THE RAPID PROTOTYPING OF AIRCRAFT WHEEL HUB MODEL WITH THE USE OF TECHNIQUES JS, SLA, FDM

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Abstract

Design work related to the implementation of new aerospace elements requires the use of 3D-CAD modelling techniques and rapid prototyping, which makes it possible to significantly accelerate the deployment of new solutions.

The article presents the possibility of using some methods of rapid prototyping to produce the research model of a wheel hub forming part of the landing gear. Incremental rapid prototyping methods - JS (Jetting System), SLA (Stereolithography), FDM (Fused Depositing Modelling) – have been characterized with regard to the technology of executing a hub model, the parameters of the manufacturing apparatus, and comparing basic technical data of materials used in the analyzed processes.

One of the elements of the process of prototyping was to process data in other equipment for rapid prototyping. This process consisted of the following steps: defining the parameters of model building, determining the appropriate model settings in the workspace of manufacturing equipment, editing the supporting structure, verifying the subsequent layers through the simulation of model building process, generating output numerical procedures for manufacturing equipment.

Manufactured prototypes have been evaluated of dimensional accuracy with the use coordinate measuring machine. Also measured the surface roughness.

Conducted studies were the basis to determine the applicability of various methods of rapid prototyping in the process of research and manufacturing aircraft wheel hub.

Keywords: *prototype, aircraft wheel hub, rapid prototyping, techniques JS, SLA, FDM*

1. Introduction

RP techniques allow making prototypes of very complex shapes, advanced designs, which include aircraft parts (including the developed and tested hub). The use of incremental methods of rapid prototyping is particularly important in the manufacture of those aircraft parts for which using traditional methods and tools are difficult or impossible [5-7, 9].

The methods of rapid prototyping (JS, SLA and FDM) presented in this paper are have been used to make prototypes of aircraft wheel hubs. The implementation of physical models was preceded by the development of CAD design of the hub, which is the subject of separate publications. Particular attention was given in the article on the characteristics of the used RP techniques and the comparative analysis of the models.

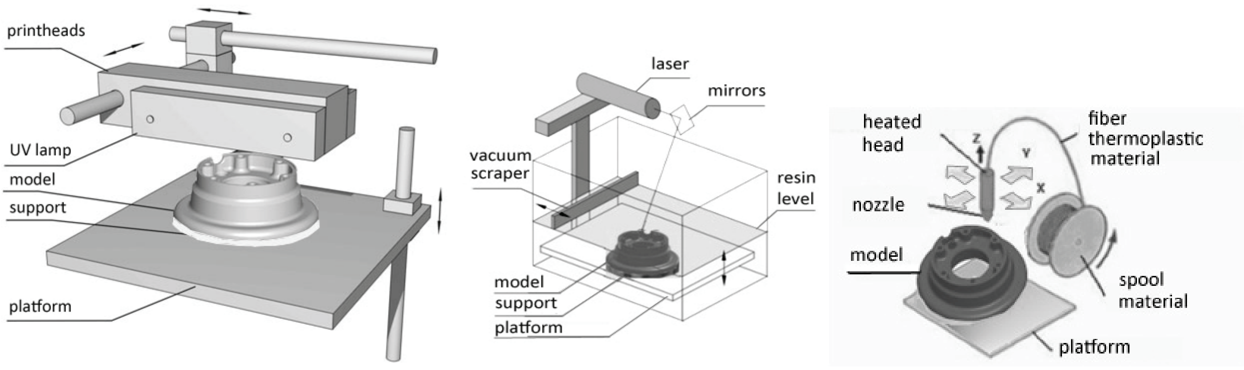
2. Characteristics of RP techniques

There have been three methods of RP used for prototyping of wheel hubs: JS - Jetting Systems, SLA - stereolithography and FDM - Fused Depositing Modelling [1, 3, 8].

The method of liquid photopolymer printing layer (JS) consists in imposing a layer of resin (photopolymer), 16 microns thick, from the print head and then curing it with UV light from the flash integrated with the print head. In this system, during the construction of the model, two materials are applied to the working platform: appropriate material (model), and support material (bracket model). Models are built on the working platform moving along the vertical axis “z” workspace. Polymer layers are applied sequentially by the print heads in a plane parallel to the work platform “x-y”. Schematic diagram of the prototype made with JS method is shown in Fig. 1.a).

