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HYBRID METHOD FOR RAPID PROTOTYPING OF CORE MODELS OF AIRCRAFT ENGINE BLADES

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Abstract

The paper presents the possibility of using CAD/RP for the design and manufacture of the core models used for precise casting of core aircraft engine turbine blades, with directional crystallization process and single crystallization.

The process of modelling 3D CAD geometry of research blade in relation to the model of the core was presented. The sample design, blade base model, was made by one of the incremental method of rapid prototyping - Jetting System. The geometry of the blade model has been designed in a way, which allows making a silicon form on the basis of a base prototype in the process of rapid prototyping tools (Rapid Tooling).

The form allows the attachment of the blade core in a place designed specifically for this purpose. The silicon form has enabled the production of wax models with the inner core. This task was achieved by proper shaping of forms with the plane of its division.

The resulting models were used to make ceramic moulds and carry further work on the development of casting technology in the process of directional crystallization and single crystallization of core blades of aircraft engines.

Keywords*: engine blades, precise casting, rapid prototyping, directional crystallization*

1. Introduction

Modern aircraft engines are equipped with a turbine, which blades are exposed to high temperatures. Increasing engine performance is associated with temperature increases of the turbine. Once the barrier to raise the temperature of turbine components are the material parameters of the hot engine. It is possible to use cooling turbine blades by means of internal cooling channels. Preparation of this type of blades in the process of precision casting requires special models with inner cores (Fig. 1).

The manufacturing of blades of aircraft engines [10, 11] can be realized 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 – PolyJet 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].

