STRUCTURE AND SURFACE ROUGHNESS OF FIRST LAYER OF CERAMIC MOULDS APPLIED IN THE INVESTMENT CASTING

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Abstract

An important role in the investment casting process is played by the surface condition of the first coating of a multi-layer ceramic mould, as it directly affects the quality of the obtained cast. In industrial conditions, it is not possible to assess surface quality of the first ceramic mould cover without breaking it. The paper presents the analysis of the structure and surface roughness tests results of the first model coatings of model and production ceramic moulds. Ceramic moulds were made of 7 coatings. Three different ceramic mixtures were used to make them, differing in the used filler (molochite, quartz) or binder (Remasol aqueous binder, hydrolyzed ethyl silicate, Ludox water binder). Samples of industrial moulds were obtained by breaking them while model moulds in the form of rectangular shaped samples were made in specially designed wax dies. Model and production moulds were heat treated at 850 °C, 900 °C and 950 °C, and then the roughness of the first coating was tested using the WYKO NT9300 optical profilometer. Samples were also subjected to microscopic examination to determine the structure of the model layer and the cross-section of the moulds. The research allowed to obtain the results of the impact of materials intended for moulds and heat treatment on the quality of the model layer.

Keywords: Ceramic moulds, roughness, structure, investment casting, lost-wax

1. INTRODUCTION

The process of investment casting with the lost wax method is used for production of high quality foundry products with relatively high dimensional accuracy and complex shapes [1, 2]. The investment casting process consists many individual processes, the most important of which are creating wax model, model set, multi-layered ceramic mould, wax melting, heat treatment of the ceramic mould, molding liquid metal, post-casting mechanical treatment and final quality control. The quality of obtained castings depends on the properties of ceramic moulds, primarily the first model layer, which is in direct contact with the cast metal [3]. Therefore, the correct selection of materials for ceramic moulds, i.e. binders, fillers or auxiliary substances, is very important. These materials should provide adequate resistance to cracking, porosity and gas permeability [4, 5]. The reactions occurring at the border of form and liquid metal have a huge impact on the final quality of the product, which is why the goal is to obtain ceramic moulds with the best parameters. The aim of the work is to analyze the influence of materials for moulds and their heat treatment on the surface roughness and structure of the first model layer and the structure of the forms.

2. METHODOLOGY

Two types of samples were prepared for tests in the form of 7-layered ceramic moulds, hereinafter referred to as model (M) and industrial (I). Three different ceramic mixtures were used to make them, the composition of which is presented in **Table 1**.

Table 1 The composition of the ceramic mixtures

Name of ceramic mixture	1 layer	2-7 layer	Filling
QUARTZ (K)	Quartz powder (SiO_2) + Ludox SK-F	Quartz powder (SiO_2) + Ludox PX-30/hydrolyzed ethyl silicate	Quartzsand (SiO_2)
MOLOCHITE (M)	Molochitepowder (Al_2O_3, SiO_2) + Ludox SK-F	Molochite powder (Al_2O_3, SiO_2) + Ludox PX-30/ hydrolyzed ethyl silicate	Molochitesand
REMASOL (R)	Quartz powder (SiO_2) + Remasol Premium Plus	Quartz powder (SiO_2) + Remasol Premium	Quartzsand (SiO_2)

Model ceramic samples were made in wax dies (**Figure 1a**). Samples from three different material mixtures (**Figures 1b-d**) were made on previously prepared and degreased wax dies. The samples consisted of 7 coatings. The method of applying a particular layer consisted: pouring, scattering, scraping off excess weight and drying. The samples were melted in an autoclave at a temperature of approximately 130 °C.

