RAPID PROTOTYPING PROCESS OF MONOCRYSTAL AIRCRAFT ENGINE BLADES

Grzegorz Budzik

Rzeszow University of Technology
Faculty of Mechanical Engineering and Aeronautics, Department of Machine Design
Powstańców Warszawy Av. 8, 35-959 Rzeszów, Poland
e-mail: gbudzik@prz.edu.pl

Hubert Matysiak

Research Centre "Functional Materials" at Warsaw University of Technology
Warsaw University of Technology, Poland
e-mail: hmatysia@inmat.pw.edu.pl

Rafał Cygan, Stanisław Bąk

WSK PZL Rzeszów
Hetmańska 120, 35-959 Rzeszów, Poland
e-mail: rafal.cygan@wskrz.com, stanislaw.bak@wskrz.com

Mariusz Cygnar

State Higher Professional School in Nowy Sącz
Staszica Street 1, 33-300 Nowy Sącz, Poland
e-mail: mcygnar@pwsz-ns.edu.pl

Abstract

The article presents process application of the rapid prototyping (RP) for manufacturing of blades of aircraft turbine in mono- crystallization and also directional crystallization of casting process. It is describing the method of modelling of the chosen elements of casting model kit with the usage of RP and RT systems. The article presents the analysis of additive rapid prototyping methods (stereolithography) in an aspect of manufacturing of casting models. The possibilities of RP system usage to the ceramic form were the main criteria of the analysis. The ceramic form is a one of the parts of process casting of monocrystal blade of aircraft engine. In the article the possibilities making of models by means of rapid tooling system based on the Vacuum Casting (VC) technology were also analysed. The Vacuum Casting technology allows producing the silicone mold under decreasing pressure. Silicone tools allow creating wax casting models as a vacuum casting process, casting process and low pressure of injection. Rapid prototyping and rapid tooling technologies allow creating casting wax models of a blade and other parts of casting models. RP and RT methods allow creating connectors of the parts. These connectors allow connecting the parts of model kit in a fast and simple method. The stereolithography and Vacuum Casting allow accelerating process of manufacturing of monocrystal blades of aircraft engines.

Keywords: *Rapid Prototyping, monocrystal, aircraft engine, blades*

1. Introduction

The manufacturing of blades of aircraft engines [10, 11] can be realised with the application methods of rapid prototyping methods on chosen stages of technological process [1, 9].

The rapid prototyping of casting models of blades is based on three-dimensional models manufactured in 3D-CAD systems having options of surficial and lump modelling. It is necessary to transform data describing three-dimensional digital model in the program way to possible form for reading by systems of rapid prototyping (e.g. format STL). Software of devices RP transforms three-dimensional model 3D-RP on set of layers from which the physical prototype is produced [2, 4, 5].

In this article the main stages of process of the rapid prototyping of elements of model kits were presented to manufacturing of ceramic forms applied to the production of monocrystal blades of aircraft engines. In this case process of rapid prototyping consists with the following stages: manufacturing of 3D-CAD model, program processing and preparation of data to process of manufacturing 3D-RP, manufacturing of the physical models. The additive method RP – stereolithography was applied to the production of base prototypes (so-called masters). The opinion of possibilities manufacturing of casting models was carried out by means of one of methods Rapid Tooling based on technology Vacuum Casting (VC). This technology concerns manufacturing of tools (matrices or silicone forms) and also prototypes under lowered pressure in the vacuum chamber. Tools of this type enable on production of the wax casting models [1, 5].

2. Manufacturing of 3D-CAD and 3D-STL models

Modelling of turbine's blades of aircraft engines needs application of 3D-CAD systems having possibilities of surficial and lump modelling (CATIA, UGS-NX, Mechanical Desktop, SolidEdge, ProEngineer etc.). The complex shape of blade's plume can be exactly made with application of option of surficial modelling. The production of the physical prototype and the export of data to format of devices RP need transformation of surficial model in lump model [8]. Fig. 1 presents 3D-CAD lump models of initiator and blade of aircraft engines.

