Production of technological plugs for engine box and oil system using additive technologies

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DOI: 10.13111/2066-8201.2021.13.S.3

Received: 15 March 2021/ Accepted: 27 June 2021/ Published: August 2021

Abstract: *Today, technological plugs designed to protect the internal cavities of parts and assembly units are manufactured using such production methods as casting or stamping. At the same time, their subsequent processing is a time-consuming process. Additive technologies can save material, save time and reduce expenses. This study considers the possibility of manufacturing technological plugs for engine box and oil system using additive technologies. The cover plugs were printed using the Fusion Deposition Modeling (FDM) method on a Russian-made ZENIT printer. PLA plastic was chosen for 3D printing. The plug models were optimised, which allowed correcting and reducing the estimated printing time. In particular, some plugs were made assemblable, which helped to avoid a large number of printing supports. The production of technological plugs using additive technology allows reducing the cost of the finished product, the weight of the plugs and the estimated time of their production.*

Key Words*: 3D printing, FDM printing, plugging devices, model optimisation, expenses*

1. INTRODUCTION

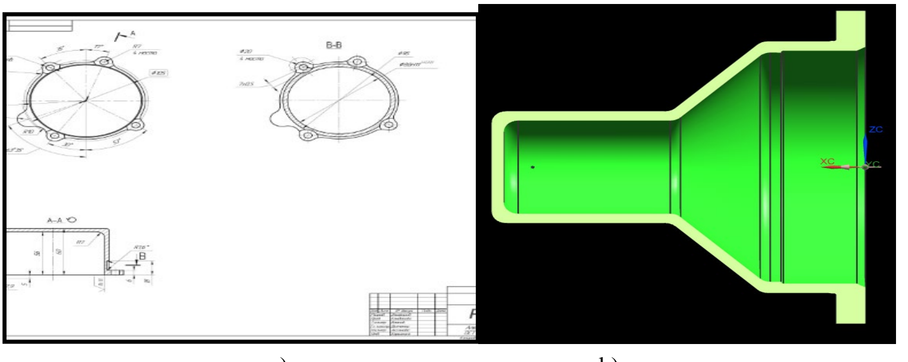
Technological plugs are designed to protect the internal cavities of parts and assemblies of gas-turbine engines and aircraft weapons, as well as fittings and tips of units from clogging and mechanical damage during transportation, storage, routine maintenance and other work [1], [2], [3]. Nowadays, the technological means of plugging the holes, flanges, and fittings of the parts and assemblies of a gas-turbine engine and aircraft weapons are manufactured using conventional production methods, such as casting, stamping, etc. Since most of the plugs have complex geometry, their subsequent processing is quite a time-consuming process and leads to a high material utilisation rate.

At the same time, additive technologies use only the required amount of material that is needed for the manufacturing of the product.

In addition, when using the additive technology of manufacturing parts and assemblies, there is no need to produce tooling required for the conventional processing methods, which significantly saves both time and material costs [4], [5].

2. MATERIALS AND METHODS

The plug blueprints were made using the KOMPAS V17 software. Modelling and optimisation were performed in Siemens PLM NX 12 (Figure 1).



a) b)

Fig. 1 – Blueprint of the breather plug in KOMPAS V17 (a) and the plug model in Siemens PLM NX 12 (b)

The plugs were printed using one of the most popular methods of additive technologies – the Fusion Deposition Modeling (FDM) method.

This technology is one of the methods of 3D printing and represents a layer-by-layer application of pre-melted material. Various materials are used for printing, including thermoplastic polymers, available in a wide variety of textures and colors. The parts produced by the FDM technology are self-coloured, strong and elastic, and have a stable set of physical characteristics that depend primarily on the material used. They can be heat-resistant, wear-resistant, have increased flexibility or impact strength, etc. [6], [7], [8], [9].

The Russian-made ZENIT 3D printer of the second generation was chosen as the equipment for the production of plugs.

It is known that this 3D printer is suitable for printing the most popular types of plastic, such as PLA, ABS, PVA, FLEX, etc., due to the heated table surface (Figure 2). In addition, for a better final result, an adjustable built-in airflow is used. The continuity of the work itself is ensured by a special take-off assembly of the thread, which practically eliminates its jamming [10], [11].