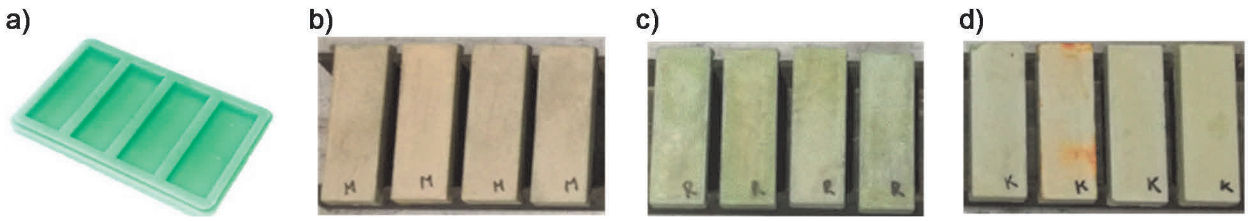

Figure 1 Wax die (a) and modelceramic samples: M (b), R (c), K (d)

Industrial ceramic moulds (**Figure 2b**) were created on pre-prepared wax model set (**Figure 2a**) by applying 7 coatings. As in the case of model moulds, three different ceramic mixtures, listed in **Table 1**, were used. Samples of industrial ceramic moulds (**Figures 2c-e**) were obtained by breaking them.

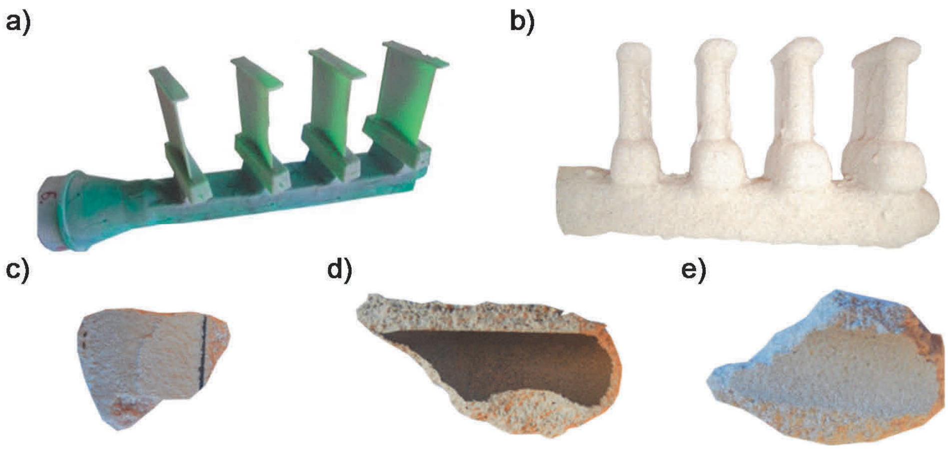

Figure 2 Wax model set (a), ceramic mould (b) and industrial ceramic samples K (c), M (d), R (e)

All samples were heat treated at 850 °C, 900 °C and 950 °C. The surface roughness of the first model layer of each sample was then examined using the WYKO NT9300 optical profilometer. The roughness parameters such as R_a (mean roughness value), R_t (total height of profile), R_q (statistically equal to standard deviation of profile ordinates), R_z (sum of the highest elevation and the largest depression) were measured. The measurement of each sample was done five times. Samples were also subjected to microscopic examination to determine the structure of model layer and the cross-section of the moulds. For this purpose, the Hitachi SU-70 scanning electron microscope was used.

3. RESULTS

Surface roughness test results of the first model coating of model (M) and industrial (I)moulds for three mixtures (K, M, R) are shown in **Figures 3-5**.

