CHARACTERIZATION OF CERAMIC SHELLS USING RUTILE (TITANIA) AS REINFORCING FILLER AT CASTING TEMPERATURE

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Abstract: The ceramic shells were fabricated with ceramic slurry containing rutile (titania) as filler material and colloidal silica binder. The shell characteristics in terms of hot bending strength and hot permeability were measured. The hot bending strength was found high at 500°C. It was witnessed the removal of grain boundary defects, grain growth, and phase transformation to larger rutile nanocrystallites at 1000°C.

Keywords: Ceramic shells, rutile, colloidal silica, hot strength, hot permeability.

1. Introduction

The materials used to build the ceramic shell, especially binders and refractories, play a vital role in the production of quality castings [1-3]. The refractory filler materials exert their influence on the properties of ceramic slurry and ceramic shell moulds and the quality of castings. Silica [4] is generally used in the form of silica glass (fused silica), which is made by melting natural quartz sand them solidifying if to form a glass. It is crushed and screened to produce stucco particles, and it is ground to a powder for use in slurries. Its extremely low coefficient of thermal expansion imparts thermal shock resistance to moulds, and its ready solubility in molten caustic and caustic solutions provides a means of removing shell material chemically from areas of castings that are difficult to clean by other methods. It is reasonably good for casting most iron-base alloys and some cobalt-base alloys that are air melted. Alumina [4] is produced from bauxite are by the Bayer process. It is more refractory than silica and is less reactive toward many alloys than the siliceous refractories. It has had some use for super alloy casting, and this application has increased with the growth of directional solidification processes. Alumina is generally considered too expensive and unnecessary for commercial hardware casting. Alumina has poor resistance to thermal shock. Castings poured in the alumina shells are relatively difficult to clean. Molochite (54-55 % Silica, 42-43%alumina) is made by the High temperature calcination of china clay [5]. China clay is produced from in the traditional way by bombarding the pit face with jets of high-pressure water take the clay into suspension together with quartz and mica. The particular qualities of English china clay's Cornish deposits provide a suitable raw material, which is refined, processed blended, calcined, crushed, graded, and packaged to deliver a product used in the manufacture of ceramic moulds for lost - wax casting.

The objective of the present work was to characterize the ceramic shells fabricated by rutile titania as a filler material added to the colloidal silica binder.

2. Materials and Methods

The colloidal silica binder was used to fabricate the ceramic shells from rutile (titania). The crystal structure of rutile (titania) is shown in figure 1. The crystal structure is tetragonal in shape The specifications of colloidal silica binder and rutile (titania) are, respectively, given in table 1 and table 2. The colloidal silica binder was used in the present work. Two grades of stuccoing sand were employed in the present investigation.

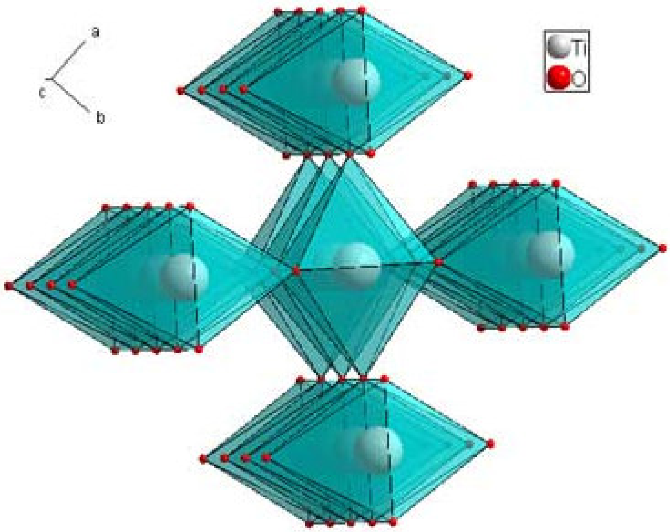

Figure 1. Crystal structure of rutile.

Table 1. Specifications of silox binder

Property	Amount
Silica (SiO_2) Wt%	30
P^H at 25^0C	10.5
Titrable Alkali (Na_2O)	0.6
Chlorides/ Sulphates	Traces
Specific gravity, g/cc	1.23

Primary sand: A finer grade silica sand having AFS grain fineness number 120. This is a synthetic sand. This sand was used for first two coats, called prime coats to get good surface finish and every detail of the wax pattern.

