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RAPID PROTOTYPING TECHNIQUE AS A MODERN TOOL TO AID ENGINEER'S WORK ON DESIGN AND FABRICATION OF PROTOTYPE ALTERNATOR DISC

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Summary. The article discusses problems related with designing of prototype castings by means of the most advanced methods assisting an engineer's work. Taking as an example alternator disc, the reader will have an opportunity to trace the successive stages of prototype formation from 3D model to the final cast. Special attention is deserved by the application of rapid prototyping techniques, including FDM, in the manufacture of tooling for CYCLONE II, which is an automatic device for rapid manufacture of ceramic shell moulds used in investment casting.

Key words: rapid prototyping, wax patterns, ceramic moulds, casting

INTRODUCTION

Rapid development of market economy demands from production plants a quick, cheap and reliable manufacture of products to satisfy the consumer demands in the best possible way. A vast range of products introduced to the market compels us to look for advanced and highly effective manufacturing methods, combined with a new approach to the engineer's work. At the same time, the newly developed processes should not raise the manufacturing costs, and this is possible in foundry industry as well as in other sectors of the industry only through development and effective application of modern manufacturing techniques.

Progress in civilisation changes also the available engineering tools, offering modern standards for the visualisation of design work and new possibilities of prototype manufacture. Depending on product application, its overall dimensions, the required dimensional accuracy, the material of which it is supposed to be made, and the available financial means, we can choose one of the numerous methods of the rapid prototyping system. Rapid prototyping has been known in industry for over a decade. This technique is used to manufacture various prototypes, patterns and ready elements. The manufacture of prototypes is based on the virtual 3D models created in a CAD graphics software.

For many years, the industry has been using the methods of Rapid Prototyping and Rapid Tooling. The former ones are used to make prototypes, patterns and ready elements. Rapid Tooling means quick manufacture of the accessories necessary in the production process. In most cases, the techniques of rapid prototyping are of an additive nature, but there are also cases that use the principle of subtraction, e.g. high-speed milling. The techniques of rapid prototyping available nowadays can be divided according to one of the factors mentioned below:

- pattern structure,
- accuracy of workmanship and overall dimensions,
- type of material used and the form in which it occurs,
- pattern application,

Patterns made by rapid prototyping techniques can be divided into the following groups:

- General patterns – reflect the features of the ready product, e.g. casting. They enable preliminary checking of some parameters, dimensions and configurations.
- Functional patterns – have some parameters identical with the parameters of the ready product. In the majority of cases, the parameters are identical with those of the final product are pattern shape and dimensions.
- Master patterns – used as a starting item in the large lot manufacture of products by, e.g. the casting process. These patterns serve as a starting tool or die to make further copies (e.g. pattern to make a foundry die).
- Ready patterns – the ready elements having the shape, dimensions and all other parameters identical with the final product. Installed in equipment, they enable testing of an element (if it is part of a mechanism), or are used to check the physical properties. Moreover, due to this procedure, it is often possible to eliminate the manufacture of a pilot lot of products, thus reducing considerably the cost, time, and labour input, and introduce very easily the necessary modifications and design improvements.

FROM 3D MODEL TO PROTOTYPE CASTING

Since it was necessary to make a prototype batch of castings of the alternator disc, and because of the number of castings included in this batch, it has been decided to use the investment casting process in ceramic layer moulds. The 3D pattern design was drawn in a CAD Solid Edge graphics software editor (Fig.1).

