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Issue Article

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EXPERIMENTAL STUDY OF SHRINKAGE OF A PLASTIC PART MADE BY 3D PRINTING

Abstract: *The shrinkage of linear and diametrical dimensions of a PLA plastic part made on a 3D printer by FDM was analyzed in the article. The smallest shrinkage value in percentage terms was noted after measuring the overall dimensions of the part, the largest shrinkage value was noted after measuring small diameter holes.*

Key words: *3D printing, PLA, shrinkage, dimension, part.*
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Introduction

Additive technologies in modern manufacturing make it possible to produce high-quality parts with complex configurations in small batches. The possibility of manufacturing products from various materials (plastic, metal, rubber, etc.) with a high degree of flexibility makes this technology more efficient than traditional methods of manufacturing parts.

Layered 3D printing of parts on 3D printers is widely used in industry and other fields. PLA-plastic [1] has good strength at a low cost, which leads to the widespread use of the material in the manufacture of parts. Modern reviews of the possibilities of 3D printing of PLA plastic parts have been carried out by researchers, a number of which are presented in the works [2-6].

However, along with the advantages of the method in 3D printing (as in any thermodynamic process of manufacturing parts), there is a change in the dimensions of plastic parts caused by volumetric and linear shrinkage [7-9]. The value of shrinkage depends on the plastic used. At the same time, the shrinkage range of PLA is minimal. Determining the shrinkage value depending on the size of the element located on the outer or inner surfaces of the physical part will allow you to adjust the final dimensions of the projected electronic model of the part for further import to a 3D printer.

Materials and methods

The linear shrinkage of the part made of PLA on a 3D printer of the PICASO Designer Classic model [10] was subject to the study. To manufacture the part using 3D printing, a three-dimensional model of the "plate" type part with nine through cylindrical holes of various diameters was created. The following overall dimensions of the part were adopted: length – 104 mm, width – 20 mm and thickness – 7 mm. The diameter of each subsequent hole increased by 1 mm, starting from 2 mm. After saving the solid-state model of the part to the STL format, the following parameters were set for 3D printing: one nozzle with a diameter of 0.5 mm; wire diameter – 1.75 mm; number of layers – 70; layer height – 0.1 mm; width of the internal filling line – 0.5 mm; internal filling density – 20%; filling pattern – grid (2D); intersection with perimeters and shell – 15%; number of perimeters – 3; indent from the edge when smoothing – 0.1 mm; pattern – zig-zag; feed ratio – 10%; regular clearance – 0.3 mm; print speed – 20 mm/s. The plastic and the table were heated to temperatures of 210 and 50 °C, respectively. It took 2 hours and 49 minutes to print the physical part with a wire consumption of 3324 mm.

The part model built in the "Kompas" software and prepared for 3D printing in the "Polygon X" software is shown in the Figs. 1-3.

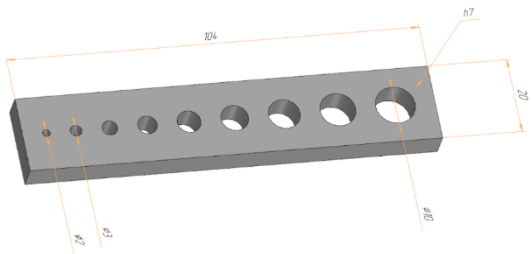

Figure 1. The solid-state model of the part created in the "Kompas" software.

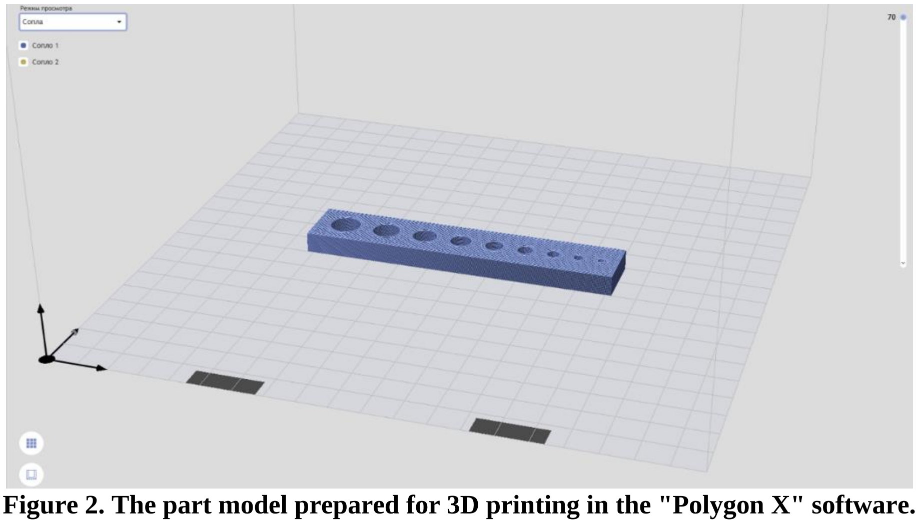

Figure 2. The part model prepared for 3D printing in the "Polygon X" software.

