Intensification of Mechanical Properties of the Investment Shell Using Camphor

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***Abstract* - Investment casting process has been a widely used process for centuries. It is known for its ability to produce components of complex shapes with dimensional accuracy and excellent surface finish. Investment casting has been used to make manufacture weapons, jewellery and art castings during the ancient civilization and today it is used to manufacture engineering components. In Investment casting wax patterns are made by wax injection and then coating of the wax patterns are done by ceramic slurry, made with silica flour and binder. After dewaxing and firing molten metal is poured in the shell and solidified casting can be achieved. Investment casting can be cast any ferrous and non ferrous metal which is difficult in die casting. Finishing operations are negligible and very thin sections as.75mm can also be cast which is not possible in sand casting but there are many challenges in Investment casting. Shell prepared by conventional investment casting method has very low mechanical properties which is very important for making heavy products. In the present work mechanical properties of the shell can be increase by addition of mixture of Camphor. It will increase mechanical properties like mould thickness, flexural strength, adjusted fracture load and plate weight of the shell.**

***Index Terms* - Investment casting, camphor, mould properties**

I. INTRODUCTION

Investment casting process has been extensively used for ages. This process is well known for producing dimensionally accurate products with excellent surface finish. This process is worldwide famous for the production of complex and near net shaped products with closer tolerance. It is used to fabricate art statuettes, jewellery and weapons in ancient civilization but today mainly used for the fabrication of engineering components [1].

In investment casting process ceramic coating is done on the pattern made by wax, plastics, frozen mercury, tin and ice. Fabrication of investment slurry is prepared by refractory flour and binder. These ingredients are mixed in investment mixer and pattern is dipped into the slurry and then coarse grained stuccos are applied by the rain fall method and pattern is placed for the drying process and this process is done for the seven to eight times and ceramic mould is made[2].

Ceramic slurry ingredients should be done with care for the achievement of optimum properties. Selection of refractory flour is important because the mesh size of the powder forms certain types of defect in the casting. If the grain size of the flour is very small, gases will entrapped at the time of pouring and solidification and if grain size is very large surface of the casting will be demolished. Most widely used binder is colloidal silica. It consists of a colloidal dispersion of spherical silica particles in water. It has excellent properties for general purposes but it slows drying process of the mould especially in inaccessible pockets or cores. Ethyl silicate, second largest used binder, is alcohol based [3]. It dries much faster than colloidal silica but is more expensive and poses fire and environmental hazards. Shells prepared with water based binder have very low green strength which is prone to cracking during wax removal and handling. Sharp corner experiences large mechanical stress during processing [5]. This problem was overcome by the addition of liquid polymer, either latex based for alkaline system or PVA based acidic binder [2].

Liquid polymers were replaced using organic fibre. Yuan and Jones added organic fibre and found increased mould thickness especially at corners and edges. However, modified moulds were showing low green strength because of smooth surface of nylon fibre. It was also seen that very less force and resistance required removing fibre from the matrix [6]. To reduce this problem, Wang *et al.* have added needle coke to outer layer of the shell. Rough surface of the needle coke had improved green strength of the shell. Shell thickness at flat section was increased by 30% and at sharp corner was increased by 60% by needle coke. Shell modified with needle coke had Investigations have done to calculate green strength and thickness at flat and trailing edges of modified mould and results were compared with mould prepared using conventional method. shown better strength and higher load bearing capacity as compared to full fused silica shell. In the present work camphor is mixed with the ingredients of ceramic slurry and shells were prepared and mechanical properties were calculated.

Fig.1 Camphor

Camphor is a natural product derived from the Camphor laurel tree with the process of steam distillation and purification by sublimination. It can also be produced artificially by vinyl chloride and cyclopentadience with intermediate dehydronorbonyl chloride [7]. Solid camphor is white in colour and shiny as shown in Fig. 1. At ordinary temperatures and pressure, camphor sublimates into its gas, avoiding liquid form [8]. In present work, camphor is used to study strength of ceramic shell. Camphor is added to primary and subsequent secondary layers of the shell. Fig. 1 shows camphor in powdered form.