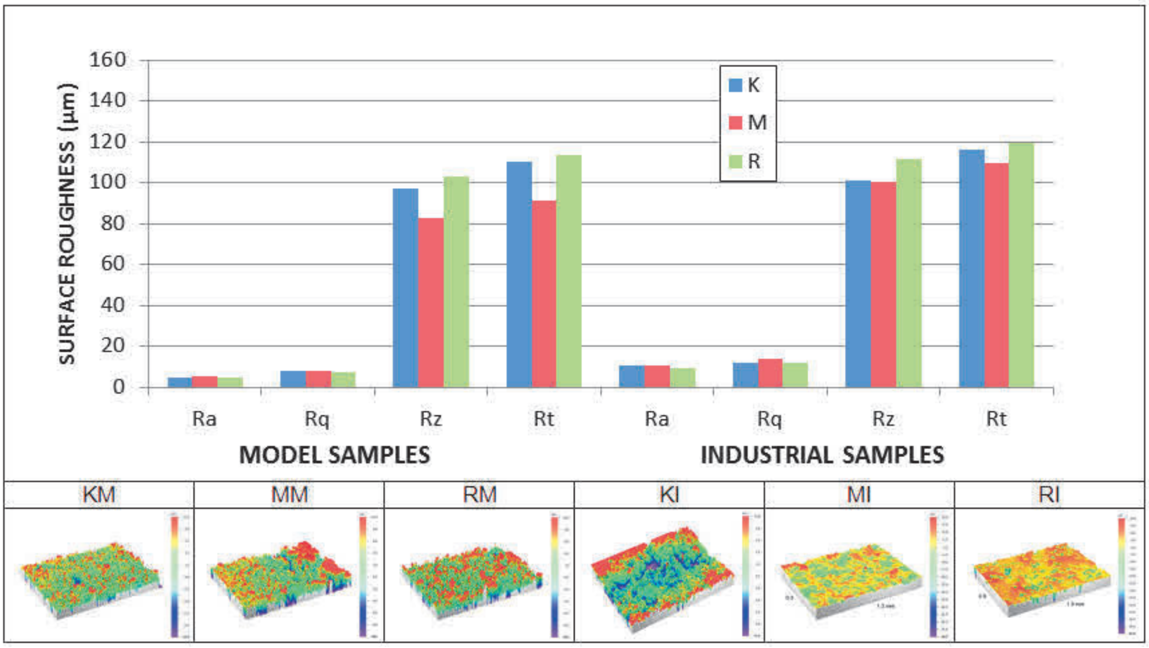

Figure 3 Surface roughness of the first model coat after heat treatment at 850 °C

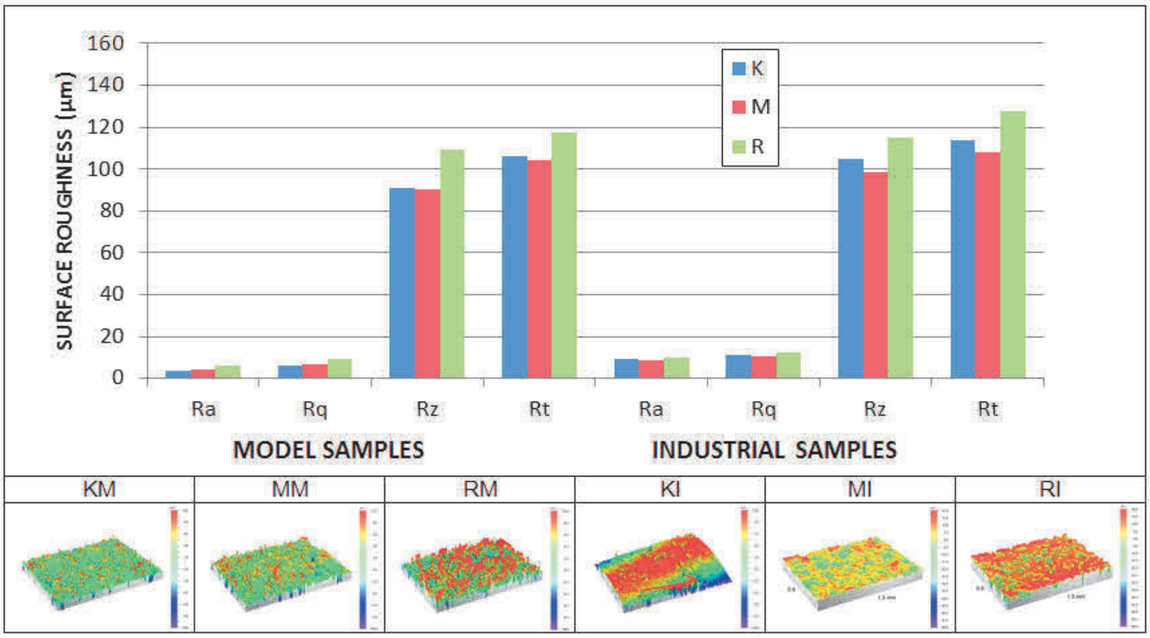

Figure 4 Surface roughness of the first model coat after heat treatment at 900 °C

