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Analysis of the Manufacturing Process of Metal Layers in Ceramic Molds of the Burnt-out Models

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Abstract

This paper presents an innovative casting method that allows manufacturing the layers on the cast by applying the metallic coating inside the mold. In order to define the possibilities of formation of the metal layers on the castings attempts were made to modify the mold and the cast for models created of two selected plastic materials. The main issue was the choice of a suitable coating material and a casting alloy. The procedure was projected in a manner that would enable the model polymer coating to get into reaction with the cast liquid metal after the burn away. The adjustment of the casting cavity was obtained by the nickel coating. The pit was then filled with the aluminum alloy, when studying the aspects of diffusion and adhesion between the two metals (Ni and Al). On the assumption that nickel coating will generate a diffusion connection with the cast material, it is potential to create intermetallic phases of the system of Ni- Al that will modify the surface attributes of the molding surface. Such designed is to obtain, in a single operation, a ready casting part with a diffusion layer surface.

Keywords: Investment casting, Polymer patterns, Metallic surface layer

1. Introduction

Precision casting is a commonly practiced method to receive details of high dimensional accuracy and complex patterns. This technology allows to obtain finished products, nonetheless, for practical reasons, may have limitations, for instance, in the shape of the low quality of the surface (roughness, surface blemishes, and so on) of the derived products or low tribological properties of castings. The surface modification of form that is suggested in the article creates a perspective of getting the ready top layer in one casting process changing its attributes, for example tribological and corrosive ones. The article gives an outline of the method as well as test answers for selected parameters of this advanced procedure [1-9].

2. Methods and results

For the execution of the selected models the following polymer materials have been chosen: high-impact polystyrene (HIPS) and copolymer of acrylonitrile-styrene-acrylonitrile (ABS). The possibility of firing the stuff from the ceramic molds as well as the simplicity of processing/treatment was the main criteria for choice. The plastic chosen as foundry models have undergone a process of autocatalytic chemical nickel plating, and then the electrochemical one, in parliamentary procedure to make the appropriate thickness of the shell (5 ÷ 40 μm). Models undergoing the electrochemical plating process have been handled with a uniform metallic coating. The outline of the planning process of the casting models was shown in Fig. 1.

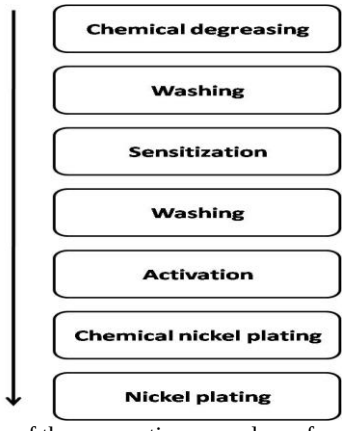

Fig. 1. Outline of the preparation procedure of casting models.

The ceramic moulds were made in such prepared models (Fig.2 and Fig.3), which were then annealed and flooded with the aluminium alloy.

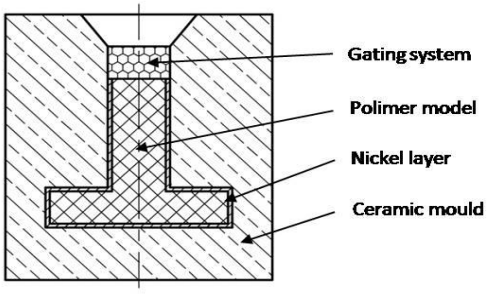

Fig 2. Outline of the ceramic moulds.

Fig.3. The casting model with nickel coating and ready ceramic mold

Filling the casting cavity was the most important aspect in the experiments carried out. Thus, the method for putting under the centrifugal pressure was taken. The metallographic specimen observations of the surface were formed by using the scanning electron microscope Hitachi S-3500N (Fig.4 and Fig.6-7), with the acceleration of electrons 15keV, however, studies on the chemical composition were done by using the detector EDS (Fig.4).

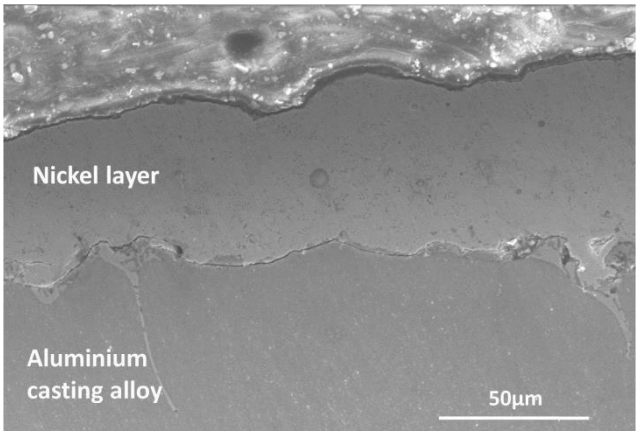

Fig. 4. Adhesive connection of nickel coating with aluminum casting, 600x .