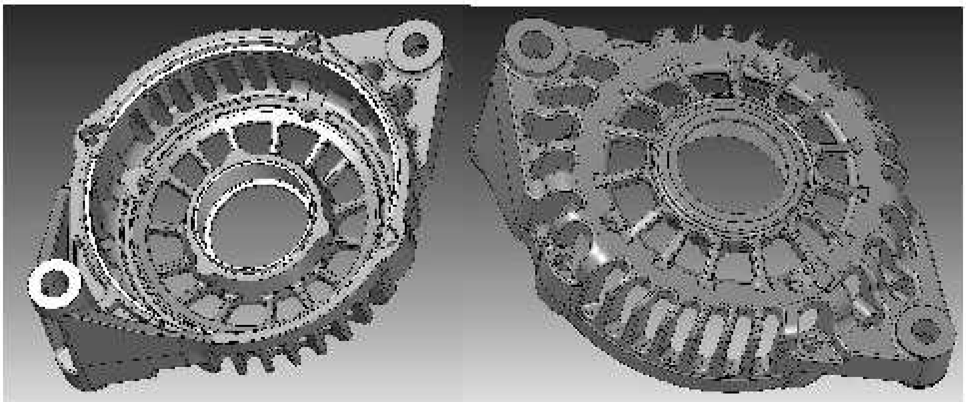

Fig.1. 3D model made in Solid Edge graphics software editor

The next step was conversion of the 3D geometrical figure to *.stl format, to enable making a useful visual model by the selected Rapid Prototyping technique.

The 3D model was created by FDM (*Fused Deposition Modelling*) technique. The process consists in building up the model by application of the successive layers of a thermoplastic, semi-solid material. The material is fed by replaceable nozzles placed in the head of a thermal device. The material in the form of fibres is uncoiled from a spool and fed to the head, where it is preheated to semi-solid state. The fed fibre is applied in layers forming a rapidly solidifying surface, which makes background for the deposition of the next layers. The heads move in horizontal axes X and Y; the bench is lowered in a vertical axis Z. Patterns are made from the following materials: ABS, PC, PC-ISO, PPSF, ABSi and PC – ABS, with the possibility of making semi-transparent or coloured details. The accuracy of a pattern depends on the thickness of the applied layer and usually amounts to 0,13 mm.

If required by the design, supports can be used. They are constructed together with the pattern and removed at the final stage of the manufacturing process. Depending on the type of material used, the supports are either broken out or dissolved in an alkaline solution using an ultrasonic washer.

The master pattern model of the disc was made from PC – ABS, because of the possibility to use a washed out support. After printing of the pattern and washing out of the support, the pattern was sprayed several times with putty, and then ground and painted to improve its surface quality (Fig.2). The next stage involved making a silicone die from the previously prepared model. The die was used for the manufacture of wax patterns (Fig.3). It was made from transparent silicone. For this purpose, the model was placed in a specially designed mould with the ready gating system and an overflow.

