CHARACTERIZATION OF CERAMIC SHELLS FABRICATED USING YTTRIA AS REINFORCING FILLER

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Abstract: The ceramic shells were fabricated with ceramic slurry containing yttria as filler material and colloidal silica binder. The slurry characteristics in terms of sedimentation and kinematic viscosity were measured. The green bending strength was determined to find the bonding strength of the ceramic shells. The yttria shells exhibit high strength for filler to binder ratio of 0.78 cc/ml.

Keywords: Ceramic shells, yttria, colloidal silica, sedimentation, viscosity, strength, 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. The problems of ceramic shell making based on different binders have been discussed in many papers. But there are very few publications, where there is an exposition of physico-chemical- thermal phenomena due to refractory materials. It is an essential to have a good binder [1-3] if it is to be used to the best advantage and consistent ceramic shells are to be produced. Many references are available to the industry today are, in general, conventional colloidal silica, colloidal silica based proprietary binders, sodium silicate, ethyl silicate and hybrids using ethyl silicate.

In addition to the binders, refractories are also used in the construction of ceramic shell mould. There are two grades of refractories used: flours (fillers) for use in the slurries and grains for stuccoing the shell. The refractory filler materials in the dip-coating slurries range from 200 to 600 mesh in particle size. Materials finer than this have higher surfaced energy, which results in sintering at appreciably, lower temperatures. Coarser materials ranging up to 325 mesh are used in backup slurries. The coarser materials produce the high porosity required for back up coats. The refractory materials for stuccoing range in size from 20 to 100 mesh, the fine material being used for the initial coat and progressively coarse grains form subsequent coats.

The refractory filler materials used today to prepare the investment slurries are silica, zirconia, alumina, and aluminum silicates. The important properties of refractory filler materials to be considered for investment shell moulds are density, refractoriness, grain size and shape, p^H and thermal conductivity. The refractory filler materials exert their influence on the properties of ceramic slurry and ceramic shell moulds and the quality of castings.

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

2. Materials and Methods

The colloidal silica binder was used to develop and characterize the ceramic shells from yttria. The crystal structure of yttria is shown in figure 1. The specifications of colloidal silica binder and yttria are, respectively, given in table 1 and table 2. The grade -3 colloidal silica binder was used in the present work. Two grades of stuccoing sand were employed in the present investigation.

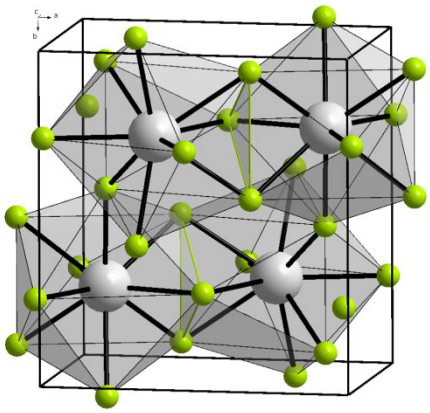

Figure 1. Crystal structure of yttria.

Table 1. Specifications of silox binder

Property	Grade-1	Grade-2	Grade-3
Silica (SiO_2) Wt%	20	25	30
P^H at 25^0C	9.5	10.0	10.5
Titrable Alkali (Na_2O)	0.4	0.5	0.6
Chlorides/ Sulphates	Traces	Traces	Traces
Specific gravity, g/cc	1.12	1.18	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 Yttria

Density, g/cc	5.01
Refractoriness, ^0C	2425
Chemical composition	Y_2O_3 (99.0% +)
Sieve analysis	200-mesh (74 µm) 325-mesh (45µm)

2.1 Preparation of the slurry

Dip coating slurries were prepared by adding the refractory filler powder to the binder liquid, using sufficient agitation to break up agglomerates and thoroughly wet and disperse the powder. The filler/binder ratio in the slurry was according to the design of experiments.