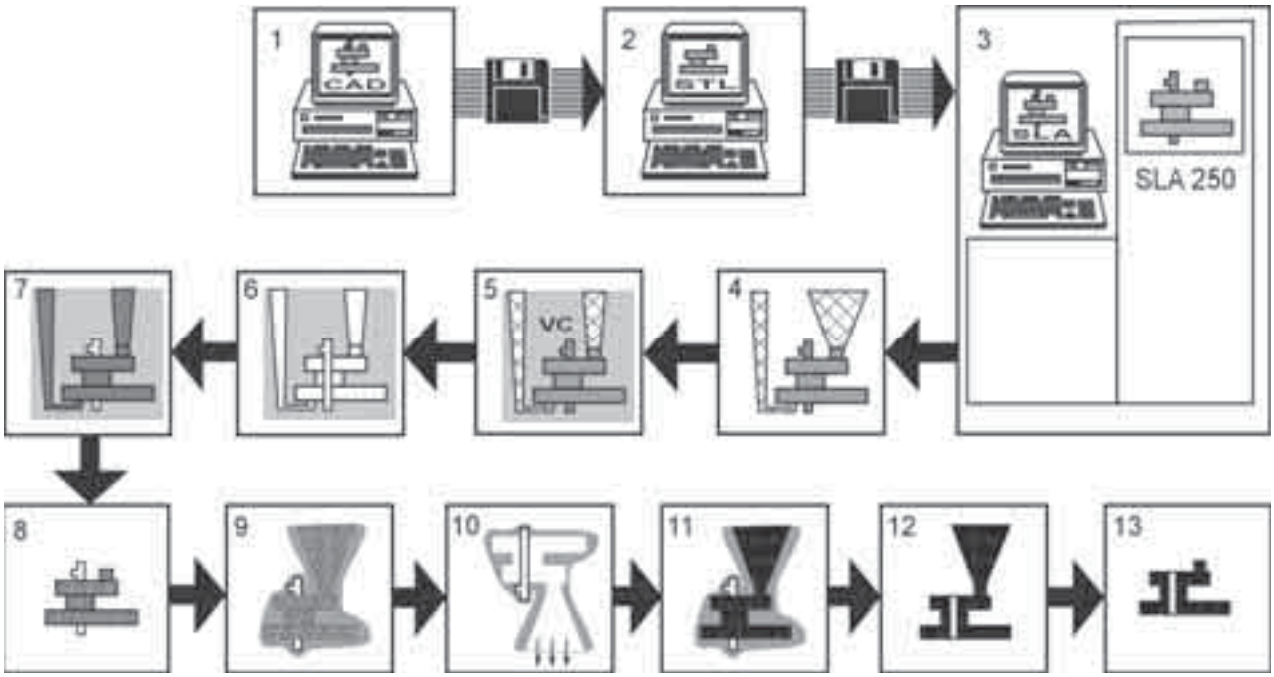

Fig. 1. Schema of application of RP techniques for precision casting core models using a hybrid RP/ RT process: 1-CAD model, 2-processing of the STL format, 2-SLA model, 4-model kit manufacturing, 5-silicon mould, 6-cut of the silicone mould, 7-insertion of the core and making wax model, 8-drawn wax model, 9-execution shell mould, 10-removing wax model of the form, 11-performance cast, 12-deletion form and core, 13-provender casting finishing

2. Manufacturing of 3D-CAD/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, MDT, SolidEdge 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 geometrical model [8]. Fig. 2 presents 3D-CAD models of core blade of aircraft engines (Fig. 2a) and tested core cylinder model (Fig. 2b).

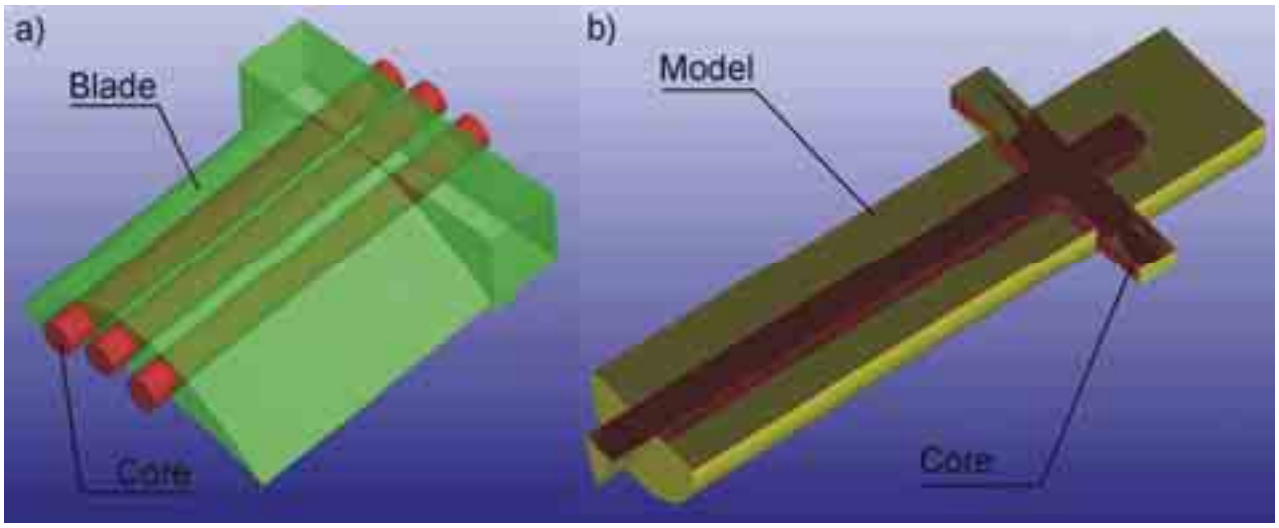

Fig. 2. The 3D-CAD prototype of core model: a) blade, b) test cylinder

3. Manufacturing casting model by means of RP/RT method

PolyJet 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 PolyJet will be particularly useful [2].

The creation of PolyJet model is based on the liquid polymerization of (photo-hardenable) resin by means of UV lamp. Fig. 3 presents PolyJet prototypes of master models.