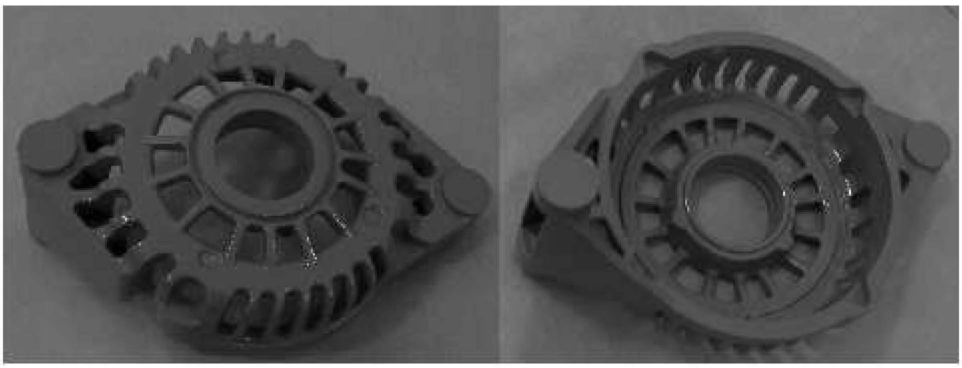

Fig 2. Model of alternator disc made from PC - ABS after puttying and varnishing

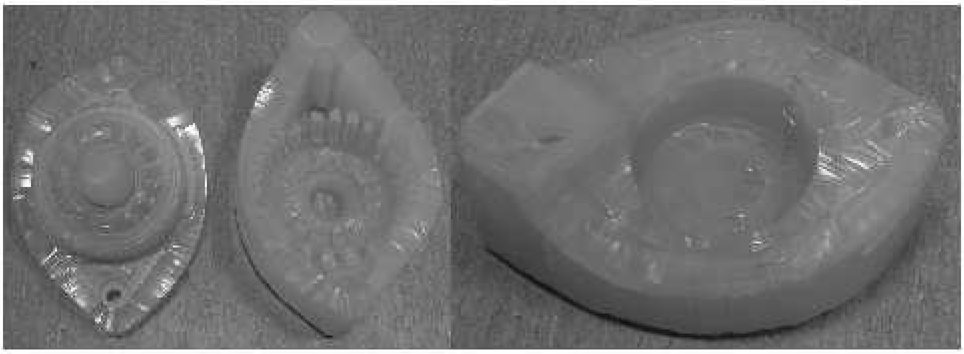

Fig 3. The ready silicone die

Pouring of the mould with silicone was carried out in a vacuum chamber to avoid the risk of the formation of blowhole defects. After the silicone solidification, the mould was dismantled, and then cut with a scalpel to take the master model out.

The silicone die prepared in this way was cleaned and coated with talc to facilitate the removal of wax patterns.

The operation of wax pouring was also performed in a vacuum chamber to ensure making the wax patterns free from the defects that might occur if the air bubbles would not escape. After the wax solidification, the pattern was taken out from the die and examined. Fine damages were repaired with special wax putty.

A batch of several dozen wax patterns was made by this route and used in fabrication of pattern tooling (Fig.4).

The pattern tooling was prepared in the form of „clusters" (Fig.5), which included the main gating system feeding the metal and patterns glued to the sides of the gating system. Parts of the gating system were made from the previously shaped wax elements. The whole device was joined together by means of a small soldering tool.

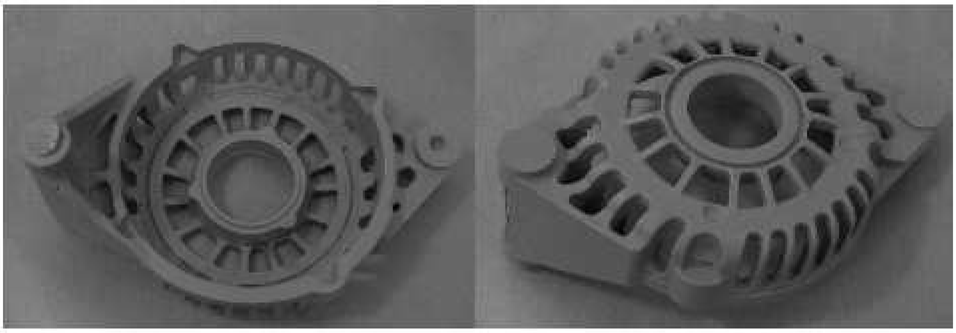

Fig. 4. A wax pattern

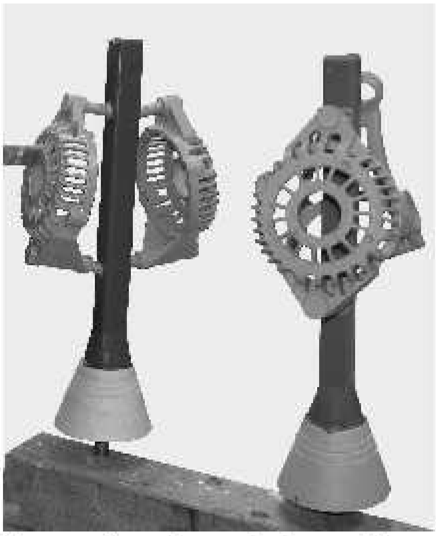

Fig. 5. Pattern tooling ready to make the ceramic layer moulds

At the next stage, a ceramic shell mould was made, using for this purpose a Cyclone II device made by MK Technology, assigned for the manufacture of prototype ceramic moulds (Fig.6). This was an integrated system including two mixers for the liquid ceramic slurries of different densities, two rainfall-type sprinkling machines for the stucco material of two different fractions, and a drying chamber. The machine was also equipped with an automated robot arm, and the whole process was monitored by a computer.