2.2 Sedimentation of the slurry

Measuring of the sedimentation was executed on the principle of determination of the sediment height in certain time interval [4]. This was performed in the glass tube of 25mm dia, 400mm high, with 1mm scaling. The tube was filled with 100ml of the silox binder, and the refractory filler powder was added in steps of 50g to prevent air trapping in the lumps. After the whole quantity has been added, the tube was sealed with a rubber plug, and the

contents were shaken for about 1min. The mixture was allowed to settle for 90min. Sediment height was registered after 15,30,45,60 and 90min. Afterward, the tube should be flushed promptly with binder and water.

2.3 Viscosity of the slurry

The ford viscosity cup to measure the slurry viscosity was designed and fabricated as per the dimensions mentioned in the ASTM HandBook [5]. The original design concept of this viscometer was derived from the Hagen- Poisuille law " which states that the efflux time of a fixed volume through a capillary is proportional to the viscosity of the fluid". The design and dimensions of ford cup are given in appendix-A. The formula to convert the time of flow in seconds, t to kinematic viscosity, ν is given by

$$\nu = 12.1 [t - 2.00] \quad (1)$$

The ford cup was adjusted in the stand as shown in fig 3.3, so that its upper edge was horizontal. The orifice of the cup was blocked by a finger, and the cup was filled by thoroughly mixed slurry, until a convex meniscus appeared above the upper edge. Excess slurry was scraped off with a straight edge. With the opening of the orifice, a stopwatch was started simultaneously to measure the time from the beginning of outflow until the first break in the stream. The kinematic viscosity was also computed. Following each determination, the cup was cleaned by methonal, water and a soft brush.

2.4 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.

2.5 Bonding strength of ceramic shells

Bonding strength of the ceramic shells was measured in terms of the green bending strength [2]. 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 design of the test-rig upon which the ceramic specimens were broken is given in appendix-B. The green bending strength of the ceramic shells was carried on a universal sand-strength testing machine (hydraulic type). The green the green bending strength was standardized with respect to the standard bending specimen (25mmX25mm).

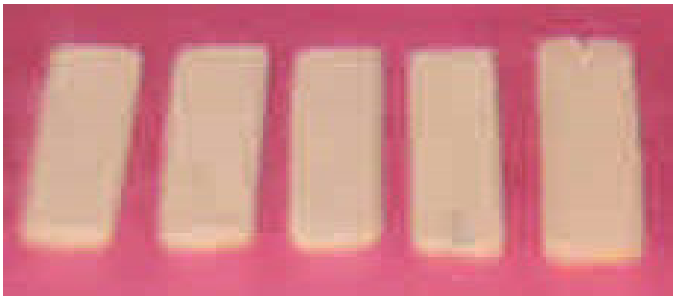

Figure 2. Specimens for bending tests

3. Results and Discussion

The characteristics of slurry and ceramic shells are discussed in the following sections. Each experiment was repeated twice and average reading was taken into consideration.

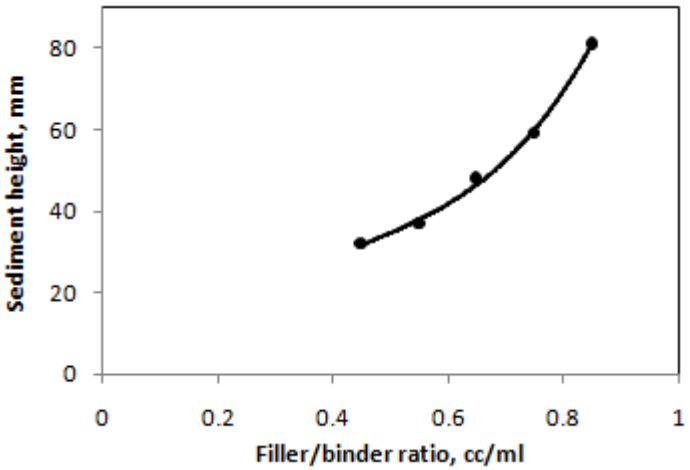

Figure 4. Effect of filler loading on sedimentation.