II. EXPERIMENTAL WORK

Ceramic slurries were prepared by conventional and modified ingredients as shown in Table 1. Full fused silica slurry consisted of colloidal silica binder and aluminium silicate refractory filler material. These ingredients were taken into investment mixer and stirred for 24-48 hours and first coat was applied on prepared wax pattern. A zircon stucco (80/120 mesh) was applied by rainfall method and dried at a temperature of 25ºC for 24 hours. Subsequent five layers were applied in same manner. Coarse stucco (16/30 mesh) was used as backup stucco. Each subsequent coat was dried at 25ºC for 4 hours. Outermost coat was applied and dried at room temperature for 24 hours and microwave dewaxing was done at 150ºC for 10 min. For modified mould, camphor was added to the slurry with the ratio of 2% wt of slurry ingredients and 5 coatings were done on same manner as done in the case of full fused silica mould. For the outermost coating conventional ingredients used and prepared shell dried at room temperature for 24 hours. Microwave dewaxing was done at 150ºC for 10 min and firing of shell done at 400ºC. Flat wax patterns of dimensions approximately 150mm×50mm×10mm were used for flat bar mechanical testing. Both conventional and modified moulds were cut into MOR plates by grinding wheel. For the testing of mould thickness 30º V-shaped wax pattern was used to prepare the mould. The V-shaped pattern was 50 mm tall, 20 mm wide with a included angle of 30º [9].

Table 1 Details of ingredients of ceramic slurry

Slurry	Conventional slurry	Camphor modified slurry
Aluminium silicate	50%	50%
Colloidal silica	40%	40%
Camphor	n/a	2-5%
Zircon powder	5%	5%
water	Few drops	Few drops

Fig. 2 shows flat bar pattern and V-shaped pattern used for testing.

Table 2 Parameters taken for the preparation of ceramic slurry

Mould system	Coat	Slurry type	Stucco	Dip time (s)	Drain time (s)	Dry time (h)
Conventional shell	1	Primary	Zircon 80/120	30	60	24
	2-5	Secondary	Zircon 16/30	30	60	6
	6	Outer	n/a	30	60	24
Modified shell	1	Primary	Zircon 80/120	30	60	24
	2-5	Secondary	Zircon 16/30	30	60	6
	6	Outer	n/a	30	60	24

Flexural strength testing was done using three-point bending over a span of 70 mm. Length of the test piece was 90 mm with a width of 10 mm. Prepared samples were loaded and tested in an Instron-5800R universal testing machine with constant load rate of 1mm/min until failure. MOR σ_{max} , was calculated using Eq. (1) [1].

(a) (b)

Fig. 2 (a) V-shaped pattern (b) Slurry coating on wax pattern

$$\sigma_{max} = \frac{3P_{max}L}{2WH^2} \qquad (1)$$

Where *P max* is the fracture load, L is the span length, W is the width of the specimens and t is the height of the specimens.
For the comparison of load bearing capacity of both moulds was calculated using adjusted fracture load (AFL). AFL is defined as the load necessary to break a normalised 10 mm wide test piece across a 70 mm span. AFL was calculated using Eq. (2) [1].

$$AFL_B = f_B \sigma_{max} H^2 \qquad (2)$$

Where f_B is a constant having value 0.1.
AFL represents the load bearing capacity of the mould when external load is applied.

