3D printing technological modes influence on the performance properties of vehicles plastic parts restored with additive technologies

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Abstract. The 3D printing parameters influence on the plastic parts performance properties (water absorption, chemical resistance) created with additive technologies is considered. It has been found that, the filling percentage has the greatest influence on the change in the water absorption value among the other printing parameters. It has been shown that the printed product structure formation should be carried out at a print job creating stage.

Introduction

The various polymer materials are widely used in modern mechanical engineering. Thus, thermoplastics are used in road vehicles parts manufacturing such as: interior elements, parts of the engine compartment, the bodies of exterior elements, etc. [1-3]. The thermoplastic materials with high glass transition temperatures have been developed during the last decade [4, 5], which makes them competitive in comparison with traditional thermosetting materials [6-9].

The plastic parts are damaged due to violations of the operating conditions and rules, unskilled maintenance and repair, during the life cycle. The technical condition of plastic machine parts is affected by the impact of various process fluids (water, oil), as well as the environment, including deicing agents in winter. All these factors lead to defects and, as a result, the need to repair parts appears.

There is a constant growth in the 3D printer’s implementation, indicating the prospects of additive technologies all over the world [1]. Fused Deposition Modeling, FDM is one of the most widely used additive technology for manufacturing parts from thermoplastics [10-12]. The machines downtime machines waiting for the delivery of spare parts, as well as the material consumption of repairs, will be reduced by the use of additive technologies in repair production will reduce.

3D printing of plastic parts can be carried out with various technological modes. The product structure is formed depending on these modes, which is confirmed by previous studies [13, 14]. In turn, the product structure affects the material moisture absorption.

The various impurities, including chemical deicing reagents which are widely used in large quantities on the roads, can also get into the part structure in addition to moisture. That is why it is necessary to study the influence of printing technological modes on moisture absorption, as well as chemical resistance to reagents. And this was the purpose of this work.

Test objects and methods

Tests for the determination of water absorption were carried out in accordance with the requirements of GOST 4650-2014 “Plastics. Methods for determining water absorption”. The resistance to the action of chemical media was determined by the method set out in GOST 12020-2018 “Plastics. Methods for determining the resistance to chemical media”.

The samples were made with different 3D printing modes (Table. 1), weighed before starting the test, then submerged in a container with water.
Table 1. Parameters for 3D-printing

| Parameter name          | Parameter value                  |
|-------------------------|----------------------------------|
| Printing speed, mm/s    | 15; 30; 45; 60; 80               |
| Layer height, mm        | 0,03; 0,06; 0,10; 0,12; 0,20; 0,25; 0,3 |
| Feed modifier (feed ratio) | 0,90; 0,925; 0,95; 0,975; 1,0; 1,025; 1,05; 1,075; 1,1 |
| Filling percentage, %   | 20; 40; 60; 80; 100              |

The samples exposure time lasted 90 days. After the expiration of the exposure period, the samples were extracted from the water and kept in the open air for a day at a temperature of +20°C to dry the outer surface. After drying, the samples were weighed to determine the mass change. The results of the change (increase) in the samples mass as a percentage are shown in Figure 1.

The following conclusions can be drawn based on the data obtained during the tests:

- an increase in the printing speed leads to an increase in the water absorption percentage;
- an increase in the fill percentage reduces the water absorption percentage;
- an increase in the feed rate reduces the water absorption percentage;
- an increase in the layer thickness leads to an increase in the water absorption percentage.
Such regularities in the change in water absorption of samples made with different printing modes can be explained by the printing parameters influence on the material structure, which, regardless of the modes, is layered-cellular. The material layering is determined by the manufacturing technology and, therefore, it is almost impossible to avoid it [1, 15, 16]. The cellular nature of the material occurs for several reasons, the first of which is the shape of the supplied plastic melt in cross-section. Since the melt passes through the hole of a circular cross-section and is applied to a flat surface, the final cross-section of each printed row (thread) takes an oval shape. The local elongation of the material and its deformation in the cross section appears with an increase in the printing head speed. Thus, pores can be observed when several parallel rows and sequential layers are applied.

The study of the material resistance to chemical deicing agents consists in placing the samples in a container with a chemical medium, holding them for 90 days, and then evaluating the changes in the material structure. As a chemical medium, an ICEMELT mix brand deicing reagent has been used, which has irregular shaped granules. The reagent contains sodium chloride (50 ... 85%) and calcium chloride (15...50%). The samples structure was examined before and after the end of the experiment (Figure 2).

**Conclusion**

The obtained results show that the ABS plastic sample structure does not change under the influence of the deicing agent used on public roads during winter. The reference data for the 3D printing material should be used regarding the resistance to other chemicals used in mechanical engineering (fuel, engine oil, coolant, headlight washer fluid).

The structure formation of a part made with the additive technologies is possible at the design stage. At the same time, the technological features of the 3D printing process should be taken into account: there are parameters that affect the structure of the entire part as a whole, and parameters that change only certain part elements. The parts with the required mechanical properties with a high degree of repeatability may be created on the base of the proper parameter selection.

**Figure 2.** The deicing agent influence on the material structure depending on various printing parameters: a – printing speed, mm/s; b – filling percentage, %; c – feed rate, %; d – layer thickness, mm

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