The SLA method is based on liquid resin polymerization with laser beam of low power - 40 mW and wavelength - 325 nm. During the process, the resulting model is placed on a platform in the tank with a liquid resin (Fig. 1.b). The need to separate the model requires the creation of platform supporting structures. The method requires supporting both the entire first layer of the model and the elements deflected from the vertical (you can choose the value of the tilt angle for which the object is propped) and fragments of the model, for which construction begins at a certain height. The resin is hardened with layers of a thickness of 0.1 mm according to the given section through the laser beam scanning of its borders and filling the area inside. After curing of a cross-section a reduction of the thickness of the work platform follows along with the executed part of the model, which is in the tank with liquid resin. Finishing involves the removal of supports, washing the model in acetone (to clean the surface from the remaining liquid resin), and additional UV irradiation to complete the polymerization of the entire volume of the model.

Fused Deposition Modelling Method (FDM) allows making objects by heating and melting thermoplastic fibbers unwounded from the spool, and the deposition of the melted material extruded from the nozzle on the surface of the produced model placed on the platform (Fig. 1.c). The layer of material applied with the extrusion head in the plane “x-y” quickly solidifies and binds to the previous layer by thermal penetration. Once embedded, the platform moves the layer (in the “z”) down a certain thickness, and continues to build the model. The apparatus is also equipped with auxiliary material administered and applied by analogy to the base material.



a) b) c)

Fig. 1. Schematic diagram of the model: a) JS, b) SLA, c) FDM

3. Selected parameters of model materials

Table 1 shows a summary of the basic technical data of modelling materials used in the processes of JS, SLA and FDM. In the case of photopolymers the following resins were used respectively: FullCure 720 (material model) and FullCure 705 (supporting material) for JS and SL5170 - for SLA. FDM was used for the spool of fibber of ABSplus material.

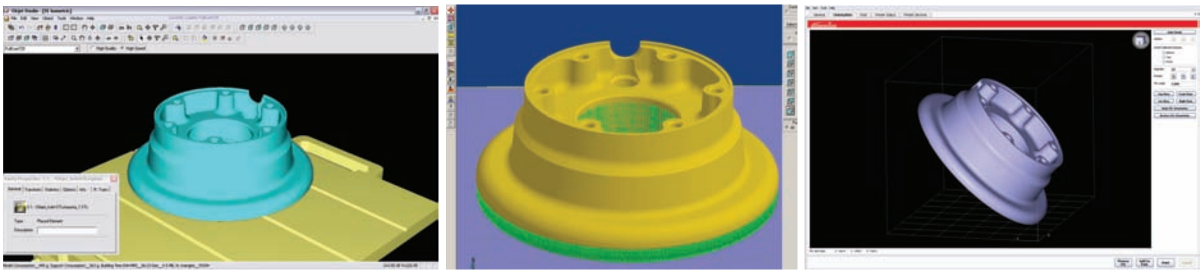
4. Hub rapid prototyping with the techniques of JS, SLA, FDM

To develop RP processes the following utilities were used: Objet Studio - JS, 3DLightyear - SLA, QuickSlice – FDM (*Fig. 2.*). The data developed before were used to carry out the JS, SLA and FDM processes [2, 4, 10-12]. Prototypes of aircraft wheel hubs were constructed using the apparatus: Objet Eden 260V - JS, 3D Systems SLA 250/50 - SLA, uPrint Stratasys - FDM. The preparation of technical equipment included:

- JS – cleaning of piezoelectric heads system and work platform, heating the team heads and UV lamps,
- SLA - installing a work platform, verifying and complementing the level of resin, laser annealing,
- FDM - installing a work platform, heating print block.
- RP processes have been completed in: 6, 5 hours - JS, 33 hours - SLA, 30 hours - FDM. In Fig. 3. models of aircraft wheel hubs are presented immediately after the RP processes.

