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Enhancement of porosity and mechanical properties of ceramic shell in investment casting process by the addition of camphor and needle coke/wax powder- A comparison

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In the investment casting process, molten metal is poured into a ceramic shell, which is created around wax pattern by the repeated application of slurry/stucco. Because of the fine ingredients used, the ceramic shell often exhibits poor permeability and leads to porosity defects. In the present study, an attempt was made to enhance the permeability of ceramic shell by mixing certain fillers like camphor, needle coke and wax powder to the ceramic slurry. In the first investigation, camphor was added to the inner coat slurry and needle coke was added to the outer coat slurry in small proportions. In the second investigation, camphor was again added to the inner coat slurry and wax powder was added to the outer coat slurry in small proportions. During the firing of the shell, these fillers (camphor, needle coke / wax) were burnt and pores were created inside the shell, which enabled escape of undesirable gases. A comparison was made between the performances and properties of the shells obtained in both the cases.

Keywords: *Investment casting, Ceramic shell, Permeability, Camphor, Needle coke and Wax powder.*

1. Introduction

Investment casting process is known for its good surface finish and excellent dimensional accuracy. Excellent surface finish of the cast component is achieved by the excellent surface finish of the inner coat of the shell, due to the very fine grain size of the refractory powder used. This very fine grain size of the ceramic powder leads to poor permeability of the shell and consequently gas porosity defects. Poor selection of ingredients could lead to poor permeability of the shell and also poor mechanical properties of the shell. To overcome these problems, organic fibres were added to the slurry ingredients to improve the mould thickness at the round edges and sharp corners. These fibres required very less resistance and forces while removal from the matrix. Further addition to this, Wang et al. have improved the thickness of the shell by adding needle coke to the outer layer of the shell. The shell, thus produced, had improved mechanical properties than the conventional shell [1].

In the present work, camphor, needle coke / wax powder were added to the inner and outer coat slurries respectively. At room temperature and pressure, camphor sublimates from solid to gas without turning to liquid [2]. Needle coke is a special type of petroleum product prepared with coal and crude oil. It is known for high strength, good resistance to thermal shock [3]. Montan wax is hard and is most resistant to oxidation which will improve the mechanical properties of the shell [4].

2. Experimental work

Ceramic shells were prepared using the slurries made up of aluminum silicate refractory powder and colloidal silica binder. In the first investigation, camphor was added to the inner coat slurry and needle coke was added to the outer coat slurry in small proportions (around 2%). In the second investigation, camphor was again added to the inner coat slurry and montan wax powder was added to the outer coat slurry in small proportions. Both the modified slurries were stirred for 24-48 hours. Six layers of coatings were given around the pattern using these modified slurries. During firing, camphor sublimated leaving micropores in the inner coating while needle coke / montan wax powder got burnt leaving macropores in the outer coatings.

2.1 Permeability measurement test

Permeability is the ability of ceramic shell to allow hot gases to escape through it. For the measurement of permeability, a sample has been prepared using silica tube of 300 mm long and 8 mm diameter, as shown in Fig.1.

Fig. 1 Sample prepared for permeability measurement.

2.2 Shell strength test

For shell strength measurement, flexural strength tests was conducted on three- point bending over a span of 90 mm using test pieces of 70 mm long 10 mm width and 10 mm depth. Instron 5800R, UTM was used for the testing machine at a constant load rate of 1 mm/min until failure. The MOR, σ_{Max}, was calculated using the following equation.

$$\sigma_{max} = \frac{3P_{max}L}{2WH^2}$$

Where P_{max} is the fracture load, L is the test span, W is the width of test piece and H is the height of test piece.

3. Results

Permeability measurement test was carried out on both the modified shells and the relation between pressure and flow of air has been measured at the constant temperature. From Fig. 2, it can be seen that modified shell 2 (with needle coke) is more permeable than the modified shell 1 (with montan wax). As the pressure was increasing, flow of air also increased.

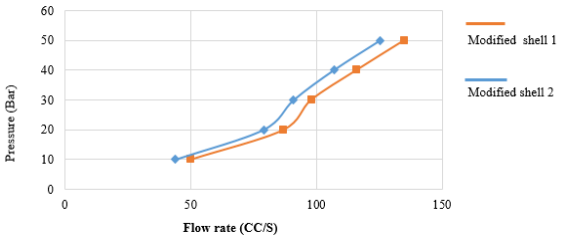

Fig. 2 Sample prepared for permeability measurement.

For the mcechanical testing, five samples were tested and MOR was calculated, as shwon in Table 1. It can be seen that modified shell 2 (with needle coke) has higher MOR (σ_{max}) for all the samples than that of the modified shell 1 (with montan wax powder). From Fig. 3, it can be seen that, after firing camphor got sublimated leaving micropores behind. Image was captured using a LIO, 435VP scanning electron microscope.

Table 1 MOR calculated for both modified shells.

Sn.	Modified shell 1	Modified shell 2
	σ_{max} (MPa)	σ_{max} (MPa)
1	8.834	9.713
2	8.528	9.640
3	8.319	9.935
4	8.480	9.404
5	8.720	9.773

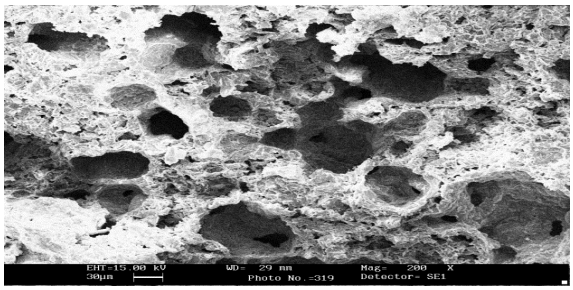

Fig. 3 Microstructure of inner coat of the shell after adding camphor.

4. Conclusions

- Needle coke modified shell has shown more permeability than montan wax powder modified shell.
- Wax modified shell has a maximum MOR of 8.834 MPa while the needle coke modified shell has a maximum MOR of 9.713 MPa.
- Modification of the ceramic slurry by the addition of camphor has improved the permeability of the shell by creating micro-pores inside the inner part of the shell.

References

[1] F. Wang, F. Li, B. He, and B. Sun.: Ceramics International. 40 (2014) 479-486.

[2] U. Bayram, S. Aksoz, and N. Marasli: Thermochimica Acta. 531 (2012) 12-20.

[3] S. Birghila, I. C. Carazeanu, and A. Dumitru: *Study on Physical-Chemical Properties of Petroleum Cokes*, (Romania Journal of Physics, 2011) pp. 976-982.

[4] O. Bemblage and D. B. Karunakr: *A Study on the Blended Wax Patterns in Investment Casting Process*, (Proceedings of the World Congress on Engineering 2011) pp. 721-727.