APPLICATION OF RAPID PROTOTYPING – SLA, FDM – – TO MANUFACTURE MODEL OF AIRCRAFT WHEEL HUB

Romana Ewa Śliwa, Grzegorz Budzik, Jacek Bernaczek

Rzeszow University of Technology
Faculty of Mechanical Engineering and Aeronautics
Powstańców Warszawy Street 8, 35-959 Rzeszow, Poland
tel.: +48 17 8651517, +48 17 8651318, fax: +48 17 8651237, +48 17 8651150
e-mail: rsliwa@prz.edu.pl, gbudzik@prz.edu.pl, jbernacz@prz.edu.pl

Abstract

Implementation of prototypes of the aircraft is a complex process - which requires a series of operations on data preparation, maintenance and inspection of the measuring apparatus.

The development overlooks the stage of design and CAD modelling which is the subject of separate publications, and presents only issues related to the RP process - the SLA and FDM.

Special attention was paid to the need to properly export to CAD models as STL and subsequent analysis of the surface after tessellation (preview generated triangle mesh describing the model).

The process of preparing data in dedicated utility software is a key step for the correct implementation of the prototype aircraft wheel hub. The correct position of the working models on the platform, generated automatically supports editing and verification output files (simulation analysis of overlapping layers) minimizes the risk of damage during the prototyping process itself as well as the subsequent finishing.

The final chapter presents the coordinate measuring of made prototypes that will help identify areas of application methods of RP in the aerospace industry.

Prototype SLA is marred by a higher error than the FDM model but allows for effective finishing operations, which eliminates the geometric errors and significantly improves the quality of the surface.

Keywords: *aircraft wheel hub, rapid prototyping (RP - SLA, FDM), a prototype, coordinate measuring*

1. Introduction

The aviation industry, like any other dynamically developing branch still looking for new technologies to streamline the production, use new materials or cost reductions.

The possibility of a direct transition from the drawing board, we are now advanced CAD systems to produce a physical model rapid prototyping techniques – RP [1, 2, 16].

Using the SLA and FDM prototypes made aircraft wheel hubs advance preparation necessary for the process of numerical data and the technology of production [3-6, 8, 14].

Models were evaluated and the comparative analysis and coordinate measurements were carried out in specific points and planes.

With the models obtained in the physical processes can be carried out to verify the hub structures for the target material which is magnesium alloy, and actually making technology and its subsequent processing [6, 7].

Prototypes will also be used for further research and measurement techniques - moulding, vacuum moulding, elastooptic analysis [10-12].

2. Characteristics of the SLA and FDM methods

Creating a model involves stereolithography liquid resin polymerization (photopolymer) laser beam at a specific wavelength. During the process, the resulting model is placed on the working platform in a tank of liquid resin [5, 13].The need to decouple the model from the platform requires

supporting structures. Technology forces propping up both the entire first layer of the model as well as the angularity of the vertical elements (you can choose the value of the tilt angle for which the object is props), and fragments of the model, for which construction begins on a certain height. Props in the latter case are performed on the first layer on the disc bases, or from previously built portion of the model, located directly under the created element. The resin is hardened layers according to the given cross-section by scanning the laser beam's borders and fills the area inside. The depth of penetration of the laser beam must reach to the previous layer to connect the layers and create a monolithic object. After hardening of one section of the lowering of the thickness of the work platform and made a part of the model, which is in the tank with liquid resin.

FDM method can process a variety of materials, mainly based on a rich range of available plastic and wax, namely: ABS (Acrylonitrile Butadiene Styrene) - used for the prototype hub, ABSi used in biomedical, precision casting wax (WaX-ICW), elastomers, and polyamides on the properties of nylon.

FDM method was chosen for the implementation of a prototype aircraft wheel hub due to the high accuracy, relatively short lead time, a satisfactory surface quality and strength (ABS).

3. Develop data for rapid prototyping

Creating models of the air requires the use of sophisticated CAD systems with hybrid modelling capabilities. Model aircraft wheel hubs were made using SolidWorks (Fig. 1). Complex shapes can be made using the surface modelling options. The creation of physical prototypes and export data into a format CNC machines and RP model requires a transformation of the surface or edge in the CAD solid model [9, 15]. An important step in preparing the numerical data for RP processes is the analysis of 3D-CAD model in order to avoid geometric errors and the proper export STL file [3, 8].