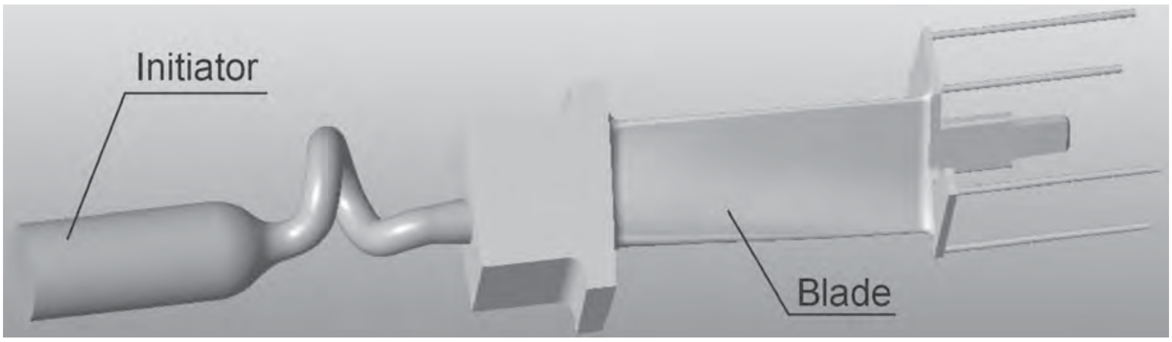

Fig. 1. Model CAD of blade and also initiator

The 3D-CAD lump model is necessary to write in form of data read by means of software of devices of rapid prototyping. Format STL is the widest applied format of writing and reading of data in RP systems [7]. Fig. 2 presents 3D-RP models of initiator and blade of aircraft engine written in format STL.

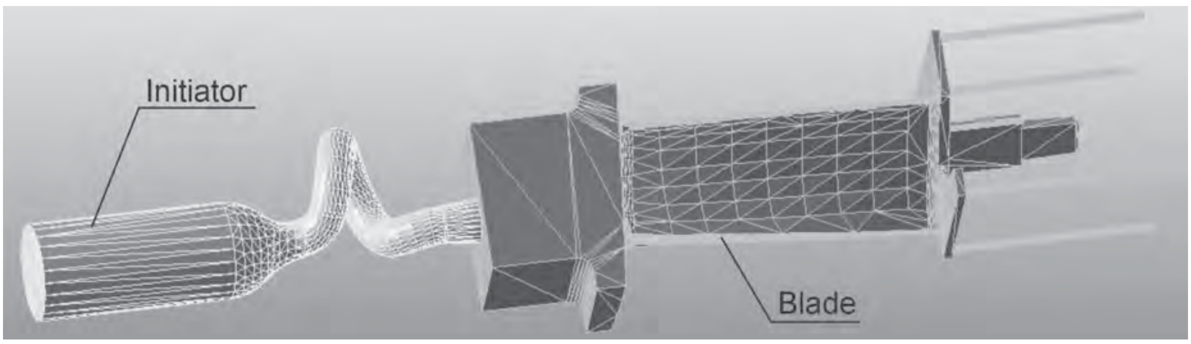

Fig. 2. Model STL of blade and also initiator

Format STL describes surface of 3D-CAD model by means of triangles' grid. Format STL enables in simple way to transform 3D-CAD model, and next to submit him successive processing and the final distribution on layers. The presented format became standard in almost all RP/RT techniques as a result of increasing application of him and also is used in systems of reverse engineering as well as methods of finite elements (MES) [7, 9].

3. Manufacturing of blades' prototypes by means of method stereolithography

Stereolithography (SLA) is one with the methods of rapid prototyping. Above all the most important advantages methods are: large repeatability, the precision of creation model and also possibility of the creation of complex internal and external structure. From this reason, if is necessary manufacturing of elements about large degree of precision – blades of aircraft engines stereolithography will be particularly useful [2].

The creation of stereolihtographic model is based on the liquid polymerization of (photo-hardenable) resin by means of laser's bundle. During of process produced model is put on working platform in the container with the liquid resin. After finishing platform together with put on her models is raised above the mirror of liquid resin. Fig. 3 presents stereolithographic prototypes of model system.