Backup sand: A coarser grade sand having AFS grain fineness number 42. This sand was used for the rest of coats, called backup coats on the ceramic shells. This is a river sand. The backup sand was employed to develop more thickness to the shell walls with minimum coats.

Table 2. Specifications of rutile titania

Density, g/cc	4.23
Refractoriness, ^0C	1843
Chemical composition	TiO_2 (99.0% +)
Sieve analysis	200-mesh (74 μm) 325-mesh (45μm)

2.1 Manufacture of ceramic shells

The ceramic shells were made of applying a series of ceramic coatings to the wax patterns. The pattern was first dipped into the dip-coating slurry bath. The pattern drains off excess slurry and to produce a uniform layer. The wet layer was immediately stuccoed with coarse silica sand. Each coating was allowed to dry in the open air. The operations of coating, stuccoing, and drying were repeated six times. The seventh coat was left unstuccoed to avoid the occurrence of loose particles on the shell surface. The first two coats were stuccoed with sand of AFS fineness number 120 and the next four coats were with sand of AFS fineness number 42. After all coats, the shells were air dried for 24 hours. Two shells of each treatment were made.

2.2 Hot strength of ceramic shells

The dimensions of specimens are 25mm X 32mm X t mm, where t is the thickness of the shell. The specimens used for bending test are shown in figure 2. The test of hot modulus of rupture was conducted on the universal sand- strength testing machine with attached electrical oven as shown in figure 2. The temperature of the oven was measured with a thermocouple attached to it. To find hot modulus of rupture, the ceramic shell specimens were heated to various temperatures and the same was tested simultaneously in the oven for the bending strength.

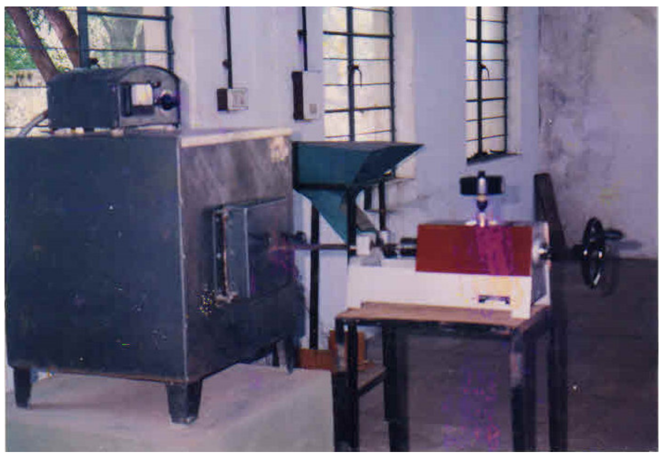

Figure 2. Hot bending strength test

2.3 Hot permeability of ceramic shells

The internal diameter of the permeability specimen is 36mm. The standard permeability meter with attached electrical oven as shown in figure 3 was employed to measure the permeability number of the ceramic shells [94]. The time taken for airflow of 2000cc under constant pressure of 10cm was measured at different temperatures. The outer diameter of the shells was measured using vernier calipers.

Figure 3. Hot permeability test

3. Results and Discussion

The effect of sintering temperature on the hot modulus of rupture of ceramic shells is shown in figure 4. The filler to binder ratio was 0.6 cc/ml. The modulus of rupture of rutile shells increases with increasing temperature upto 500 °C and latter on the modulus of rupture starts decreasing with increasing temperature. This is due to polymorphic transformation of TiO2.TiO2 in bulk form exists in three crystalline polymorphs : Two tetragonal phases anatase (figure 5a) and rutile (figure 5b) and a third orthorhombic phase, brookite. With increasing temperature, rutile nucleates within the anatase phase and grows in size consuming the surrounding anatase. The removal of grain boundary around the packed small crystals is seen at 500oC (figure 6b). The migration of atoms is revealed from the interface of small crystallites to larger crystallites at 700°C and grain growth (figure 6c). From figure 6d it is observed the removal of grain boundary defects, grain growth, and phase transformation to larger rutile nanocrystallites at 1000°C.