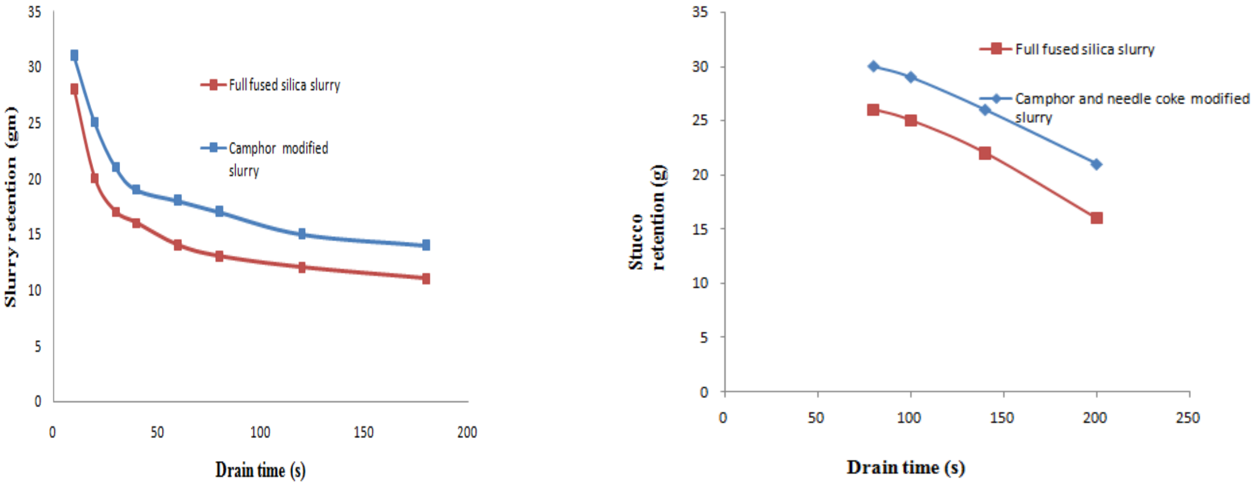
III. RESULTS AND DISCUSSION

Mould build

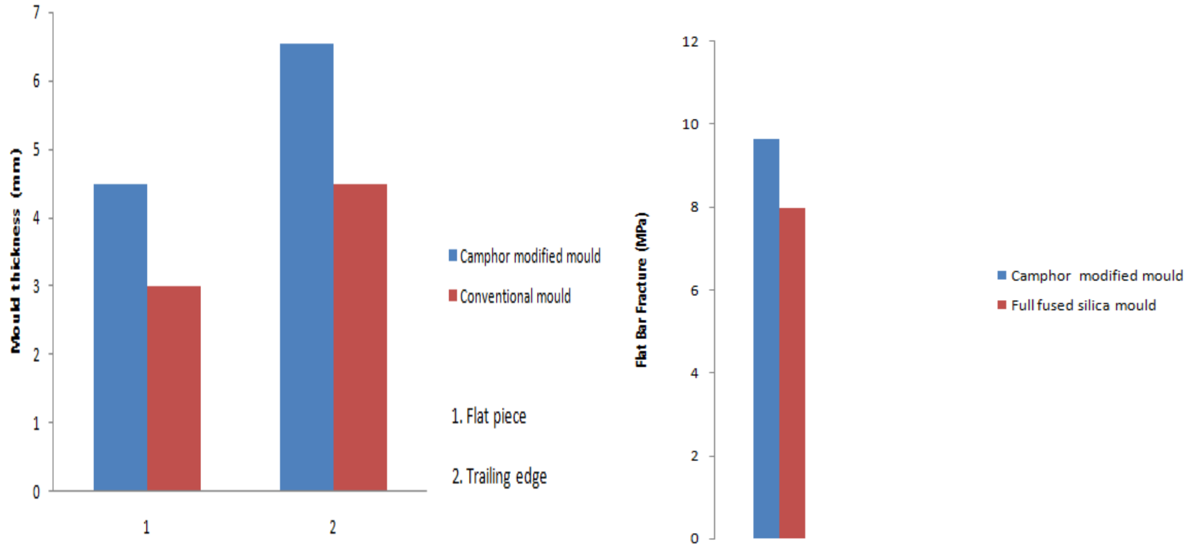
In order to determine the plate weight after coating the slurry a metallic plate has been taken and coats have been applied and retention of slurry and stucco with respect to drain time have been calculated. Plate weight test is basically to find out the adhesive properties of the slurry and stucco to metallic plate. Retention of slurry with respect to drain time has been shown in Fig.3 (a). From the figure it is seen that camphor modified slurry has more retention after dipping as compared to conventional full fused silica mould. From the Fig.3 (b) it can be seen that the mould having camphor had a higher stucco retention rate as compared to mould with full fused silica.

