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To cite this article: J N Dementyeva *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **570** 012015

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## Disadvantages of the selective laser sintering technology in the manufacture models for investment casting

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**Annotation.** Preparation of production and development of new science-intensive products is a complex and time-consuming process, including the creation of product models for carrying out a series of experimental studies to refine computational models, and then manufacturing the necessary technological equipment. The use of digital production technologies can reduce the laboriousness of this process. The technology of selective laser sintering eliminates the need for the design and manufacture of casting equipment. This paper presents an analysis of the difficulties encountered when using the SLS process for the manufacture of polystyrene smelted models.

### Introduction

Casting and smelting models are common methods of obtaining accurate, thin-walled, complex in the configuration of castings from various metals and alloys. Extensive industrial use of these methods began in the 60s of the last century. And it is associated with the development of equipment for investment casting and burning models of polystyrene foam. Styrofoam has good properties for this method: the burning temperature is within 560 °C, the burning time is from 10 to 20 s, the mass of the non-gasified residue reaches 0.015% of the mass of the model. In addition to polystyrene, there are other materials. For example, PMMA (Doro Chemical USA) [1] has a mass of non-gasified residue 20 times less than that of foundry polystyrene.

For the manufacture of polystyrene models used equipment, manufactured both by traditional methods, and using additive technologies. This can significantly reduce the time of pre-production. The technology of selective laser sintering is one of the most common technologies for growing polystyrene models.

During casting, melt pouring is carried out into the working cavity of an integral mold, obtained after preliminary burning or melting of the model from the mold. The ceramic shell is ignited and heated before melting.

Initially, polystyrene foam models (Replicast-CS [1]) traditionally produced in molds were used for the manufacture of shell molds, and with the advent of additive technologies at present, it became possible to use “grown” models. With all the advantages of selective laser sintering technology, there is no information in the literature about the existing shortcomings and problems that the manufacturer may encounter when using this technology [2]. Therefore, the purpose of this work



was to identify the difficulties encountered when using the SLS process for the manufacture of polystyrene smelted models

### Main part

In experiments on selective laser sintering, we used the sPro 60 HD (3D Systems), USA. sPro 60 HD is an industrial selective laser sintering plant that creates physical models from powder compositions, mostly polymer ones. This installation is actively used in aircraft building, machine building, automotive industry, military-industrial complex, medicine for creating prototype models. Features: the construction area is 381x330x437 mm, the thickness of the layer is 0,08-0,15 mm, the printing speed is 1,0 l / h, the scanning system is ProScan CX (digital), the scanning speed is 6 m / s, the laser power is - 70 W / CO<sub>2</sub> laser. The installation uses commercial materials - polyamide, polystyrene, polypropylene, glass-filled nylon 12.

It is known that the glass-transition temperature of the material is  $T_g = 89^\circ \text{C}$ . Do not exceed this temperature on the surface of the layer to avoid sticking the material to the screed roller. The layer thickness is 150  $\mu\text{m}$ . A laser power of 28 W is required for a layer of 150  $\mu\text{m}$ . Laser scanning speed - 6 m/s.

CastForm PS powder (3D System) was used in the studies. It generates accurate low density samples suitable for investment casting [3]. These samples are coated with wax, then they can be polished to a smooth surface [4].

The mechanical properties of structural materials play a key role in their application. The basis for understanding their properties is information on how the material reacts to the operating external mechanical load, which are determined by such parameters as tensile strength, elongation at break, modulus of elasticity, plasticity coefficient, etc. For the evaluation of these properties, first of all, universal testing machines (UIM) during the testing of materials for tensile, compression, bending, shear, torsion. Universal testing machine GT-7000S with heat chamber UGT7001-HC6. Floor two-column machine with maximum effort 500 kgf. and 2000 kgf. Modern mechanics, high-precision force and displacement sensors, an external extensometer for elastomers, a user-friendly interface allow you to solve various research tasks.

Impact toughness was determined by the method of Charpy without a notch (GOST 4647), the energy of the hammer is 7.5 J.

The results of the mechanical tests of the obtained samples are presented in Figure 1 and in Table 1. Based on this information, it is possible to conclude that the low mechanical properties of the obtained samples. This will cause great difficulties in extracting samples from the construction chamber and cleaning it from “green” powder. The high brittleness of the samples will lead to their destruction when the powder is removed, especially those having a thickness of less than 1 mm. The test results for impact strength showed that it is equal to 1.498, 1.206, 1.353 kJ / m<sup>2</sup>.

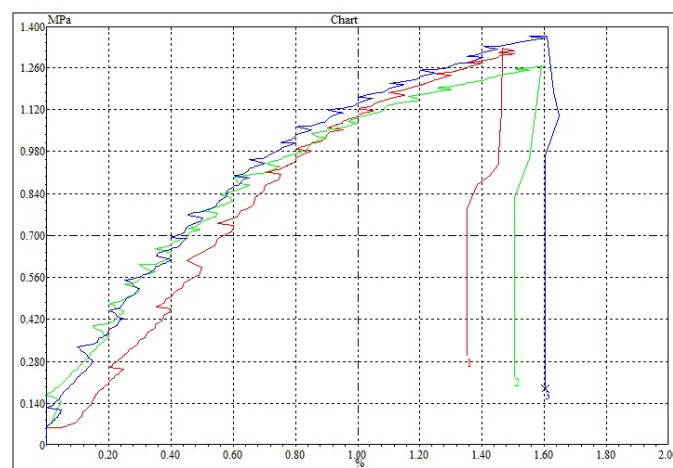


Figure 1 The results of the mechanical tests of polystyrene sls samples

Table 1. The results of mechanical testing of polystyrene sls samples

Test No	Elastic modulus kN/m <sup>2</sup>	Max. Load MPa	Max. Load kgf/cm <sup>2</sup>	Elongation Gauge %	Speed mm/min	Thickness mm
1	145800.609	1.3	13.5	1.4	50.0	2.98
2	113237.086	1.3	12.9	1.5	50.0	3.05
3	130114.602	1.4	13.9	1.6	50.0	2.91

Tests were conducted on the cultivation of complex elements of aviation products. Photographs of the samples are presented in Figure 2.