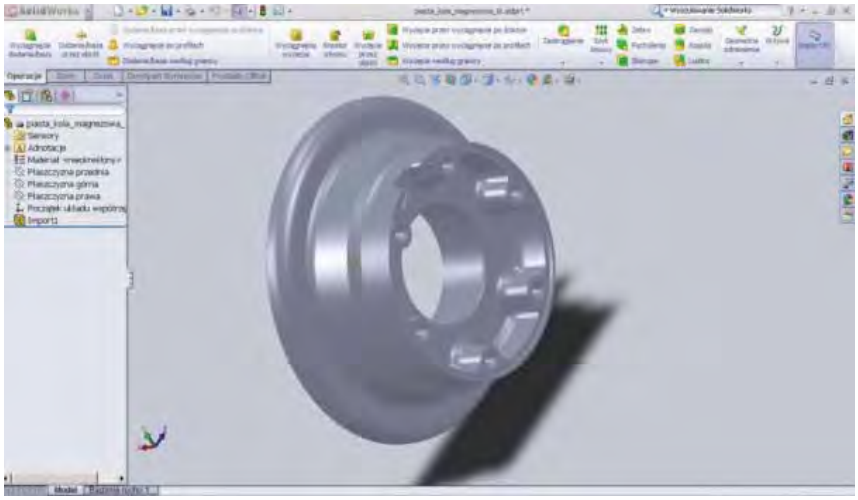

Fig. 1. Solid model of the aircraft wheel hub

The SLA and FDM analyzed the processes to implement model of the hub model saved in *.stl (Standard Triangulation Language). In order to give an accurate physical model provided a high rate of accuracy of approximation when exporting the model to the STL format [4, 17].

4. Prepare and carry out processes RP of the aircraft wheel hub model

4.1. The process of SLA

With a properly generated STL files, you can begin preparing for the SLA. STL model must be checked using the program 3DLightyear (Fig. 2). You can at this stage to fix any errors. Leaving the wrong model for the process resulting in damage to the SLA prototype.

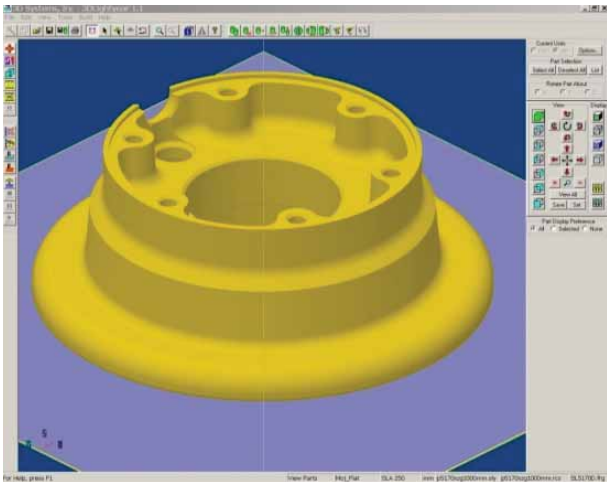

Fig. 2. Import STL model and verification hub to the working platform

Revised model should be "supported" by using the automatic generation of algorithms offered by the structure of supporting software. Once generated, the structure of supporting it should be analyzed and possible editing. The package generated files to be exported to a computer that supports controllers coupled with the SLA apparatus [13].

After preparing the machine starts the process stereolithography (Fig. 3).

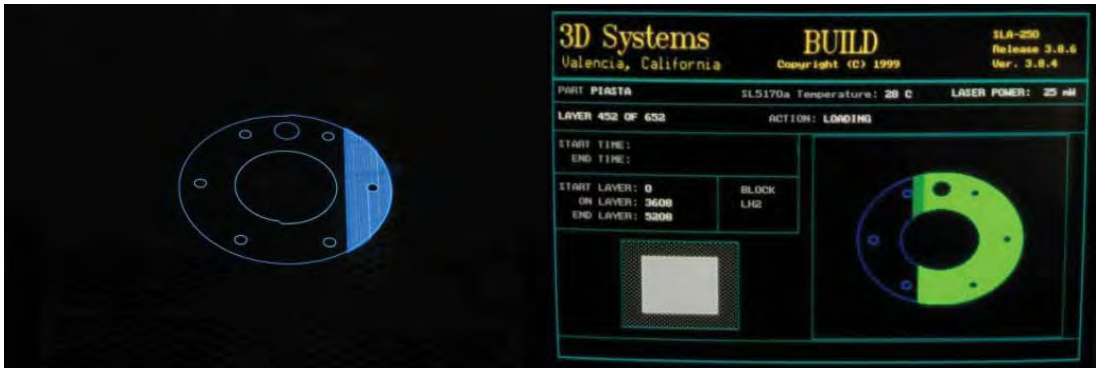

Fig. 3. Laser beam irradiation of the resin (Photopolymerization layer model)

The creation of the prototype aircraft wheel hub in the apparatus SLA250/50 lasted 33 hours. After completion of the working platform was removed from the chamber of the apparatus and began the process of post-processing model, consisting of isolation of the platform, removed and cleaned, supports the model of chemically and physically. After this process we get ready model (Fig. 4).

