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Influence of Ceramic Filter on Surface Defects in Investment Casting

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Abstract-Although casting in vacuum atmosphere can reduce some metallurgical defects, surface defects in investment casting in vacuum induction melting (VIM) furnace are usual and inevitable. As a result, if the cleanliness of ingot and crucible are not controlled, these defects will elongate the time of finishing process or even worse, will cause the reject of casting parts. In this investigation the effects of ceramic filter on preventing inclusions to the mold cavity is studied. To perform this study practically, eight firs nozzle vanes from the gas turbine of MS5002D are cast in VIM furnace. The alloy was cobalt base super alloy FSX-414 and the pouring temperature was 1485 °C. The filter used in all of the melts made from zirconia. The mesh of filter was 10 ppi, and its thickness was 20 mm with diameter of 90 mm. The crucible was made from Alumina. The results showed in four molds the filter remained in the gate of pouring cup but in the others it floated on the top of the melt. Finally, the fluorescence inspection test uncovered that in the latter group which filter was not floated, the percentages of the surface defects were lower and reached to minimum 0.4 percent. In addition, the scanning electron microscope (SEM) images demonstrated that the inclusions were almost aluminum and its oxide which may relate to the reaction between melt and crucible walls.

Keywords-ceramic filter, surface defects, investment casing, super alloy.

I. INTRODUCTION

Many casting parameters are involved in investment casting process to attain the parts with at least no defects. Therefore, to be assured to reduce defects, all of these parameters have been to be controlled. These defects include the ones which related to the pouring process, size, shape and the temperature of the mold cavity [1].

Common surface defects in the gas turbine parts which produced by investment casting process made from cobalt base super alloy, includes inclusion, slag and hot tear. Among these defects, the inclusions are observed in most of the casting parts. As a case, the below image shows the statistical results of these defects investigated in the previous studies (Figure 1) [2].

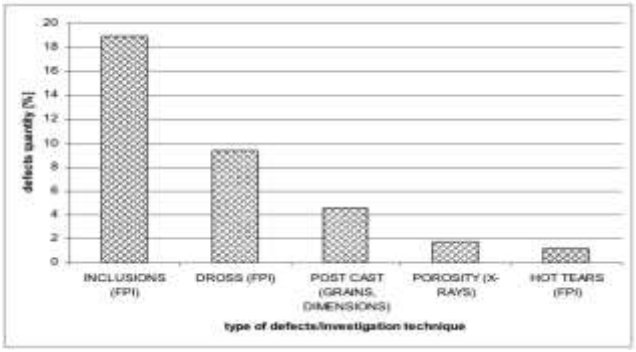


Figure 1. The statistical results of investment casting defect in Co base super alloys [2].

Moreover, some previous studies have showed that the inclusions are related to the reaction between the melt and crucible. Below result shows the magnesium (Mg) and its oxide (MgO) inclusion by the Energy-dispersive Spectrometry (EDS) method in IN713LC alloy (Figure 2) [3].

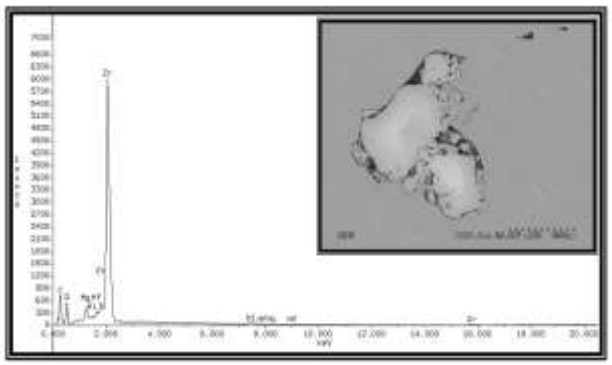


Figure 2. microstructure of the crucible inclusion [3].

Furthermore, some defects like pinholes and subsurface blowholes, for example, are related to the pouring process and finally observe as the surface castings. Sometimes these defects cannot be observable before machining. Actually, they form after the reaction between the core material and the resins in the melts. As a result, if the sufficient vents are not provide, they cannot exit easily from the mold [4-5].