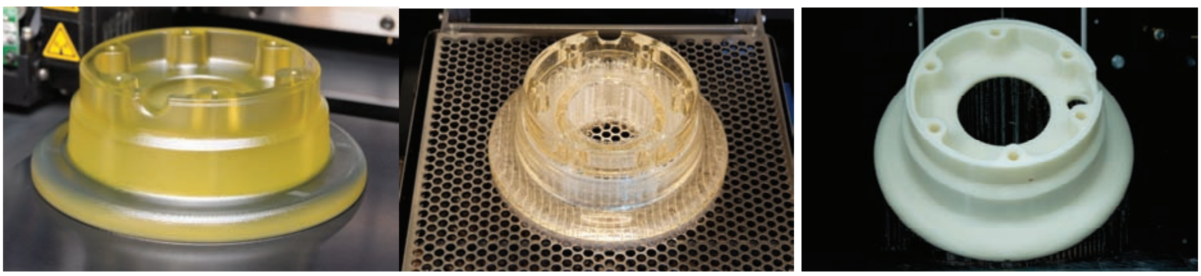
Tab. 1. Summary of basic material data

Parameter	ASTM	Units	FullCure 720	SL5170	ABS Plus
Tensile strength	D-638-03	MPa	60.3	59 - 60	36
Modulus of elasticity	D-638-04	MPa	2870	3737 - 4158	2265
Elongation at break	D-638-05	%	20	8	4
Flexural Strength	D-790-03	MPa	75.8	107 - 108	52
Flexural Modulus	D-790-04	MPa	1718	2920 - 3006	2198
Izod Notched Impact	D-256-06	J/m	23.6	27 - 37	96
HDT, °C @ 0.45MPa	D-648-06	°C	48.4	55	96
HDT, °C @ 1.82MPa	D-648-07	°C	44.4	49	82
Density of the solid state		g/cm³	1.189	1,22	1.04



a) b) c)

Fig. 2. Hub models in the windows of the RP programs: a) JS - Objet Studio, b) SLA - 3DLightyear, c) FDM – QuickSlice

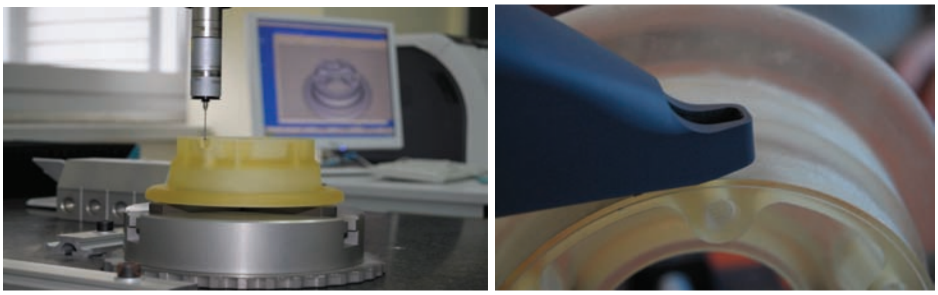


a) b) c)

Fig. 3. Models of aircraft wheel hubs immediately after completion of the RP: a) JS, b) SLA, c) FDM

5. Evaluation of dimensional accuracy and models surface quality

JS, SLA and FDM prototypes of the wheel hub were measured on the WENZEL machine. The starting point for measurement was the export of a solid model to IGES format which provides a database of reference in measuring machine control software. Then placed on a bench in turn prototypes and conducted a number of measurement points on the surface characteristics. The next stage of evaluation of RP models were measurements of surface roughness models using equipment HOMMEL.



a) *b)*

Fig. 3. Evaluation of dimensional accuracy and surface quality models: a) measurements of coordinates, b) measurements of surface roughness

Summary of average values of dimensional accuracy and surface roughness is given in Tab. 2.

Tab. 2. Dimensional accuracy and surface roughness of JS, SLA and FDM models

RP METHOD	DIMENSIONAL ACCURACY (average value)	SURFACE ROUGHNESS (average value)
JS	0.09 mm	10.20 μm
SLA	0.08 mm	1.34 μm
FDM	0.06 mm	17.86 μm

6. The conclusions of the measurements

Analyzed methods are characterized by diverse methods of dimensional accuracy and quality achieved in the process area. Different types of errors, their size and the areas of selection techniques allow for the implementation of the aerial part and studies of its mechanical properties.

- JS - the largest errors (about 0.16 mm) occur in the inner hub area (in places with difficult access of leach material supporting the nozzle) for fitting models of optically active coatings and physical tests.
- SLA - the error is positive, the highest value (about 0.14 mm) is achieved in areas with large radius curves (visible layers), and places the structure of the supporting, tractable material, which allows for high quality surfaces, models for the VC process and for production of optically active coatings.
- FDM – the error is a contraction of up to approximately 0.1 mm, sharp edges are prone to damage (material losses visible), the mechanical treatment is possible after the surface coating due to the heterogeneous, fibrous structure which also prevents the use of silicone molds (VC), models for physical design verification.

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