Fig.6. The Cyclone II equipment and setting of process parameters

Fig. 7. The successive stages of making a single layer of the ceramic mould

Owing to the use of a special drying chamber, the mould manufacturing time was reduced from several days to several hours only. After setting of process parameters (Fig. 6), i.e. the number of layers, the time of immersing the pattern in liquid ceramic slurry, the time of sprinkling with stucco material, and the time of drying the successive layers, the mould manufacture was started.

The arm applied the layer of the liquid ceramic slurry, and placed the cluster in a sprinkling device where the liquid slurry was coated with a ceramic stucco material (Fig.7). The so prepared layer was next dried in a chamber provided with an infra-red radiator and a system of fans, which ensured very rapid drying of the successive layers without the need of preheating the whole cluster.

After drying of the last layer, the ready mould was placed in a steam autoclave (Fig. 8), where under the effect of the high steam pressure, the wax was melted out.

Next, the ceramic mould was placed in a chamber furnace where it was baked at the temperature of 800°C to remove the residual wax and increase the mechanical strength.

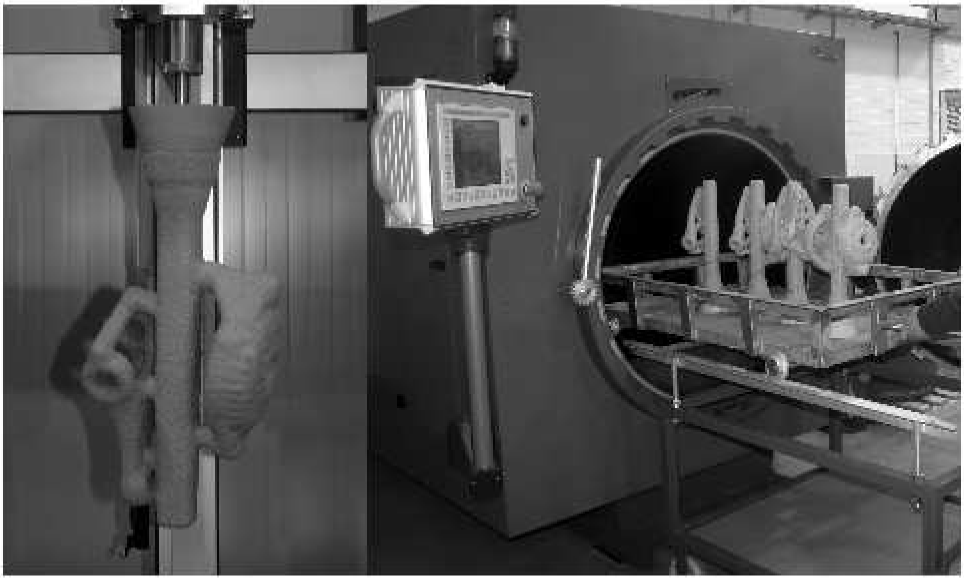

Fig 8. The ready ceramic layer mould placed in autoclave for melting out of wax

The hot self-supported mould was placed in a special fixture in the furnace where the metal melt had been prepared and was poured with this metal (Fig. 9).