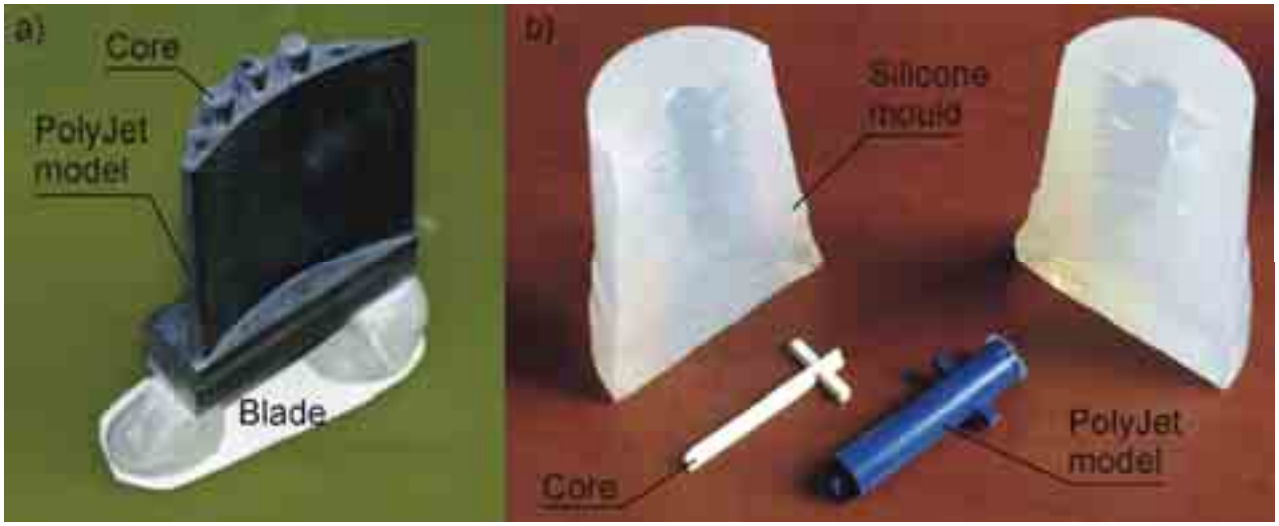

Fig. 3. PolyJet model of core blade (a), PolyJet model and core and silicone mould (b)

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 mould contains the next stages:

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

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. Silicone matrices enable on manufacturing of casting models from polymer resins and also casting waxes. Fig. 4 and 5 present silicone mould produced on the basis of model kit. Model kit consists from model of blade manufactured by means of PolyJet method and also the channel leading liquid wax to form (Fig. 5). The leading channel is connected in the bottom part to model of blade what enable correct course of process of filling of mould.