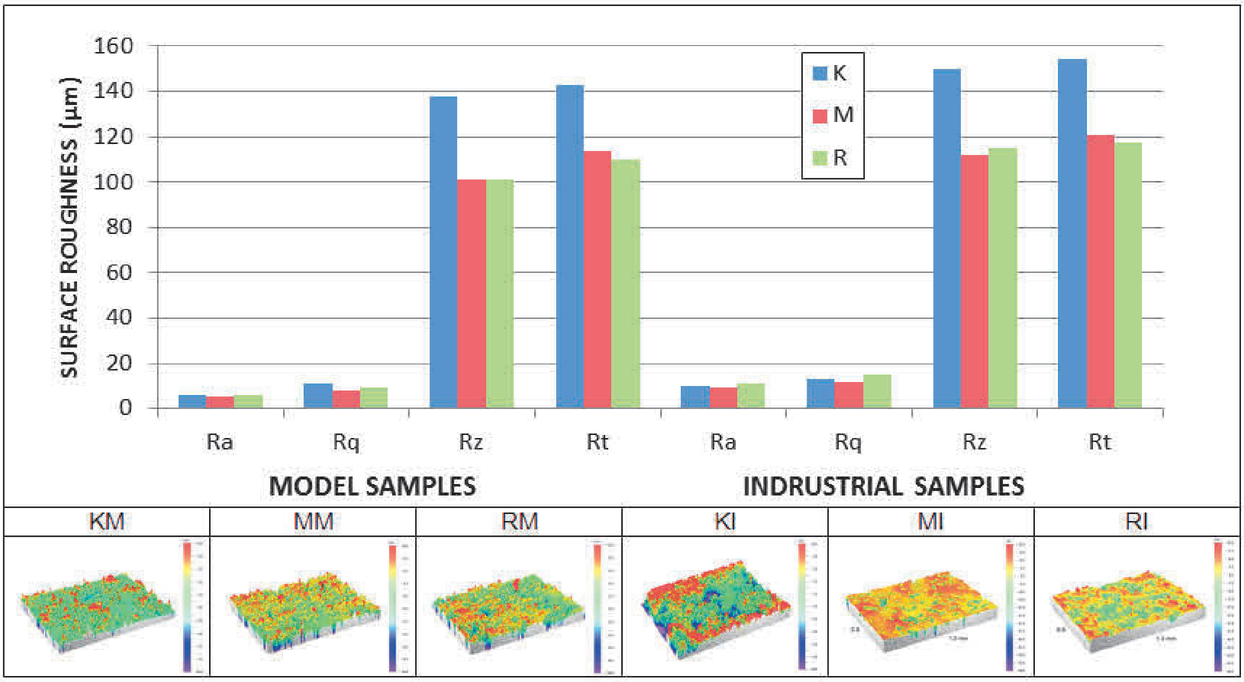

Figure 5 Surface roughness of the first model coat after heat treatment at 950 °C

Surface roughness parameters of model samples for all three mixes are lower compared to industrial samples, whereas these results are comparatively due to the applied heat treatment. K and R ceramic mixtures show the best quality of the first coating after heat treatment at 850 °C, whereas samples of the M mixture at 900 °C. **Figures 6-8** show SEM photos of moulds on sample cross-sections.

a) b) c)