In fact, slag inclusions are most common in casting. Below image shows this defect in the latest investigation. Moreover, some porosity inclusion which relate to the internal gas have been demonstrated (Figure 4, 5) [6].

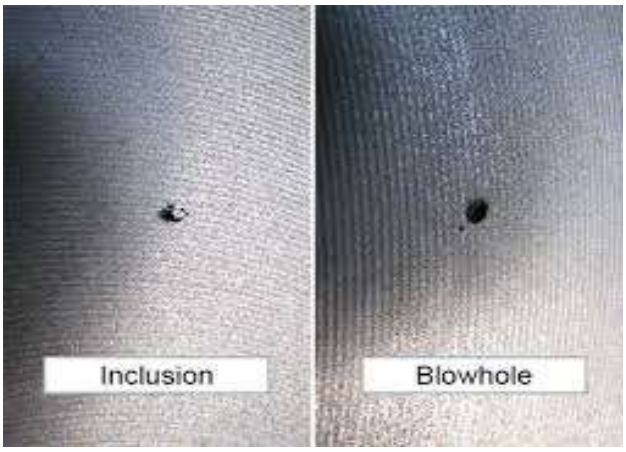


Figure 4. Inclusion [4-5].

Figure 5. Gas porosity [6].

In addition, surface defects are formed in different states during investment casting process including de-waxing in autoclave process. Whenever the ceramic mold is exposed to the high temperatures above 180 °C , some fine surface defects like some fillers existed in the wax are formed in the ceramic mold which ultimately appear on the casting surface [7-8].

II. EXPERIMENTS

In this investigation the influence of ceramic filter on preventing inclusions to the mold cavity is studied. In this regard, eight firs nozzle vanes from the gas turbine of MS5002D are cast in VIM furnace. The alloy was cobalt base super-alloy FSX-414 and its (Table 1, the results are in weight percentage). The pouring temperature was 1485 °C. The crucible was made from Alumina. The filter used in all of the melts made from zirconia. The mesh of filter was 10 ppi, and its thickness was 20 mm with diameter of 90 mm. the image of the real filter used in the incvestigation is showed (figure 6). Figure 7 and 8 show the assembled wax mold and the place of filter, respectively. (Figure 7, 8) In addition, figure 9 shows place of the filter after solidification (Figure 9) .

Table 1. Chemical composition of FSX-414 alloy.

C	**Si**	**Mn**	**P**	**S**	**Cr**
0.220	0.0876	0.0235	0.0069	0.0042	29.84
Mo	**Ni**	**V**	**W**	**Co**	**Cu**
0.0074	11.21	0.0141	6.76	51.5	0.0026
Fe	**Ti**	**Al**	**B**	**N**	**Ta**
0.182	0.0109	0.0225	0.0104	0.0184	0.0550
Nb					
0.0109					

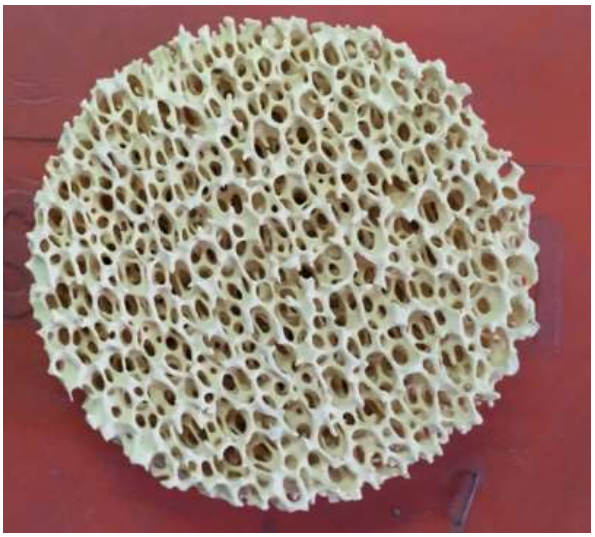


Figure 6. ceramic filter.

Figure 7. assembled mold.