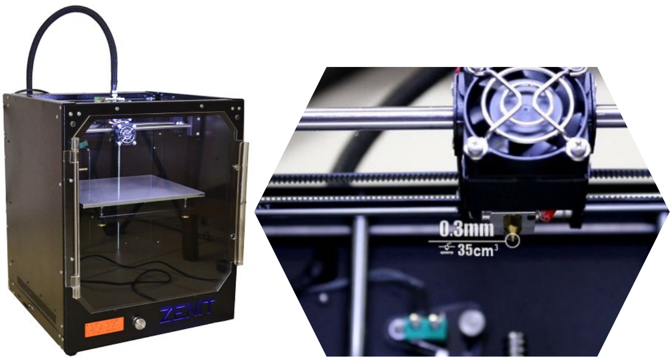


Fig. 2 – ZENIT 3D printer

After a comparative analysis of the materials used for 3D printing on the ZENIT printer (Table 1), PLA plastic was selected, the main properties of which are presented in Table 2. The choice of this material was motivated by the following characteristics: PLA-plastic (polylactide, PLA) is a biodegradable, biocompatible, thermoplastic aliphatic polyester, the structural unit of which is lactic acid [12]. In addition, PLA plastic is non-toxic; it has a wide color palette, and also has the following characteristics:

– when printing, there is no need for a heated platform;
– its dimensions are stable;
– ideal for moving parts and mechanical models;
– excellent sliding of parts;
– energy savings due to low thread softening temperature;
– there is no need to use Kapton to lubricate the surface to build up the prototype;
– smoothness of the printed product surface;
– getting more detailed and fully ready-to-use objects [13], [14], [15].

After manufacturing, it was allowed to modify the plugs at the installation site with subsequent adjustment of the 3D models.

Table 1 – Comparative analysis of the main plastics for 3D printing by properties

Property	ABS	PLA	FLEX	PVA
Simplicity of printing	+ + +	+ + + + +	+ +	+ + +
Rigidity	+ + + +	+ + + + +	+ +	+ + + +
Simplicity of mechanical processing	+ + + + +	+ +	+	+ + + + +
nterlayer adhesion	+ + +	+ + + + +	+ + + + +	+ + + +
Outdoor durability	+ + + +	+ +	+ + + +	+
Heat resistance	+ + + + +	+ +	+ + + + +	+
UV resistance	+	+ + + + +	+	+
Impact resistance	+ + + +	+ + +	+ + + + +	+ +
Oil resistance	+ + + + +	+ + + +	+ + +	+
Petrol resistance	+ + + +	+ + + +	+ +	+
Operating temperature	-40°C to +80°C	-20°C to +40°C	-40°C to +80°C	-10°C to +30°C

Table 2 – Properties of PLA plastic

Indicator	**Value**
Glass transition temperature	60-65°C
Density	1.23-1.25 g/cm^3
Tensile strength	3.3 GPa

Elongation (relative)	3.8%
Tensile strength	57.8 MPa
Flexural strength	55.3 mPa
Heat resistance	50°C
Melting point	170-180°C
Minimum wall thickness	1 mm

3. RESULTS AND DISCUSSIONS

For engine box and oil system, a batch of plugs (23 pieces in total) was printed (Figure 3). Based on the results of printing the first batch of plugs, it was found that optimisation of the models was necessary since the estimated production time of some of the plugs was very high (Table 3).

The point of the optimisation was to make some plugs assemblable to avoid a lot of supports when printing [16], [17], [18], [19], [20]. Next, the study considers the optimisation using the example of the breather plug A022 (Figure 4).

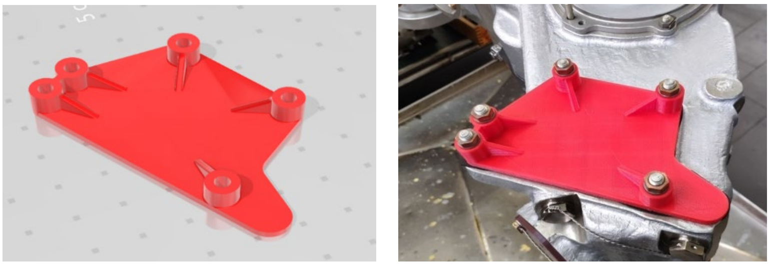
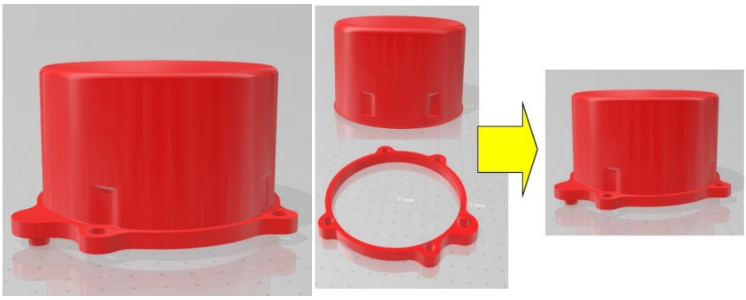


Fig. 3 – Plug for the PU of the evacuation pump unit (EPU)