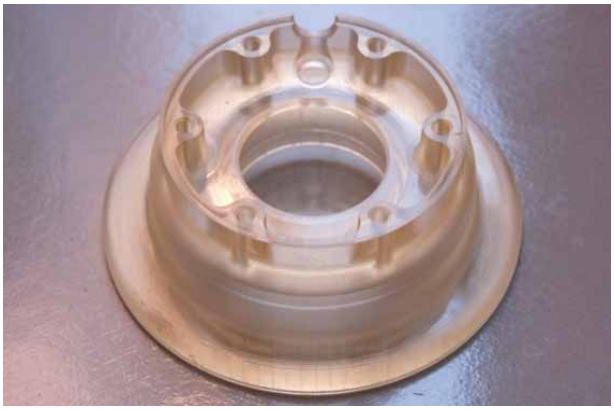

Fig. 4. Prototype SLA after UV irradiation (prepared for the final stage of cleaning and polishing the surface)

4.2. Implementation of FDM process

Another of the carried out rapid prototyping methods for aircraft wheel hub is the modelling of liquid plastic - FDM.

As in the case stereolithography, a key step to a properly FDM conducted trial is appropriate STL model and the analysis of numerical data generated for the machine uPrint in dedicated software QuickSlice by the manufacturer.

After importing the model hub for the work platform should be properly set it relative to a frame of reference.

Unfortunately the dimensions of the model go beyond the limits inside of the machine, forcing a different way of setting the hub - it is necessary to tilt angle of 45 degrees to the XY plane (Fig. 5).

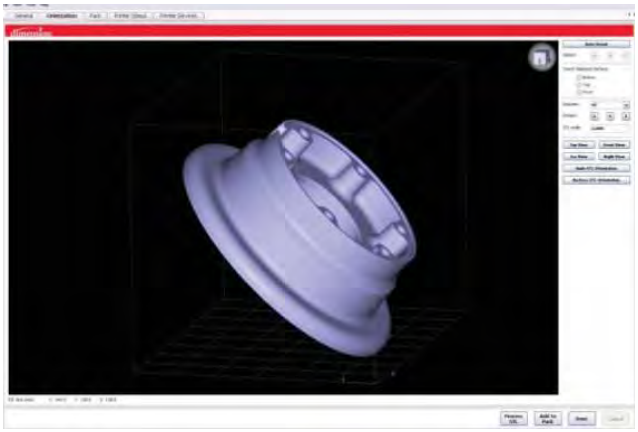

Fig. 5. Setting the hub model at 45 degrees to the XY

After making sure that the position of the model is optimal and feasible in the planned process, you can proceed to generate the structure of supporting.

Before the export of data to the apparatus is analyzed individual layers - there is a risk of incorrectly converted layers which can cause damage to the prototype. In case of errors it is necessary to re-treatment program model.

Properly developed process can be started - the export of data to the machine.

In Fig. 6a see a working chamber apparatus uPrint impose another layer of the hub model.

a) b)