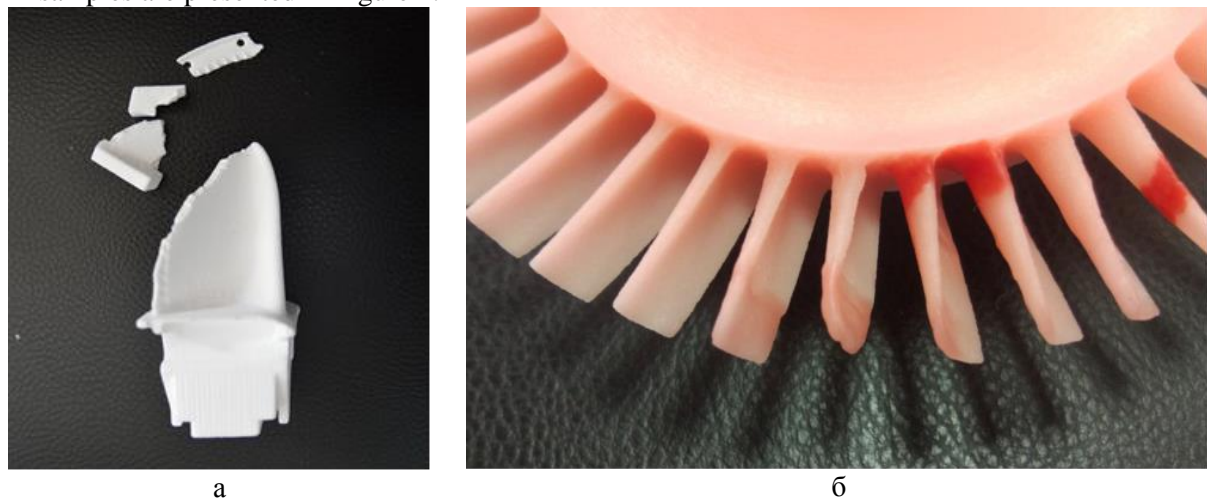


Figure 2 Prototypes of polystyrene models, damaged during the removal of powder residues. As can be seen, the samples are destroyed in the process of extracting powder from the construction and cleaning chamber. This causes certain difficulties at production plants, as it requires performers who are able to gently clean the products for this work.

To increase the strength of these models need to be impregnated with wax. Without wax impregnation, they cannot be covered with a ceramic coating and create a refractory shell form. At this stage, it may also be difficult to impregnate thin-walled or small-sized products. Figure 3a shows a sample of a monowheel after wax impregnation with observance of technological conditions. In Figure 3b, the temperature of the autoclave was not observed, which led to a distortion of the geometry of the blades of the monowheel.

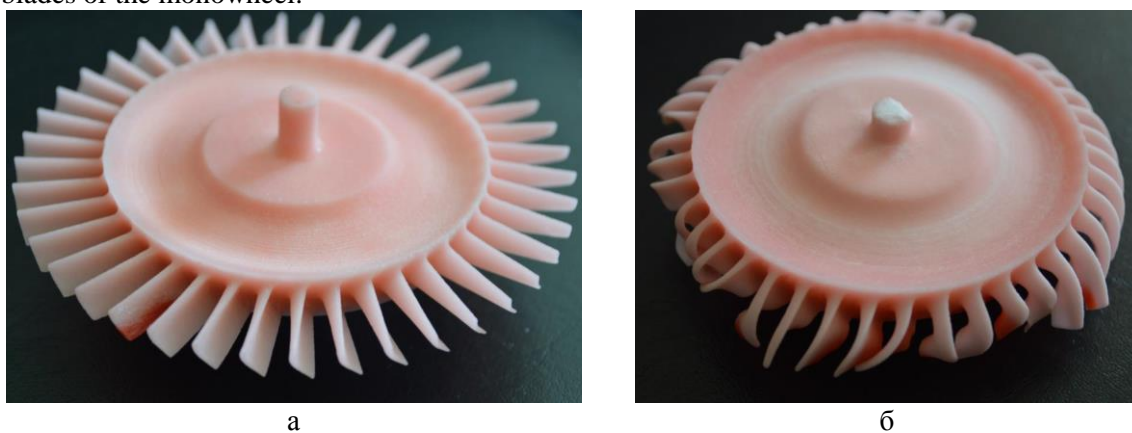


Figure 3 The results of waxing polystyrene models.

## Conclusion

As a result of the research it was found that, despite all the advantages of the technology of selective laser sintering, it has several disadvantages in the manufacture of polystyrene models. The first is the low mechanical characteristics of the samples. The second is the need for waxing to increase strength. The third is the possibility of distortion of geometry in case of non-observance of technological procedures for impregnation with wax. And of course, there are new technologies for additive manufacturing, which work on PMMA material and do not use laser radiation. All this suggests the need to create new materials for the SLS process eliminating all the above disadvantages.

### **Acknowledges**

The work was carried out in the framework of the Base part of the state task of Ministry of Science and Higher Education of the Russian Federation (3.9399.2017/8.9)

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