockwell, Shore, Knoop, etc. The Shore method is most often used to test the hardness of rubber and plastics. The Shore method is a method of indentation testing and is standardized according to ASTM D2240 and ISO 48-4[6].

Depending on the hardness of the tested material, different scales are used - For semi-hard and hard plastics, the D scale is used. The D scale indenter is a cone with a 30 degree apex angle. and a diameter of 1.4 mm[7]. The indenter material is hardened steel, and the standardized applied force is 44.5 newtons. The standardized holding time during testing is 15 seconds. The hardness tester is calibrated using reference blocks before testing. The measurement is in dimensionless units from 0 to 100. The accuracy of the method is ±0.05 units.

The minimum number of measurements is 5 per sample, for better precision, 10 experimental measurements were made on each sample. All standardized measurement requirements were met - the tests were made through 4 times the diameter of the indenter, the penetration depth was more than 10 times smaller than the thickness of the test samples, the samples were placed on a solid support, no measurements were made near the edges of the test plates. The hardness tester was calibrated for accuracy. The measurements were made on both sides of the test samples in order to obtain more precise experimental data. Before the test, the surface of the samples was cleaned so as not to compromise the penetration depth, and hence the experimental results. The tests were made in laboratory conditions in strict compliance with the standards for the application of the method - ASTM D2240 and ISO 48-4 - Fig. 2

ABS was chosen as the material for the hardness test. It is widely used in engineering practice due to its good mechanical strength, thermoplasticity, chemical resistance, light weight and smooth surface after processing. It is one of the most common materials used for 3D printing and is used in the automotive industry, electronics boxes, toys, packaging, housings and the construction industry[8],[9]. Its annual use exceeds 10 tons per year, which makes experimental studies of its mechanical performance very relevant. The disadvantages of ABS are low UV resistance and it is not biodegradable. ABS material is preferred for engineering applications where small force loads are required, due to its easy processing[10].

Fig. 2 Measurement of the test specimen.

3. Results and discussion

Results are presented in tab. and in fig.3.

Table 1: Measured Shore D hardness of the test specimens

Specimen 1	Specimen 2	Specimen 3	Specimen 4
76.5	77.2	78.7	77.8
77	78	78.1	76.1
77.4	77.4	77.5	77.7
76.2	76.2	78.4	78.2
79.1	79.1	77.3	78
77.9	77.9	78.4	77.3
79	79	77.8	76.8
78.3	78.3	77.7	77.7
78.4	78.4	78.7	77.8
77.3	77.3	78.7	78.9

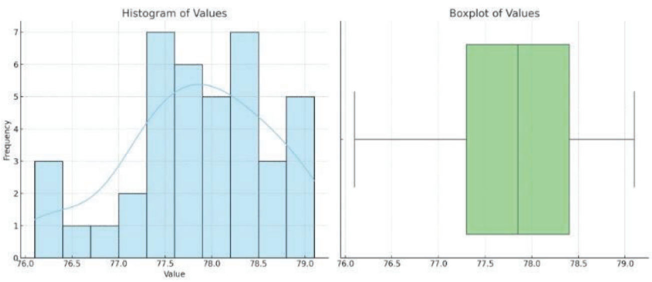

Fig. 3 Histogram of values and boxplot of values

The minimum measured value is 76.1, and the maximum is 79.1, the range is 3.0. The arithmetic mean is 77.76, the median is 77.75, and the modes are two - 77.3 and 78.4. The distribution in Figure 3 shows a symmetric distribution around the mean, with no outliers noted. The results in the box are compact and have low variance. The bimodal distribution is completely realistic in real experimental tests. The 95% confidence interval of the sample is in the range of 77.58-78.09.

4. Conclussions

Based on the 40 test tests performed using the standardized method for measuring the Shore D hardness of ABS, the following conclusions can be drawn. The results are in the range of 76.1 to 79.3, the distribution is symmetrical and compact, no anomalous results have been recorded, the variation is low, the experimental results can be used in the selection of material, as well as indirectly for strength sizing. The statistical analysis of the data validates their correctness.

5. References

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