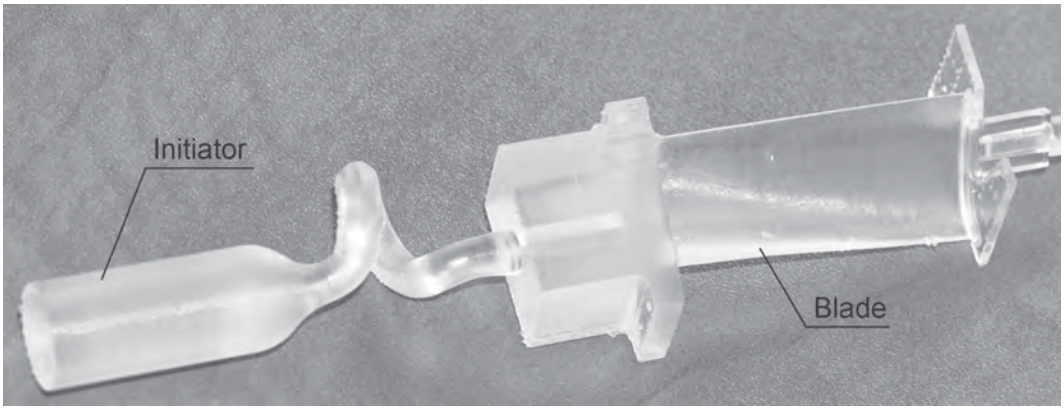

Fig. 3. Model SLA of blade and also initiator

Next finishing processing – so-called Post Processing – contains removal of supports, washing of model in the acetone or isopropanol and also additional irradiation light UV in purpose of completion of polymerization in whole model's capacity [6].

4. Manufacturing of the wax models of blades' models in silicone matrices

The Rapid prototyping of casting models of blade in silicone matrices belong to indirect methods RP relying on application of technique Rapid Tooling (RT) i.e. silicone matrices in technology Vacuum Casting (VC). Manufacturing of silicone mold contains the next stages:

- preparation of the pattern model (e.g. JS, SLS, SLA, FDM, 3DP),
- making of mold's construction and model system,
- preparation of mold's casing and filling of him by means of silicone,
- thermal processing of mold,
- gash of mold and the removal of model system [2].

Silicone matrices enable on manufacturing of casting models from polymer resins and also casting waxes. Fig. 4 presents silicone mold (Fig. 4a) produced on the basis of model kit (Fig. 4b). Model kit consists from model of blade manufactured by means of stereolithography method and also the channel leading liquid wax to form. The leading channel is connected in the bottom part to model of blade what enable correct course of process of filling of mold.

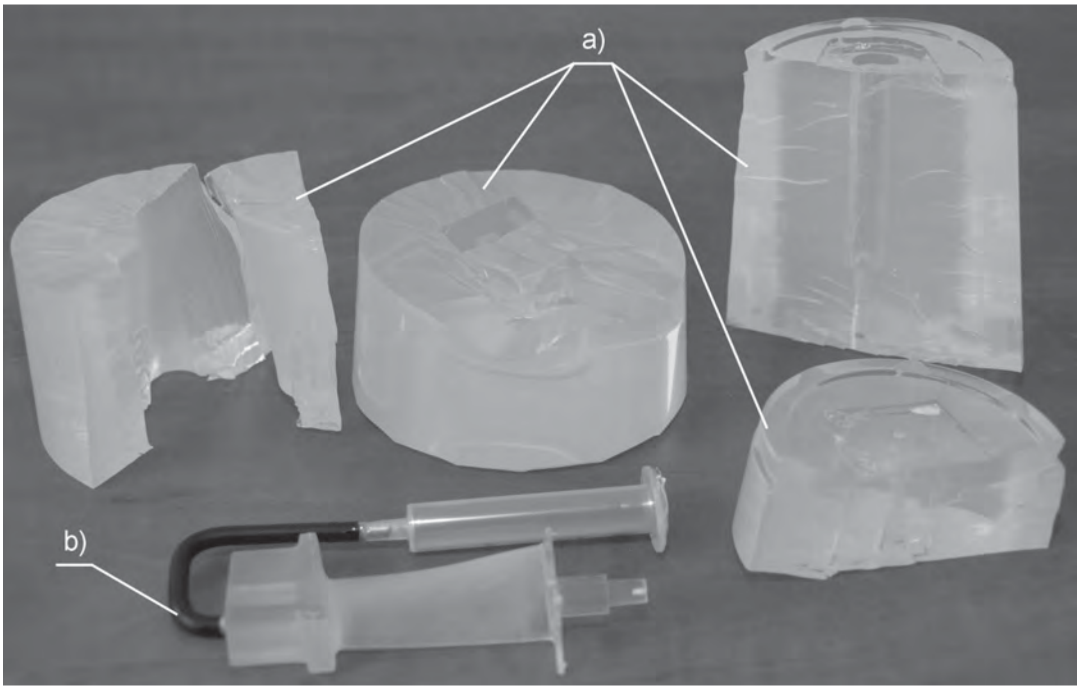

Fig. 4. Silicone mold (a) manufactured on the basis model kit (b)

