

POSSIBILITIES OF USING VACUUM CASTING PROCESS FOR MANUFACTURING CAST MODELS OF TURBOCHARGER IMPELLERS

Grzegorz Budzik

Rzeszów University of Technology
Faculty of Mechanical Engineering and Aeronautic
Al. Powstańców Warszawy 8, 35-959 Rzeszów, Poland
tel.: +48 17 8651642, fax: +48 17 8651150
e-mail: gbudzik@prz.edu.pl, amarc@prz.edu.pl

Abstract

Possibilities of producing cast models of turbocompressor impellers in silicon matrices by vacuum casting process are presented. Vacuum casting process enables producing cast models of impellers for precision casting. A standard model for silicon matrix making is a prototype produced with stereo lithography technique. The advantage of stereo lithographic model is its easy machinability that enables higher quality of impeller model surface. Silicon matrices enable casting of prototype models from foundry plastics, such as: casting wax, polyurethanes, polyester and epoxy resins. Properties of the plastic material used determine the shape of die parting. Because of its low strength, casting wax enforces die parting into a larger number of elements, thus enabling to pull it out without damage. The prototypes made from casting resins require considerably fewer parting surfaces. Silicon matrices enable to manufacture from several to several dozen cast patterns of prototype turbocharger impellers. The basic advantage of vacuum casting process is the shortening of prototype making time and cost, compared to traditional methods. The silicon matrixes permit casting and low-pressure injections of plastics. Some plastics may be used for producing foundry patterns for various metal alloy casting processes.

Keywords: turbocharger impeller, rapid prototyping systems, Vacuum Casting

1. Introduction

Making of prototypes in silicon moulds by Vacuum Casting (VC) is counted among indirect Rapid Tooling (RT) techniques [6]. In that method the silicon mold or matrix is produced on the basis of base models and reflects the prototype geometry through a negative [3]. The base model may be produced with Rapid Prototyping techniques [10]. The silicon mold is a tool that serves for producing elements of plastics (polyester resins, epoxy polyurethanes) and plastic composites, including nano-composites [4]. Molds made of silicones that have higher resistance to high temperatures may serve for producing single castings of nonferrous metals. Silicon may also be utilized for producing matrices for wax patterns for precision casting [5].

Processing tools of silicon are suitable for making short series, from several to several dozen, of products [2].

Depending on the type of molded material, prototypes may be produced in silicon molds through:

- gravitational casting at ambient pressure,
- vacuum casting,
- low-pressure injection with mechanical piston.

2. Silicon matrix creation process

The process of making silicon matrix, cavity or mold consists of the following stages:

- a) Preparing of master model/pattern with Rapid Prototyping (RP) method [1, 7, 8, 9, 11],

- b) Preparing of mold design:
- designing and preparing of canals to feed the processed material into the mold (the feeding canals may be made and connected directly with the model during its building with any RP technique),
 - designing and preparing of overflow and venting canals (the canals may be made during mold creation or can be cut out after it has solidified),
 - designing of mold parting profiles and planes. The parting planes must run so as to enable model removing without damage.
- c) Preparing of mold casing. The mold casing should ensure tightness and have suitable overall dimensions (it is limited by the size of the vacuum equipment chamber, see fig. 1):
- stable connection of all elements of the model with each other, with gating and venting systems, as well as with the mold casing,
 - covering of model system elements with a separating agent.



Fig. 1. Vacuum Casting apparatus, VAKUUM UHG 400 type

- d) Mold filling with silicon:
- mixing of liquid silicon with hardener (e.g. silicon VTV 750 with hardener CAT 750 at the ratio of 10:1) and subject to initial degassing in vacuum unit. During the initial degassing silicon foams violently. That is why the degassing vessel should have a 10-times larger volume than the initial volume of the silicon.
 - The mold box should be poured with degassed silicon.
 - Repeated degassing. Violent foaming of silicon does not occur at the second stage of degassing.
- e) Heat treatment of the mold – soaking at 70°C for 12 hrs:
- f) Removing of model system:
- Mold removal from its casing,
 - Mold dividing (see fig. 2),
 - Removing of model, as well as gating and venting systems.