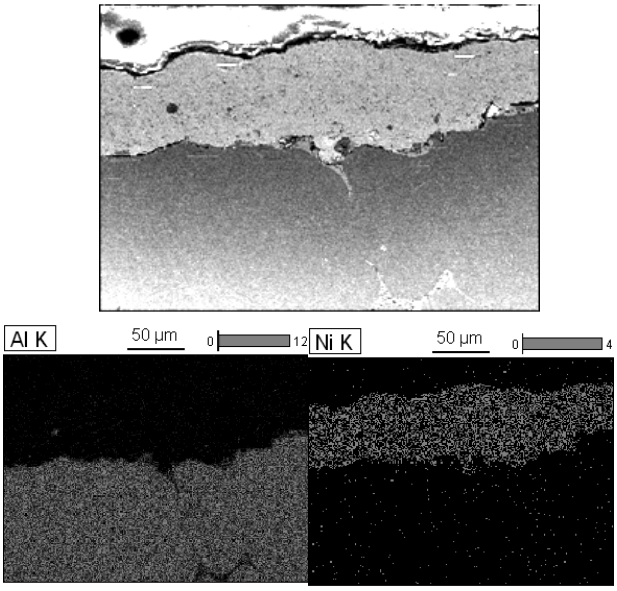

Fig. 5. Qualitative distribution of nickel and aluminum on the cross of adhesive connection with the coating surface, 500x .

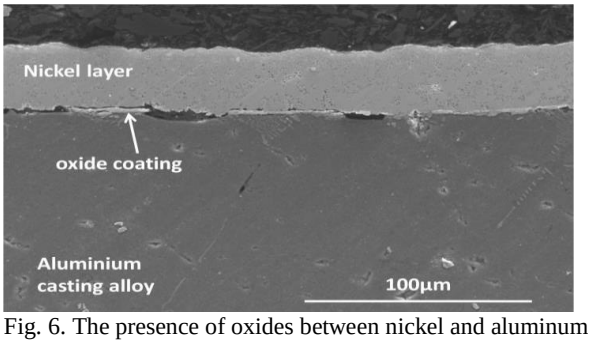

Fig. 6. The presence of oxides between nickel and aluminum alloy

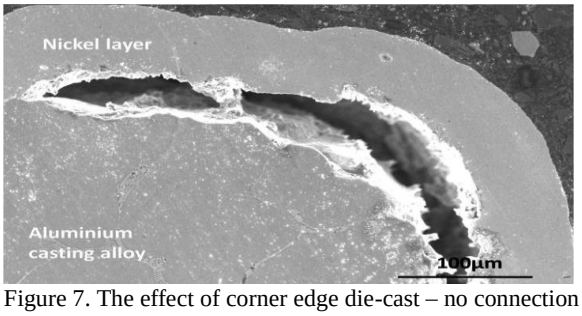

Figure 7. The effect of corner edge die-cast – no connection to the shell and aluminum alloy.

4. Discussion and summary

Such studies allow analyzing a novel means of manufacturing the precision casting and the various stages of technology. It was concluded that a few important factors which are discussed below are the basic problem of the new technology.

Metallic coating on plastic models was one of the first issues to be analyzed. Before the very process of galvanic plating of materials such as HIPS and ABS it was extremely important to get the surface of samples. The processes of grinding and sanding are to get the adequate roughness to the models to affect a better adhesion of implementing metal on their surface. Problems with burning the models and the upkeep of a suitable purity of the shell in the form as well as its thermal extensibility was an interesting aspect of the new method of manufacturing. Thither is a sort of consensus between the ignition temperature of form where the diffusion processes occur, and the temperature, where the oxidation of the nickel coating takes place. Its distortion is a consequence of the phenomena associated with thermal extensibility. Excessively high temperature of the mold has a rapid oxidation of the surface of the nickel coating, but it is beneficial due to the intensification of the diffusion processes.

Optimization of parameters of flooding allowed to obtain a secure shell connection with the Al alloy (Fig.4) at a temperature of burning of 750^{0}C, shell thickness of 40 µm and polystyrene HIPS as the exemplar/model material. The qualitative distribution of the elements along the cross – segment (Fig.5) shows the continuous link in the system: nickel coating - die-cast aluminium alloy. Thither is a clear boundary line between areas rich in nickel and aluminum. In cases when the temperature of burning the form/mold was about 800÷900^{0}C, there was a rapid oxidation of the metal come into contact, therefore preventing the full connection between the foundry alloy and coating. In figure 6 pores are visible, and also considerably the lack of connectedness between the casting and coating which under these conditions most likely drive the establishment of a relatively dense layer of brittle aluminum oxides. Figure 7 indicates the total lack of consistency between the coating and casting in the corner site. This may ensue from the state of stresses in the novel stage of metal between the layer of Ni-Al, which is presently the subject of the research.

4. Summary

The method of making up the precision coating with metallic layers are made directly in the ceramic mold which may be both cognitive and applicable from the scientific perspective. In a typical cycle of creation of models, ceramic molds and casting the cast are created featuring completely different properties of the surface and the core. A wide range of technical parameters is possible to apply in such innovative process. This article presents selected issues in three primary phases, i.e. creating models with metallic layers, ceramic mold technology with an internal layer of metal and the casting process. The main conclusions are as follows:

1. Plastic models with metallic layers require the selection of the right form of polymer materials and the preparation of its surface for application processes of putting the nickel layers on. Studies indicate that high-impact polystyrene species (HIPS) had the best technological properties.

2. Burning out the polymer models from the ceramic molds must take place in a suitable temperature due to both giving the relevant properties of ceramics and cleaning the cast cavity from the model residuals. It was found that stirring up the molds and pouring it at a temperature of less than 800^{0}C gives the best results to obtain better quality of the cast.

3. The process of casting of the liquid aluminum alloy to the mold with the nickel layer inside creates the connection of these two metals in the cavity of the mold. It is associated with the occurrence of the soak-time of the aluminium alloy with the nickel layer, but likewise with other products, for instance, oxide ones unfavorable due to the quality of the layer of the casting and its properties.

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