To manufacturing of models of blades were applied different kinds of waxes used in serial production to production of elements of model system in process of the n injection to metal matrices. Application of this type waxes needed determining of parameters of technological process of manufacturing wax models in silicone tools. These parameters were determined on research way [3]. Fig. 5 presents wax models of blade and initiator made in silicone mold from modelling wax A7FR/60 of the firm BLAYSON.

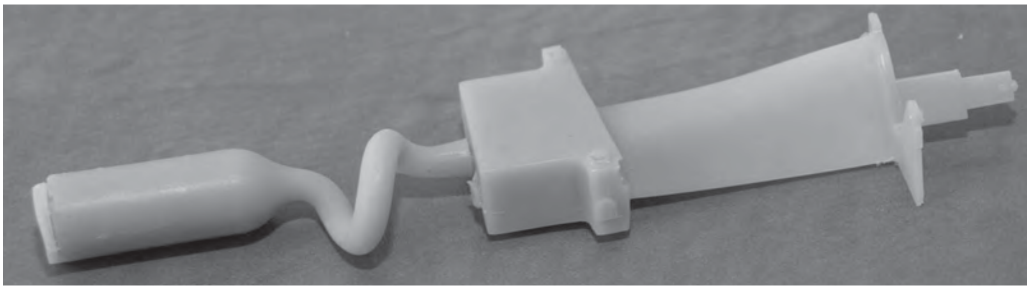

Fig. 5. Model kit from casting wax

Wax models of blades as well as remaining elements of model system were made with application of technique RP and also traditional technologies of injection were connected in model system (Fig. 6a). On this basis ceramic forms were made, put next in casting chamber (Fig. 6b). After finishing of processes of casting and mono-crystallization (Fig. 6c), forms were broken and blades initially cleaned (Fig. 6d).

4. Conclusions

Technologies of rapid prototyping enable on manufacturing of elements of model kits for ceramic casting forms. Prototypes of elements of model system were produced by means of stereolitography's method need application of special ceramic construction of casting form as well as special process of removal of models. It is caused as a result of course of removal's process of model produced from epoxy and polyester resins from ceramic form. During of such process large of gasses is created, and which pressure often causes damage of forms. It is possible to prevent this as a result of application of indirect method of rapid prototyping based on rapid manufacturing of tools (silicone matrices), in which next wax casting models are manufactured.