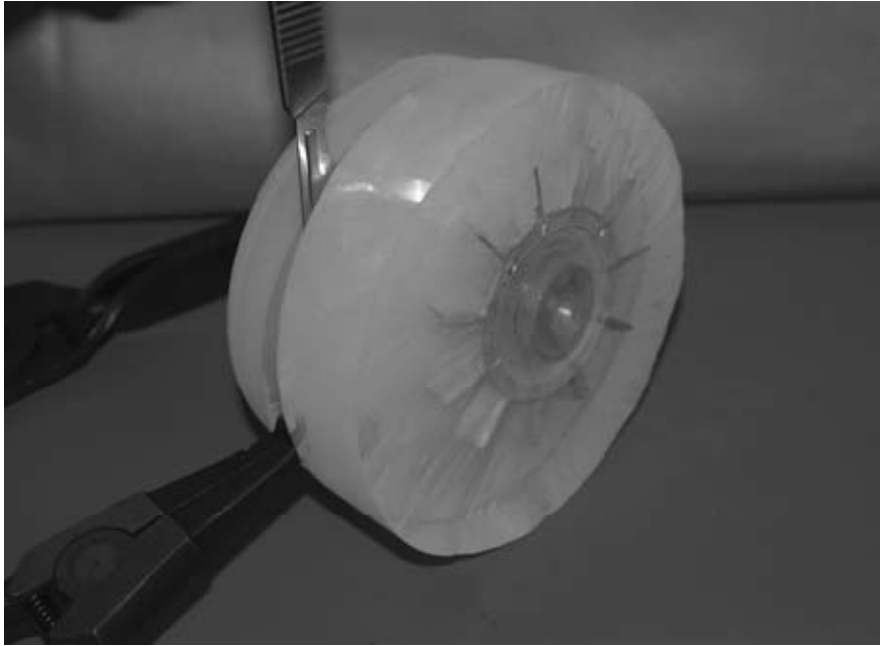


Fig. 2. Silicon mold dividing

3. Casting of wax patterns of impellers in silicon matrixes

The process of wax pattern producing with rapid prototyping techniques consists of four major stages:

- a) preparing of a CAD model,
- b) producing of stereo lithographic model,
- c) making of silicon matrix,
- d) making of wax pattern.

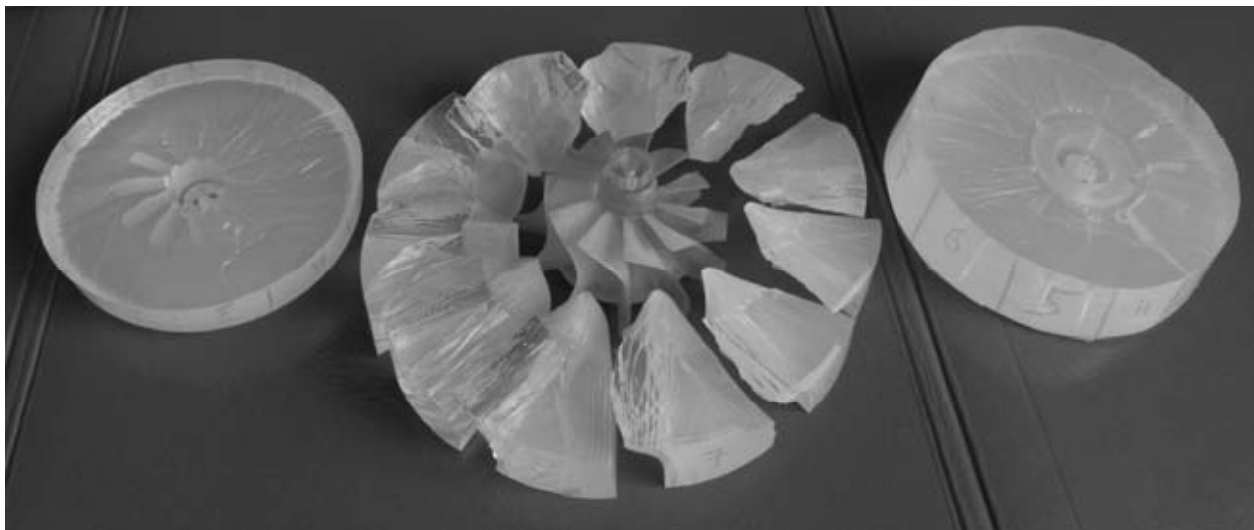


Fig. 3. Manner of silicon matrix dividing

Silicon matrixes were made on the basis of stereo lithographic base models presented here above. The casting wax is the material which reflects the model shape precisely but has small resistance. For this reason the silicon matrix had to be divided so as to enable wax pattern removing without damage (fig. 3).