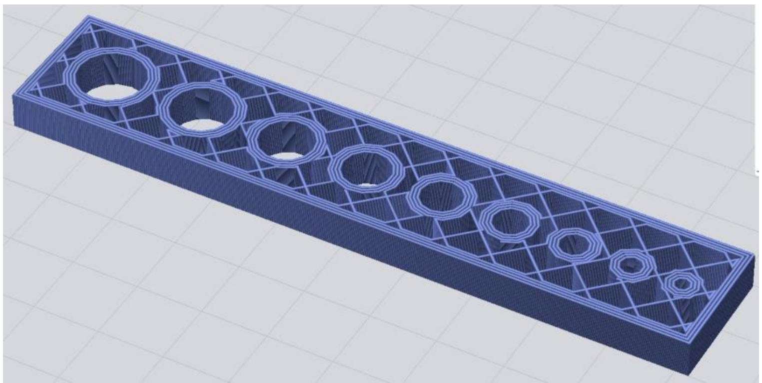

Figure 3. Detailing the quality of the part model before 3D printing.

Results and discussion

The partially printed part on the 3D printer is shown in the Fig. 4. After manufacturing the part, it was subjected to stripping operations (chamfering along the contours of the overall dimensions and in the holes). This minimized the errors in measuring the dimensions of the part with a caliper with an accuracy of 0.01 mm. Each size was measured three times to calculate the arithmetic mean.

Figure 4. The partially printed part on the 3D printer.

As a result of the measurements, the following size values were obtained:

Length: size by model – 104 mm, the actual size of the physical part – 103.8 mm, shrinkage – 0.19%;

Width: size by model – 20 mm, the actual size of the physical part – 19.92 mm, shrinkage – 0.4%;

Thickness: size by model – 7 mm, the actual size of the physical part – 6.81-6.83 mm, shrinkage – 2.43-2.71%;

Hole diameters:

size by model – Ø2 mm, the actual size of the physical part – Ø1.69 mm, shrinkage – 15.5%;

size by model – Ø3 mm, the actual size of the physical part – Ø2.61 mm, shrinkage – 13%;

size by model – Ø4 mm, the actual size of the physical part – Ø3.72 mm, shrinkage – 7%;

size by model – Ø5 mm, the actual size of the physical part – Ø4.66 mm, shrinkage – 6.8%;

size by model – Ø6 mm, the actual size of the physical part – Ø5.78 mm, shrinkage – 3.67%;

size by model – Ø7 mm, the actual size of the physical part – Ø6.74 mm, shrinkage – 3.71%;

size by model – Ø8 mm, the actual size of the physical part – Ø7.74 mm, shrinkage – 3.25%;

size by model – Ø9 mm, the actual size of the physical part – Ø8.75 mm, shrinkage – 2.78%;

size by model – Ø10 mm, the actual size of the physical part – Ø9.76 mm, shrinkage – 2.4%.

The size of the thickness of the physical part changed by 0.02 mm. The largest size was defined in the middle, the smallest to the edges of the part.

Based on the results obtained, it can be concluded that the largest shrinkage occurs in small diameter holes, and the smallest shrinkage occurs in terms of the overall dimensions of the part (length and width).

Conclusion

When manufacturing parts using 3D printing, it is necessary to take into account the shrinkage of the material after cooling. The dimensions of the electronic part model must be adjusted to obtain the required dimensions of the physical part. Experimental results show that during the application of layers, the actual thickness (height) of the part settles somewhat and a bulge forms in the middle. The larger the size of the part along the Z axis, the greater this deviation will be. At the same time, the remaining overall dimensions of the physical part have a shrinkage of no more than 0.5%. The greatest shrinkage of the material is observed when making holes, and depending on the size of the hole can reach 2.4-15.5%.

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