Table 3 – List of plugs, estimated production time, and material consumption

STL model designation	Estimated production time (1 piece)	Consumption of PLA with a diameter of 1.75 mm (in m, in kg)
A024.stl	35 min.	2.44 m, 0.0073 kg
A025.stl	1 h. 10 min.	5.29 m, 0.0167 kg
A016.stl	5 h. 15 min.	23.23 m, 0.0633 kg
A021.stl	30 min.	2.12 m, 0.0064 kg
A01.stl	4 h.	20.32 m, 0.0606 kg
A003.stl	2 h. 50 min.	14.97 m, 0.0447 kg
A005.stl	18 min.	1 m, 0.003 kg
A006.stl	30 min.	1.95 m, 0.006 kg
A007.stl	2 h. 50 min.	15.3 m. 0.0456 kg
A09.stl	40 min.	2.8 m, 0.0083 kg
A011.stl	3 h.	13.21 m, 0.394 kg
A014.stl	45 min.	3.88 m, 0.0116 kg
A026.stl	1 h. 30 min.	7.01 m, 0.021 kg
A027.stl	30 min.	1.78 m, 0.0054 kg
A022.stl	9 h.	36.9 m, 0.110 kg
A023.stl	55 min.	3.73 m, 0.0112 kg
164.stl	5 h.	46.7 m, 0.143 kg



a) b)

c)

Fig. 4 – Plug A022: a) – before optimisation (estimated production time – 9 hours); b) – after optimisation (estimated production time – 4 hours) – model; c) – after optimisation (printed plug)

In addition, it was found that with the help of 3D printing, it is possible to achieve a significant reduction in the weight of the product. For example, the weight of the AL9 alloy casting is about 5 times greater than the weight of a similar plug printed from PLA plastic. Figure 5 shows the plug 164, the weight of which, when produced in the conventional way, is 0.750 kg, and when produced using 3D printing was no more than 0.143 kg.

Optimisations also allow reducing the number of supports when printing plugs, and consequently, saving plastic [21], [22], [23], [24].

After removing the supports, if necessary, sanding can be performed to smooth out the part and remove all obvious defects. The grade of the sandpaper depends on the thickness of the layer and the quality of the print: for layers of 200 microns or less, or for printouts without blotches, the P150 sandpaper can be used. If there are blotches visible to the naked eye, or the object is printed with a layer thickness of 300 microns or more, the sanding should begin with P100 [25], [26], [27], [28].

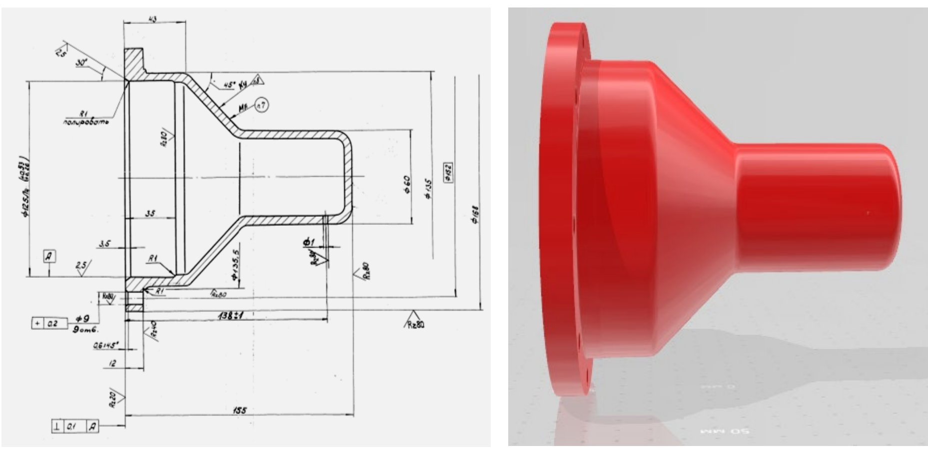


Fig. 5 – Plug 164 for the shaft

4. CONCLUSIONS

In the course of the study, it was found that the production of technological plugs using the additive technology allows significantly reducing the weight of both the plugs and the product itself during transportation, as well as reducing the estimated production time of the plugs, and, consequently, reducing labour intensity. Notably, the plugs manufactured by the additive technology ensured the tightness of the internal cavities of engine box and oil system. In addition, with some refinement and optimisation, the plugs can be used again, and the possibility of developing universal plugs for various modules and products can also be considered. In addition, it was found that the results obtained in this study indicated that the production of technological plugs by the additive technology has the following advantages:

- significant reduction of the cost of the finished product;
- the possibility of improvement when installing plugs on engine box and oil system;
- the weight of the proposed plugs is 5 times lower than the weight of the same plugs manufactured by the conventional method;
- the possibility to optimise geometry;
- no need to create fittings;
- no post-process machining is required;
- low material utilisation rate (practically non-existent);
- reduction of the estimated production time and, as a result, labour intensity;
- the plugs made by the additive technology ensure the tightness of the internal cavities of the propulsion unit and oil systems.

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