The matrix must be suitably prepared for wax pattern making. Matrix parts are joined together (the container in which the matrix has been made, metal clips or assembling tape may be used for that purpose).

The matrix is heated up to temperature that is a few degrees higher than that of wax melting, while liquid wax is prepared at the same time. Then, the matrix is filled with liquid wax and left for solidification. After complete cooling of the matrix, the operation of wax pattern removal may be started. Individual elements of the matrix are split and the wax pattern removal shall proceed carefully and precisely so as to not damage the wax pattern. It is particularly significant for impeller pattern (see fig. 4).

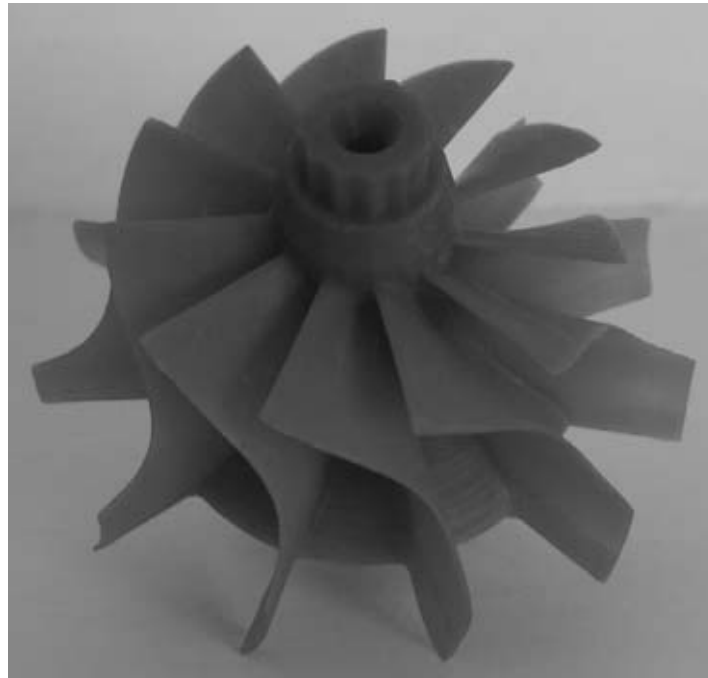


Fig. 4. Wax pattern of turbine impeller

4. Casting of plastic impellers in silicon molds

Silicon molds permit making of testing prototypes from plastics or, when using special grades of silicon, from non-ferrous metals. The service life of a matrix depends on the shape of the prototype as well as on chemical properties of cast plastics.

The method of low-pressure casting silicon matrixes enables making of usable prototypes from highly-resistant polyurethane plastics.

Prior to casting the ingredients of polyurethane plastic must be heated and weighed very precisely in proportion as recommended by the producer. Ingredients in separate containers and the silicon mold are soaked at suitable temperature. Then the mold and polyurethane ingredients are put into vacuum machine.

Upon reaching the assumed pressure, the ingredients are mixed and poured into the mold. Low pressure makes mold filling and polyurethane degassing easier. Observance of process recommendations, concerning temperatures, time, pressure, proportion of ingredients and the manner of mixing them, is extraordinary important. Since polyurethane is highly-reactive the hardening reaction is highly exothermic. Although the time from polyurethane ingredient mixing to hardening is short (from few scores of seconds to several minutes), the process is significantly extended by the mold soaking stage lasting frequently for several hours.

Very significant is the plastic pot-life time since the moment of mixing with hardener. In case of polyurethane plastics their pot-life time is short (1 ÷ 3 minutes). That is why the ingredient shall be

degasified separately and the mixing process shall be done directly before matrix filling in the vacuum unit.

The polyester resins have the pot-life time reaching up to fifteen minutes. Therefore, it is possible to degasify ingredients mixed together. Polyester resin pouring may be carried out by gravitation at ambient pressure.

The pot-life time of polyester and epoxy resins may be regulated through the number of hardener being added. However, it should be remembered that too small amount of hardener added to epoxy resin causes a sudden lowering in strength of the plastic, whereas too high amount of hardener causes a violent chemical reactions and sudden emission of high amounts of heat. Phenomena of this type may cause a mold losing its tightness. Large amount of hardener is a source of incorrect networking of the plastic in the largest cross sections of the model.