Fig 9. Pouring of mould with molten metal

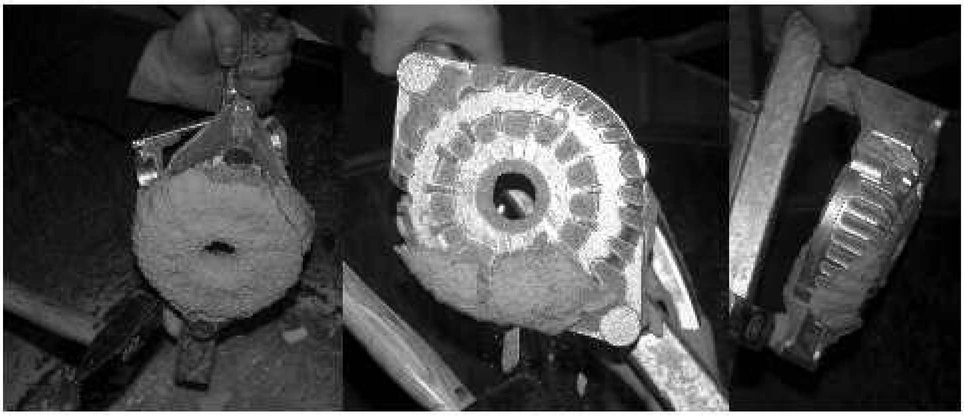

Fig.10. The successive stages of casting fettling

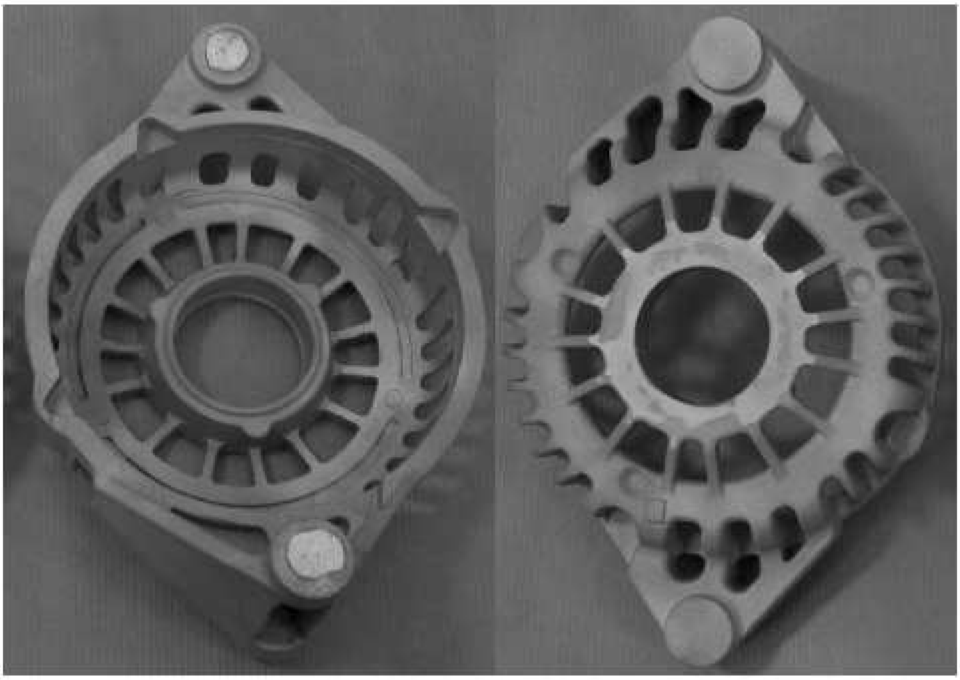

Fig.11. The ready casting

After cooling, the mould was broken into pieces and castings were cut off from the gating system. They were fettled by sand blasting to remove the residual ceramic material.

CONCLUSIONS

The article describes the successive stages of the process of making a casting by the selected techniques of Rapid Prototyping. It discloses the procedure of pattern making, the manufacture of a ceramic layer mould, and pouring of the ready mould with liquid metal. The application of modern RP techniques enables foundry plants to assume an individual approach to the problem of making prototype patterns and reduces to minimum the time necessary for implementation of a ready product.

The disclosed methodology shows one of the numerous possible means of making castings by the RP techniques.

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TECHNIKI SZYBKIEGO PROTOTYPOWANIA JAKO NOWOCZESNE NARZĘDZIE WSPOMAGANIA PRACY INŻYNIERA W PROCESIE POWSTAWANIA PROTOTYPOWEGO ODLEWU TARCZY ALTERNATORA

Streszczenie W artykule zostanie omówiona problematyka powstawania prototypowych odlewów przy zastosowaniu najnowocześniejszych metod wspomagania pracy inżyniera. Na przykładzie tarczy alternatora czytelnik zapozna się z kolejnymi etapami powstawania prototypu od modelu 3D do gotowego odlewu. Na szczególną uwagę zasługuje zastosowanie technik szybkiego prototypowania z uwzględnieniem technologii FDM do wykonania oprzyrządowania i automatu CYCLONE II do szybkiego wytwarzania ceramicznych form skorupowych dla metody wytapianych modeli.

Słowa kluczowe: szybkie prototypowanie, modele woskowe, formy ceramiczne, odlewanie