3.1 Characteristics of ceramic slurry

The effect of filler loading in the slurry on sedimentation is displayed in figure 4. It is observed that the slurry becomes growingly denser with increasing content of filler in the slurry. The resultant downward force (gravity force due to filler loading minus buoyancy force of liquid binder) is higher for larger filler to binder ratios, and subsequently result the settling down of filler particles in the slurry column. The effect of aging on the slurry viscosity is shown in figure 5. The kinematic viscosity of dip – coating slurries increases with aging time (ripening). During aging time, some part of liquid content in the slurry evaporates. The evaporation makes the slurry denser. The ripening of dip – coating slurry promotes the wettability of filler particles and pre – gelling of the slurry. The pre – gelled and denser slurry takes more time to pass through the orifice of Ford cup and subsequently resulted high kinematic viscosity to the dip – coating slurry.

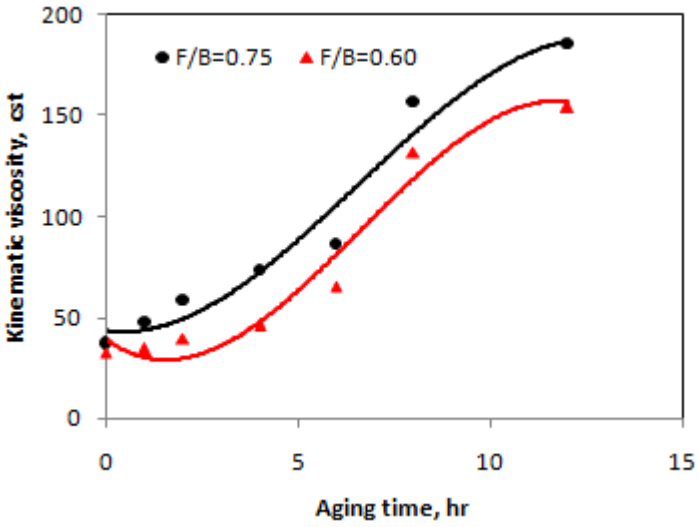

Figure 5. Effect of aging time on viscosity of ceramic slurry.

3.2 Bonding strength of ceramic shells

Figure 6 reveals the effect of filler loading in the slurry on the bonding strength of shells. Yttria shells exhibit high strength for filler to binder ratio of 0.78. This is mainly due to

completion of electrostatic bonds between silicon radicals in the binder, filler particles and stuccoing sand grains at this slurry composition.

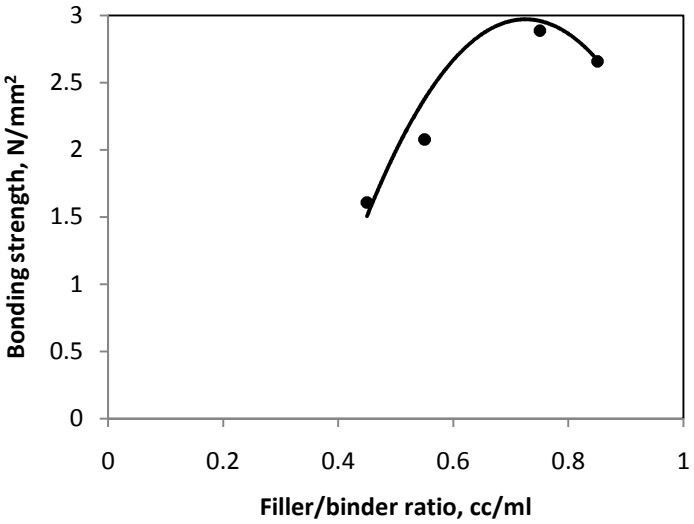

Figure 6. Effect of filler loading on shell strength.

4. Conclusions

The sedimentation increases with increasing content of filler in the slurry. The kinematic viscosity of dip – coating slurries increases with aging time. The yttria shells exhibit high strength for filler to binder ratio of 0.78 cc/ml.

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