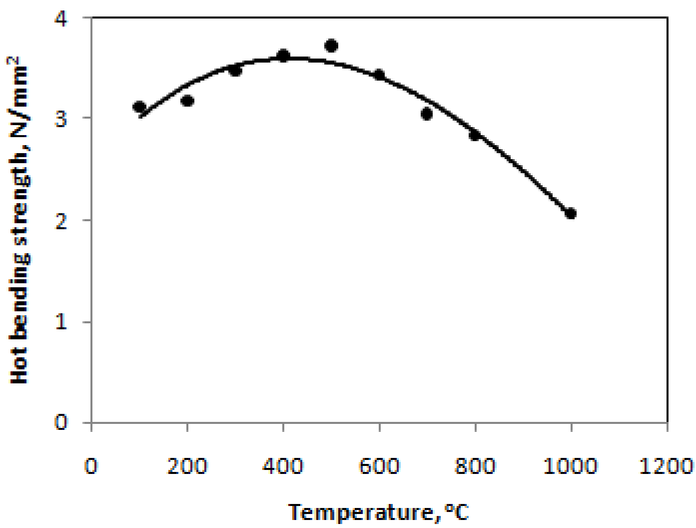

Figure 4. Effect of temperature on hot shell strength.

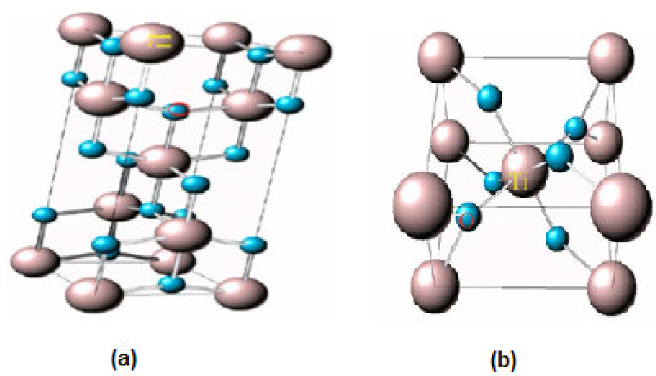

Figure 5. Crystal strucuture of TiO2: (a) anatase Phase and (b) rutile Phase.

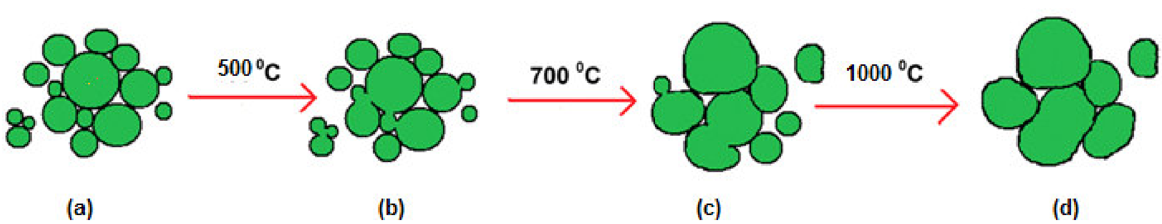

Figure 6. Schematic representation of temperature-induced grain growth of TiO_2.

The affect of sintering temperature on hot permeability of shells is observed from figure 7. Initially the hot permeability increases with increasing temperature on account of loss of water content from the pores of ceramic shells. The permeability is maximum at 200 °C. The permeability of shells decreases beyond 200 °C of temperature due to sintering. The sintering results in closing of voids in ceramic shells.

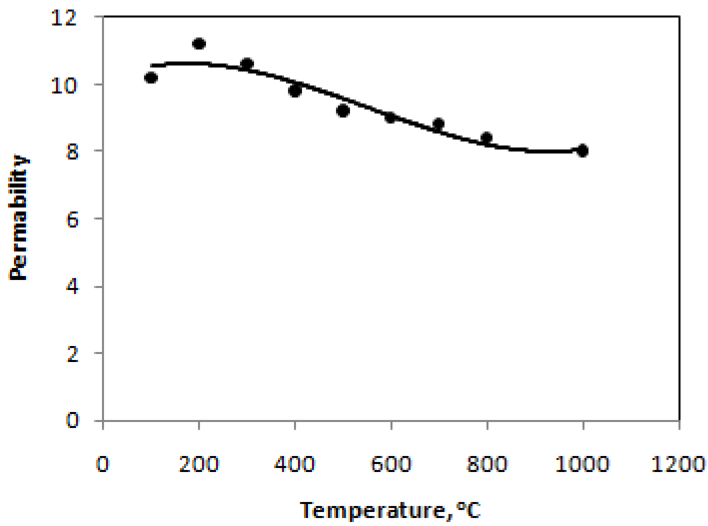

Figure 7. Effect of temperature on shell permeability.

4. Conclusions

The modulus of rupture of rutile shells increases with increasing temperature upto 500 °C and latter on the modulus of rupture starts decreasing with increasing temperature. The permeability is maximum at 200 °C.

References

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