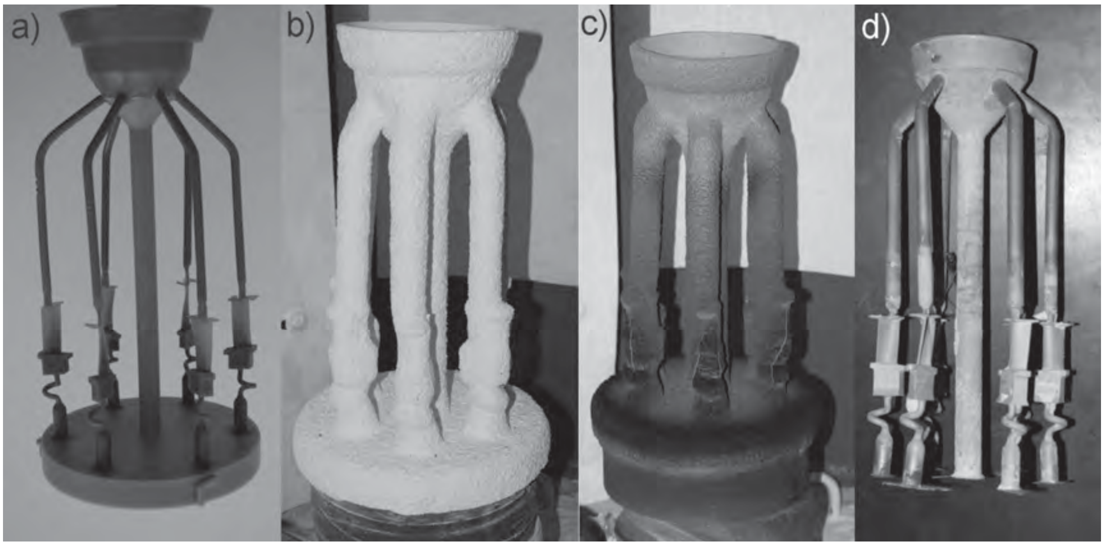

Fig. 6. Application of wax models to manufacturing of monocrystal blades: a) wax model kit, b) ceramic form before casting, c) form in the stove after casting, d) monocrystal blades

Application of combination of methods Rapid Prototyping and Rapid Tooling enable on achievement of casting models of blades of aircraft engines and also remaining elements of model system. These methods enable also on suitable form of connections of respective of elements of model kit, what enables acceleration of process of preparation of casting forms and in this way made monocrystal casts of blades of aircraft engines.

References

[1] Budzik, G., *Possibilities of Using Vacuum Casting Process for Manufacturing Cast Models of Turbocharger Impeller*, Journal of KONES Powertrain and Transport, Vol. 14, No. 3, pp. 125-130, Warszawa 2007.

[2] Budzik, G., *Synteza i analiza metod projektow ania i wytw arzania prototypów elementów o skomplikowanych kształtach na przykładzie wirników turbosprężarek*, Oficyna Wydawnicza Politechniki Rzeszowskiej, Rzeszów 2007.

[3] Budzik, G., *The analysis of the possibility of the application of the casting waxes in the process RP*, Archives of Foundry Engineering, Vol. 9, No. 2, pp. 133-136, 2009.

[4] Budzik, G., Cygnar, M., Sobolak, M., *Analiza dokładności geometrycznej metody stereolitografii*, Prace Naukowe Instytutu Technicznego PWSZ w Nowym Sączu, PWSZ, Nowy Sącz 2004.

[5] Budzik, G., Kozdęba, D., Sobolak, M., *Wykorzystanie technologii Rapid P rototyping w odlewnictwie precyzyjnym*, Archiwum Odlewnictwa, PAN o/Katowice, Komisja Odlewnictwa, Nr 18 (2/2), , s. 207-212, Katowice 2006.

[6] Budzik, G., Markowski, T., Sobolak, M., *Metody zwiększenia dokładności prototypów wykonywanych wybranymi technikami RP* , Projektowanie procesów technologicznych TPP 2006, Komisja Budowy Maszyn PAN O/Poznań, s. 65-70, Poznań 2006.

[7] Budzik, G., Sobolak, M., *Generating stereolithographic (STL) files from CAD systems*. Acta Mechanica Slovaca, 2B/2006 PRO-TECH-MA, pp. 73-78, Košice 2006.

[8] Cygnar, M., Budzik, G., *Wybrane aspekty projektowania elementów wiruj ących maszyn przepływowych z wykorzystaniem wspomagania komputerowego* , Wydawnictwo Państwowej Wyższej Szkoły Zawodowej w Nowym Sączu, Nowy Sącz 2005.

[9] Liu, W., *Rapid Prototyping and engineering applications - a toolbox for prototype development*, Taylor & Francis Group, 2008.
[10] Matysiak, H., Michalski, J., Cwajna, J., Sikorski, K., Kurzydłowski, K. J., *Wady powierzchniowe w precyzyjnych odlewach krytycznych elementów silników lotniczych wykonanych z nadstopów niklu IN 713C*, Innowacje w odlewnictwie, Część I (red. J. Sobczak), Instytut Odlewnictwa w Krakowie, s. 73-79, Kraków 2007.
[11] Sieniawski, J., *Kryteria i sposoby oceny materiałów na elementy lotniczych silników turbinowych*, Oficyna Wydawnicza Politechniki Rzeszowskiej, Rzeszów 1995.

The present study was financed from resources of MNiSzW as part of the PBZ-MNiSW-03/I/2007 project.