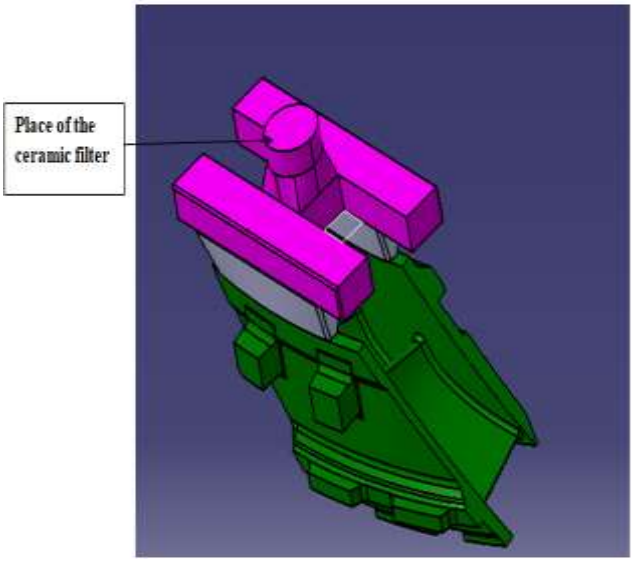


Figure 8. place of ceramic filter in the schematic image.

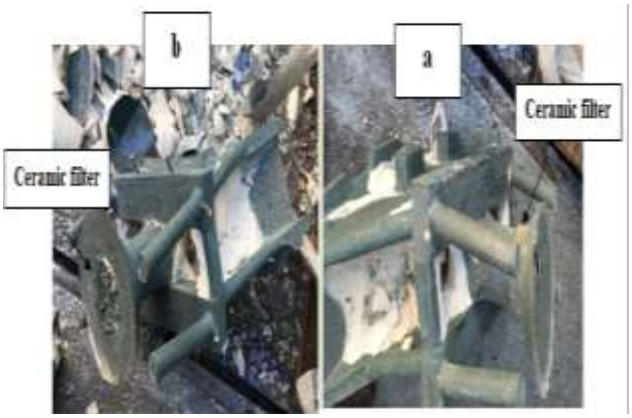


Figure 9. place of ceramic filter after solidification, a) filter is not floated, b) filter is floated.

III. RESULTS AND DISCUSSION

The results showed in four molds the filter remained in the gate of pouring cup but in the others it floated on melt. After heat treatment, the fluorescence inspection test revealed that in the casting which filter was not floated, the percentages of the surface defects were lower and reached to minimum 0.4 percent. According to the heat treatment cycle, the castings hold in the furnace at the temperature 1150±10 °C and then cooled in the argon ambient by the rate of 10-20 °C/min and finally cooled to below 600 °C [9-10]. In addition, the scanning electron microscope (SEM) images demonstrated that the inclusions were almost aluminum and its oxide which may relate to the reaction between melt and crucible walls. The defects percentage is calculated by equation 1. In figure 10 the surface defects in fluorescence inspection test in the high defects percent and low one has been shown. The defects surface percentages are demonstrated (Table2, Figure 10, 11) .

$$\frac{(\text{Area of the circle defects})\times(\text{Number of defects})}{(\text{area of the Airfoils of the vane})} \times 100 \qquad (1)$$

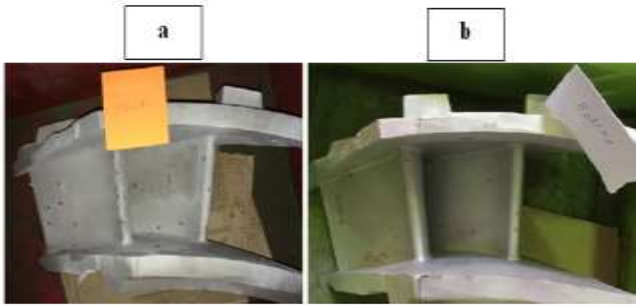


Figure 10. the surface defects in fluorescence inspection test for high defects percent (a) high defect percent, and (b) low defect percent.

Tabel 2. surface defects percentage of the parts.