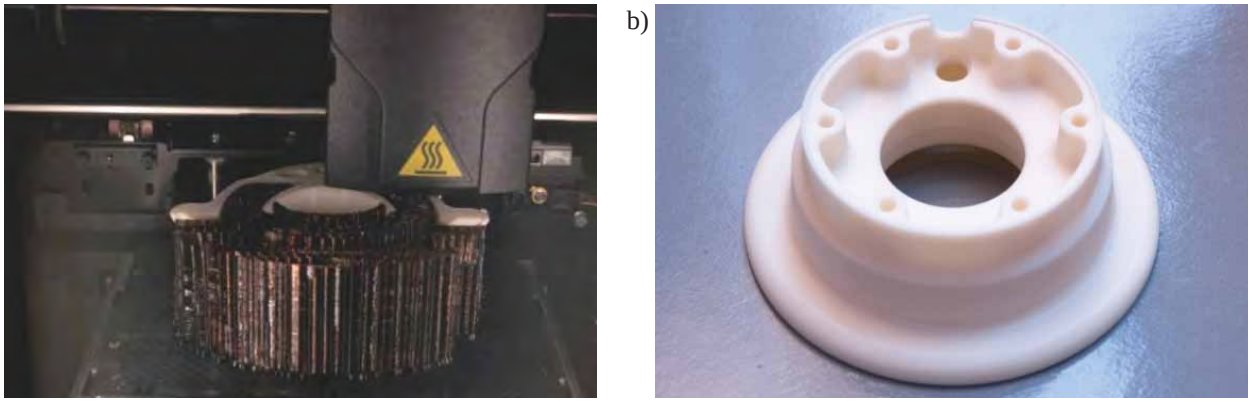

Fig. 6. The process of FDM: a) Imposing another layer of the hub model in the chamber apparatus uPrint, b) FDM prototype aircraft wheel hub after ultrasonic bath

Implementation of a prototype aircraft wheel hub in the FDM machine took 30 hours.

After completion of the work platform pulls the machine chamber, and the model together with a supporting structure is separated from the base model and pre-cleans the loose supports. Then

a prototype glued together with hard (difficult to mechanically remove) supports immersed in an aqueous solution of a special detergent in an ultrasonic cleaner. After an hour an ultrasonic bath, all props have been dissolved - the hub model is rinsed under running water and dry.

5. Coordinate measuring models FDM and SLA aircraft wheel hub

Made SLA and FDM prototypes aircraft wheel hub were measured on the Wenzel machine.

The starting point for measurements was the export hub for the solid model format IGES, which provides a database of reference in measuring machine control software.

Then placed on a bench prototype sequence (Fig. 7) and carried out a number of measurement points on the surface characteristics.

a) b)

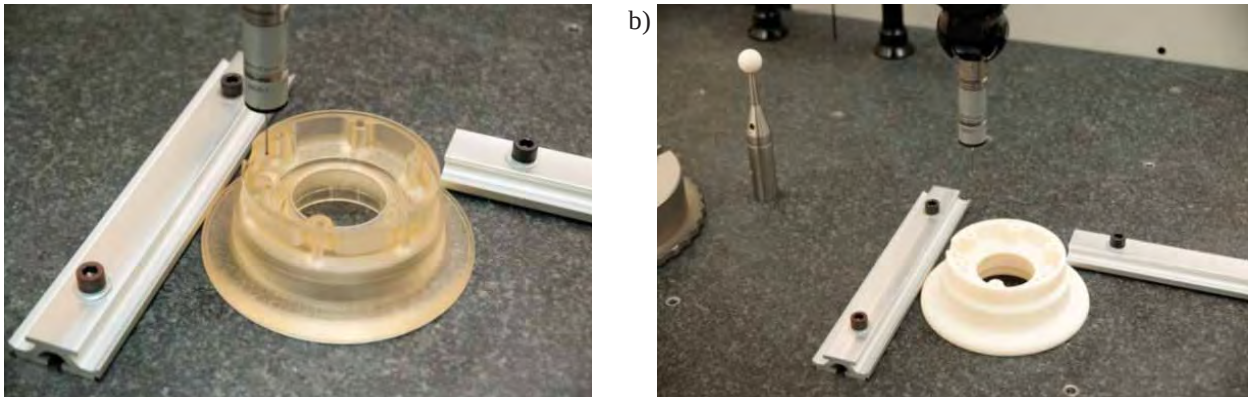

Fig. 7. Coordinate measuring prototypes wheel hub plane: a) SLA, b) FDM

Analysis of test reports (Fig. 8) reveals that there are errors in the case of negative FDM prototype and positive for SLA.

The absolute size of the recorded amendment indicates the clear advantage of FDM technology. However, please note that we are dealing with the shrinkage is difficult to overcome in the finishing treatment - will be necessary filling model.

However, positive patch SLA prototype is the result of residues of supporting structure, and side “steps” layers, easy to remove when grinding and polishing the final.

Characteristic surface damage FDM prototype arose as a result of setting it in terms relative to the base model.

However, significant deterioration of the surface of the simply supported model of SLA is the result of supporting the application of a dense structure needed to maintain the prototype of the large size and weight.

6. Conclusions

Rapid Prototyping Technology is a key step in the initial phase of product life cycle in the aerospace industry. Implementation of prototypes of the aircraft components is a complex process - which requires a series of operations on data preparation, maintenance and inspection of the measuring apparatus.

The techniques SLA and FDM, allow the execution of very accurate models that will allow construction of a physical check of the aircraft wheel hub for the applicability of the target material and the development of production technology.