Some resins acquire their nominal parameters after the process of soaking at higher temperature. This process should be carried out after the resin has solidified prior to prototype removing from the mold. The prototype soaking at higher temperature after removal from mold may cause its distortion.

Casting of prototype impellers of plastics does not require as many parting planes as casting of wax models. It is caused by higher strength and elasticity of plastic material compared to wax. Refer to fig. 5 for the examples of casting mold parting and examples of impellers cast from plastics.

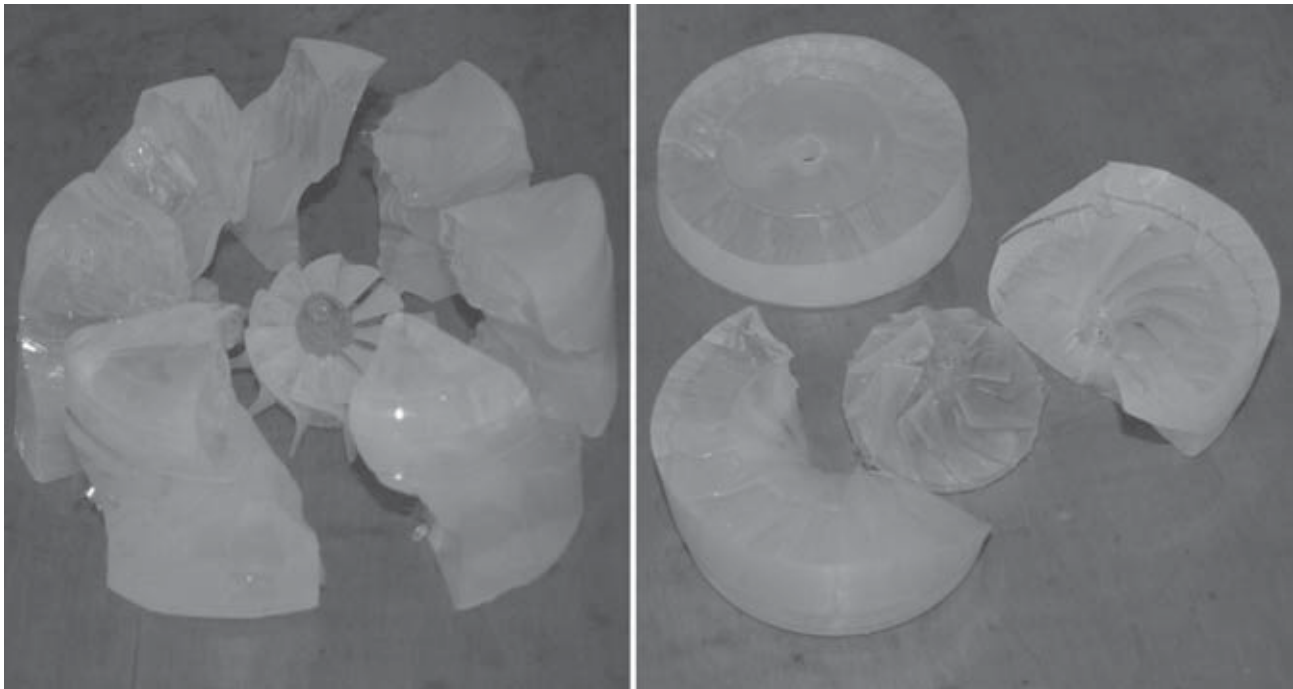


Fig. 5. Prototype impellers of plastic cast in silicon molds

5. Conclusions

The wax pattern method making in silicon matrixes permits eliminate of expensive metal matrixes at the stage of preparing prototype wax patterns of cast turbocharger blades and impellers. The limiting factor for the application of this method is the service life of silicon matrixes, permitting to make a few scores of patterns only. If a small number of wax patterns are needed, this limitation is not significant. Wax patterns produced in this way may be used for testing of new designs of gate systems and for processes of casting new designs. They could also be used for casting prototypes for testing and special uses.

The silicon matrixes permit casting and low-pressure injections of plastics. Some plastics may be used for producing foundry patterns for various metal alloy casting processes.

The basic advantage of vacuum casting process is the shortening of prototype making time and cost, compared to traditional methods.

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