Number of the parts	Defect percentage on the Airfoils	Place of the filter after solidification
1	1.5	Up
2	4.3	Up
3	7.8	Up
4	1.8	Up
5	1.1	Down
6	1.1	Down
7	1.7	Down
8	0.4	Down

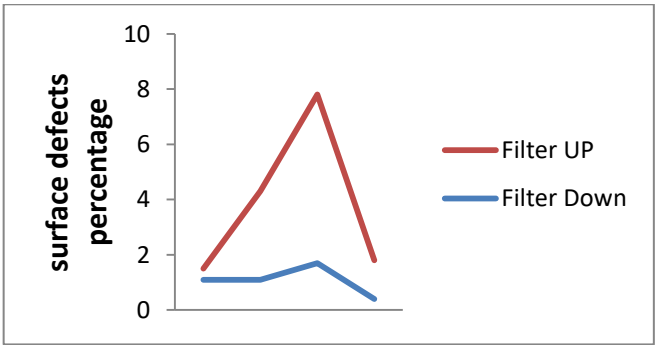
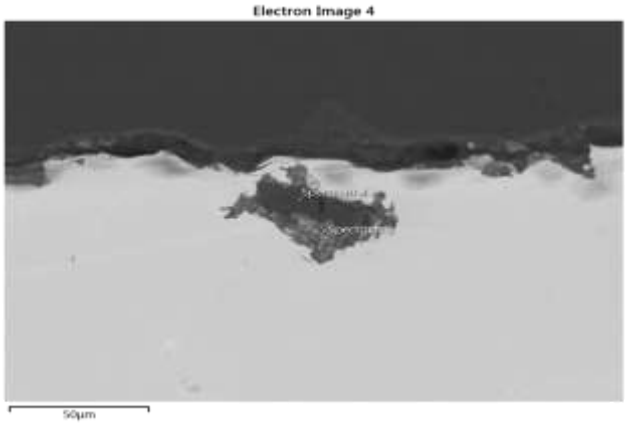


Figure 11. surface defects percentage of the parts.

Finally, by investigation of some specimen by scanning electron microscope (SEM) can be conclude that the inclusions observed in these images may relate to the reaction between the aluminum in the crucible walls and melt. The result revealed that the inclusions are mostly aluminum (Al) element and its oxides (Figure 12)



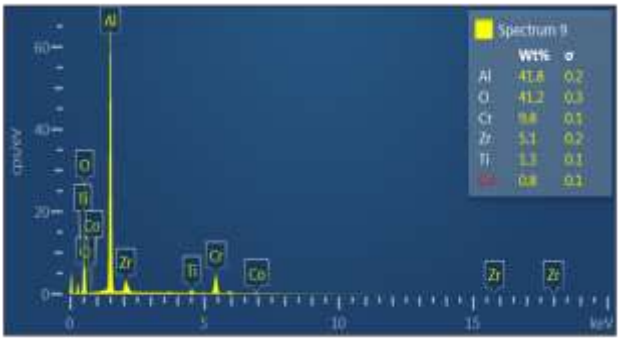


Figure 12. different inclusion in SEM results.

IV. CONCLUSION

According to the surface defects on the airfoils of the vanes discussed in this study, it can be concluded that in those case which the filter was not floated on the top of the melt , the percentage of the defects have been reduced significantly. As a result, the time and cost of the finishing are reduced, so it would prevent the production process from being time-consuming. Therefore, the influence of the ceramic filter on the preventing of inclusions and other defects to the mold cavity would be positive. The lowest percentage of the surface defects obtained in this study was 0.4 percent. Moreover, the scanning electron microscope demonstrated that the defects showed in the microscopic images related to the reaction between melt and crucible.

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The authors have been working and investigating on gas turbine blades for more than 10 years. The corresponding author has a ISIS published paper in Nickel base turbine blades with title of "Simulation of Ni-Based Super-Alloy and Optimizing of its Mechanical Properties in a Near-Shaped Turbine Blade Parts ". Hindawi Publishing Corporat ion Indian Journal of Materials Science, 19 March 2015.