The V-shaped pattern produced for the measurement of thickness of the mould at flat and sharp corners are shown in Fig. 3 (c). From the figure it has been seen that camphor has improved the mould thickness at flat section by 30% as compared to full fused silica mould in a six- coat system. In sharp corners and edges thickness was improved 45% by adding camphor as compared to full fused silica mould.

The results obtained for mould strength tests at 400ºC are dipicted in Fig.3 (d). Camphor modified shell had higher flexural strength, 9.658 MPa, as comperd to a full fused silica mould having 7.976 MPa. For mould modified with camphor fracture load of 30.67 N while full fused silica had fracture load of 11.59 N. Fig. 4(a) shows application of load at different positions for shells prepared with both slurries. Fig 4 (b) shows comparison of strength and load capacity of green mould sample.

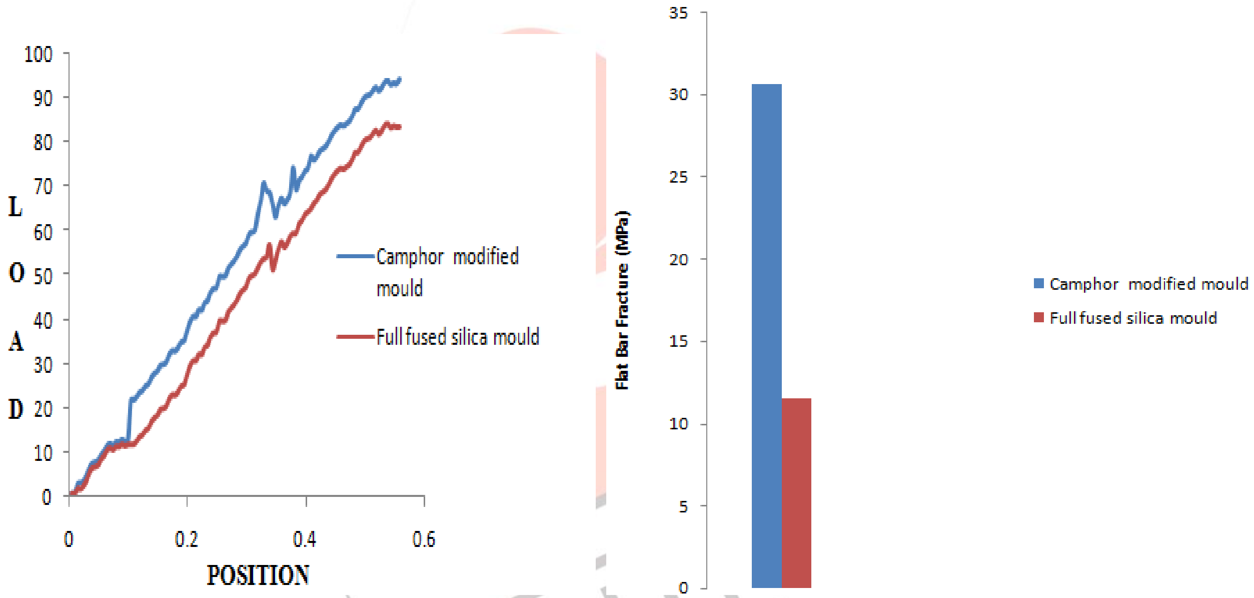


(a) (b)



(c) (d)

Fig. 3 (a) Drain time vs. retention of slurry, (b) Drain time vs. retention of stucco, (c) Mould thickness comparison of both slurries, (d) Flexural strength graph of both slurries.



(a) (b)

Fig. 4 (a) Comparision of strength of both shells (b) comparison of load bearing capacity of the moulds.

IV. CONCLUSION

Addition of camphor has increased the thickness at flat surfaces by 30% and at trailing edges by 45% ,as compared to a full fused silica slurry. To equate this there will be less number of coats required for camphor and it will reduce the production cost and time in the industries. Flexural strength of the shell is very high in case of camphor modified shell as compared to full fused shell.

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