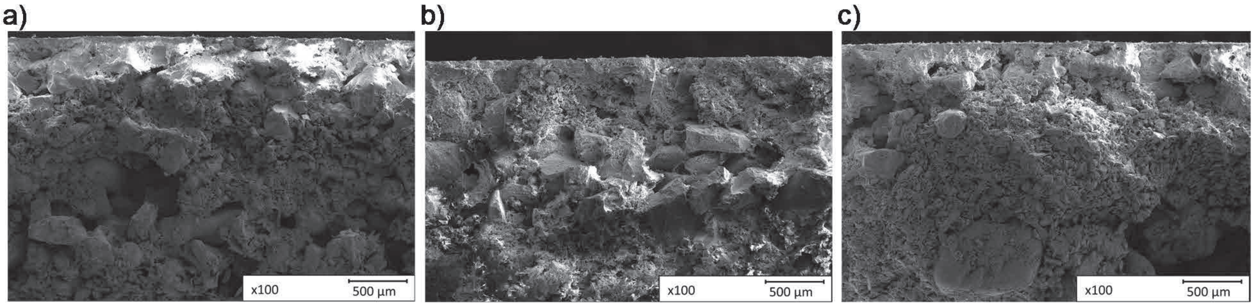

Figure 6 Structure of moulds made of material K (a), M (b), R (c) after heat treatment at 850 °C

a) b) c)

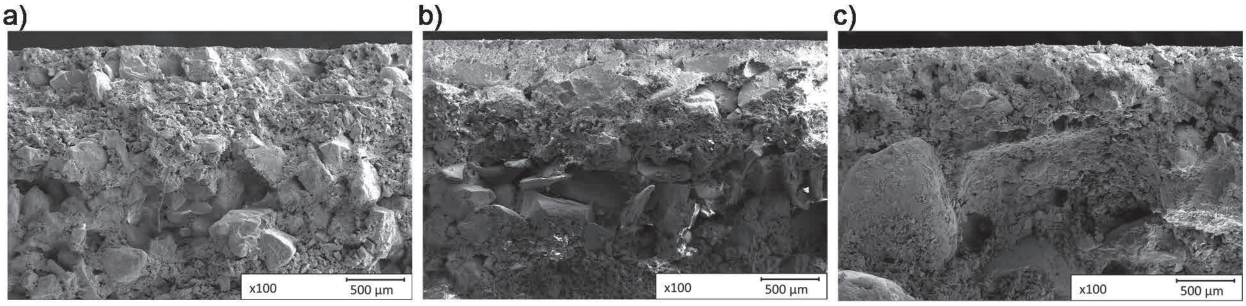

Figure 7 Structure of moulds made of material K (a), M (b), R (c) after heat treatment at 900 °C

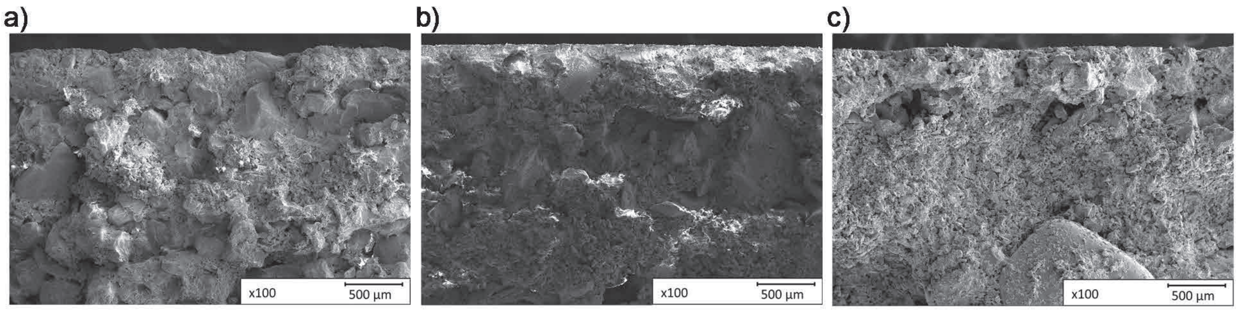

Figure 8 Structure of moulds made of material K (a), M (b), R (c) after heat treatment at 950 °C

Figure 9 presents photos of structures of the model layer of industrial moulds.