Special attention was paid to the need to properly export to CAD models as STL and subsequent analysis of the surface after tessellation (preview generated triangle mesh describing the model).

The process of preparing data in dedicated utility software is very important for the correct implementation of the prototype aircraft wheel hub. The correct position of models on the platform,

Fig. 8. Reports measuring models of wheel hub plane: a) SLA, b) FDM

generated automatically supports editing and verification output files (simulation analysis of overlapping layers) minimizes the risk of damage during the prototyping process itself as well as the subsequent finishing.

The coordinate measuring of made prototypes, which helped to determine the suitability of the RP methods used in implementations of the industrial elements of aircraft structures.

Although the SLA has increased the amendment - but this is an error positive (thickening of the supports) is easy to correct in the post processing.

In the case of FDM is necessary to examine the possibility of compensation (called offsets) at the CAD modelling for this method.

Coordinate measurements permit adequate finishing preparing prototypes for the next phase of research.

Acknowledgments

Financial support of Structural Funds in the Operational Programme - Innovative Economy (IE OP) financed from the European Regional Development Fund - Project "Modern material technologies in aerospace industry", Nr POIG.01.01.02-00-015/08-00 is gratefully acknowledged.

Reference

[1] Horvath, I., Yang, D., *Rapid technologies: solutions for today and tomorrow*, Computer Aided Design, Vol. 34, pp. 679-682, Elsevier 2002.
[2] Gebhardt, A., *Rapid Prototyping*, Carl Hanser Verlag, Munich 2003.
[3] Stroud, I., Xirouchakis, P., *STL and extensions*, Advances in Engineering Software, Vol. 31, pp. 83-95, Elsevier 2000.
[4] Lee, S., Kim, H., Hur, S., Yang, D. *STL file generation from measured point data by segmentation and Delaunay triangulation*, Computer Aided Design, Vol. 34, pp. 691-704, Elsevier 2002.
[5] Nee, A., Fuh, J., Miyazawa, T., *On the improvement of the stereolithography (SL) processs* , Journal of Materials Processing Technology, Vol. 113, pp. 262-268, Elsevier 2001.
[6] Bernard, A., *Rapid product development case studies and data integration analysis*, Computers in Industry, Vol. 43, pp. 161-172, Elsevier 2000.
[7] Bullinger, H. J., Warschat, J., Fischer, D., *Rapid product development — an overview*, Computers in Industry, Vol. 42, pp. 99-108, Elsevier 2002.
[8] Budzik, G., Sobolak, M., *Generating Stereolitographic (STL) Files from CAD Systems* , Acta Mechanica Slovaca, 2B/2006 PRO-TECH-MA, Kosice 2006.
[9] Chlebus, E., *Techniki komputerowe CAx w in żynierii produkcji*, Wydawnictwa Naukowo-Techniczne WNT, Warszawa 2000.
[10] Chlebus, E., *Innowacyjne technologie Rapid prototyping – Rapid Tooling w rozwoju produktu* , Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław 2003.
[11] Budzik, G., Kozdęba, D., Sobolak, M., *Wykorzystanie technologii Rapid Prototyping w odlewnictwie precyzyjnym*, Archiwum Odlewnictwa, No. 18 (2/2), pp. 207-212, Katowice 2006.
[12] Kopecki, H., *Problemy analizy stanów naprężenia ustrojów w świetle badań eksperymentalnych metodami mechaniki modelowej*, Zeszyty Naukowe Politechniki Rzeszowskiej, No. 78, Mechanika, z. 26, Rzeszów 1992.
[13] 3D Lightyear SLA File Preparation Software – User's Guide 2001.
[14] Budzik, G., Markowski, T., *Kryteria doboru metody szybkiego wytwarzania kó ł zębatych*, XXIV Sympozjon PKM, Białystok – Białowieża 2009.
[15] Budzik, G., Markowski, T., Sobolak, M., *Hybryd foundry patterns of bevel gears*, Archives of Foundry Engineering, Vol. 7, Iss. 1, pp. 131-134, 2007.
[16] Liu, W. F., *Rapid Prototyping and engineering applications – a toolbox for prototype development*, Taylor & Francis Group, Boca Raton, USA 2008.
[17] Budzik, G., *Odwzorowanie powierzchni krzywoliniowej łopatek części gorącej silników lotniczych w procesie szybkiego prototypowania*, Oficyna Wydawnicza Politechniki Rzeszowskiej, Rzeszów 2009.