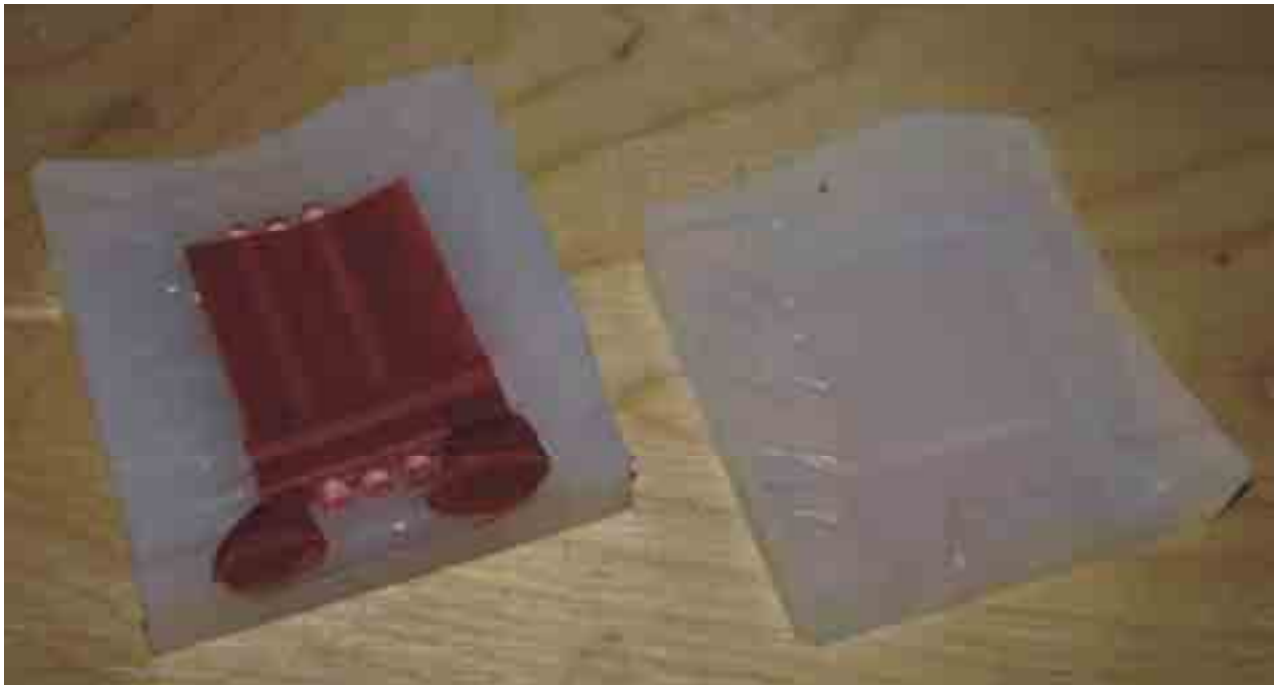

Fig. 4. Wax model of core blade and silicone mould

Fig. 5. Silicone mould pouring cylinder core wax model

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. 4 and 5 presents also wax model of blade and cylinder model made in silicone mould from modelling wax A7FR/60 of the firm BLAYSON.

Wax models of blades as well as remaining elements of model system were made with application

of technique RP and also traditional technology of injection was connected in model system (Fig. 6a). On this basis ceramic forms were made (Fig. 6b), put next in casting chamber. After finishing of process of casting and mono-crystallization, forms were broken and cast parts initially cleaned (Fig. 6c).

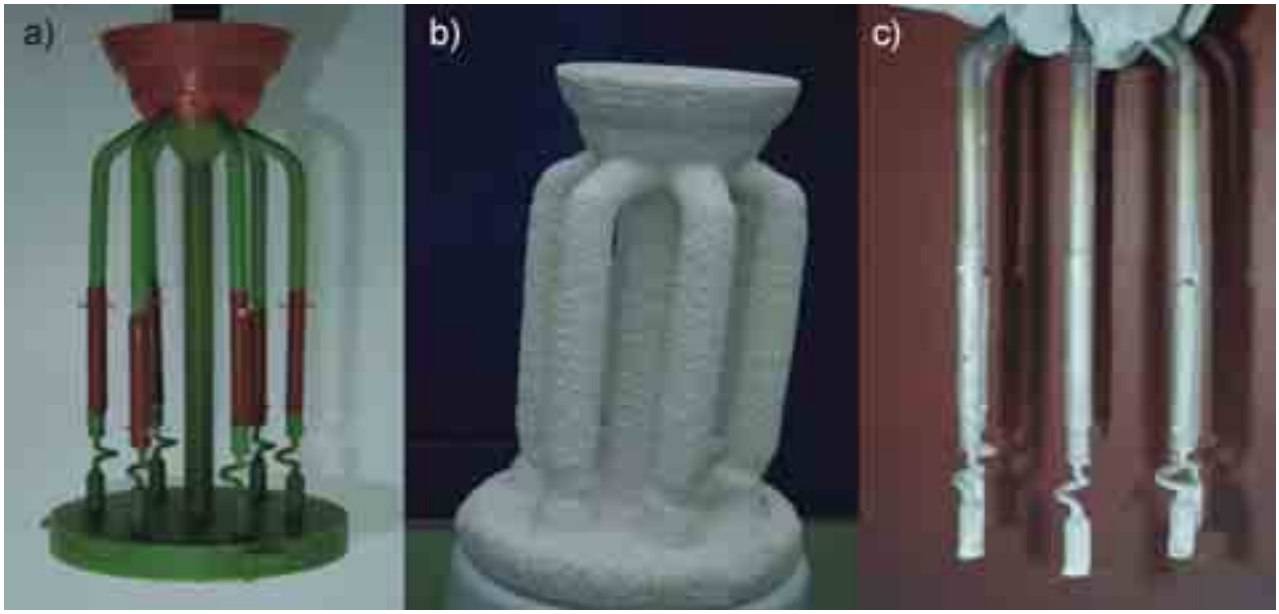

Fig. 6. Photographs subsequent manufacturing steps of casting core models: a) set a model, b) casting mould, c) cast parts (test core cylinders)

4. Conclusions

Technologies of rapid prototyping enable on manufacturing of elements of model kits for core ceramic casting forms. Prototypes of elements of model system were produced by means of PolyJet 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.

Application of combination of methods Rapid Prototyping and Rapid Tooling - hybrid methods - enable on achievement of casting core 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 singlecrystal casts of blades of aircraft engines.

Acknowledgement

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