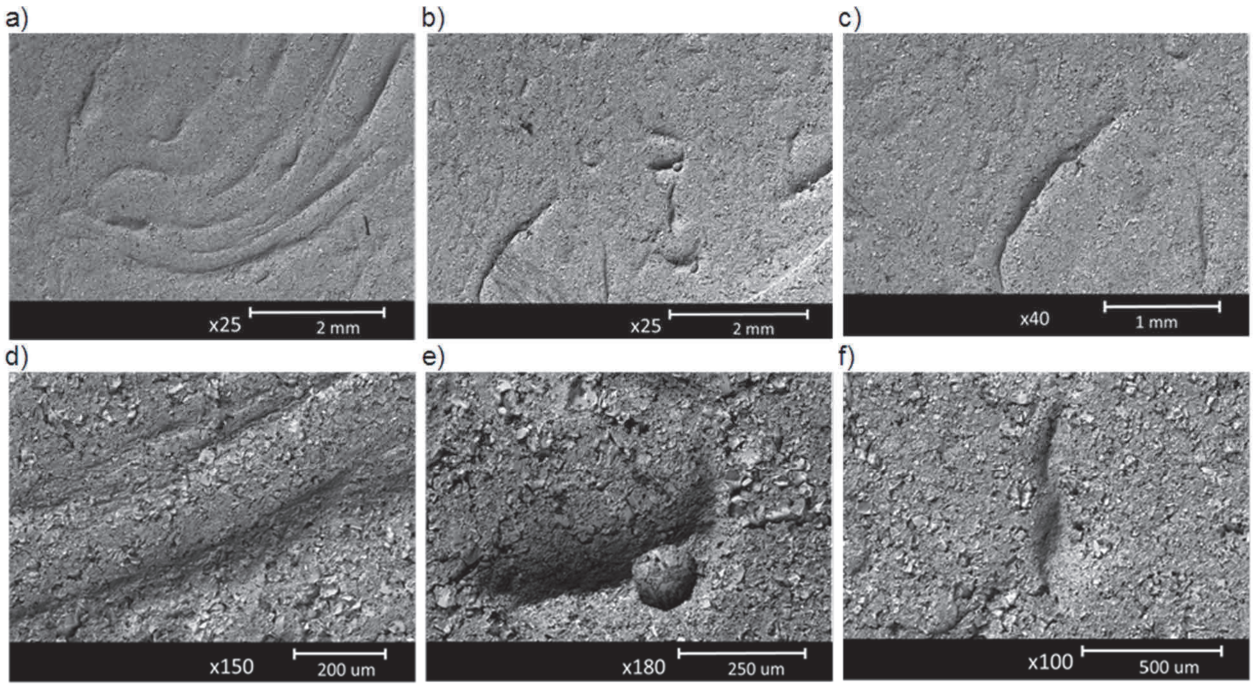

Figure 9 Structure of surface of the model layer after heat treatment at 950 °C for materials K (a, d), M (b, e), R (c, f)

Due to the fact that the influence of heat treatment on the surface structure of the model and industrial moulds was not significant, the publication presents microscopic observations only for the model layer of the heat-treated industrial moulds at 950 °C. Studies on the electron microscope showed a relatively large variation in grain size from a few to several dozen micrometers. The results of the above studies indicate that the sources of surface imperfections may be related to the process of applying layers, mainly the first layer to the wax model, in particular their leakage, drying and firing. The grain size variation is related to the grain size distribution of the powders used, and to some extent may also result from the formation of grain aggregates in the technological solution.

4. CONCLUSION

The following conclusions can be made on the basis of completed research:

- The roughness parameters of the model samples are lower compared to the industrial samples, but the distribution of results due to the applied heat treatment is very similar.

- Quartz and Remasol ceramic mixtures show the best quality of the first coating after treatment at 850 °C, whereas Molochite at 900 °C.
- The results of microscopic observations indicate a more developed surface of SiO_2 particles and their variation in size and shape for masses with alcohol binder. Colloidal silica masses have a more compact structure, SiO_2 particles have a sharp-edged and irregular shape and smaller size, which probably favors a better coverage of the wax model surface.
- SEM tests showed good adhesion at the interface between ceramic materials M.

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