ANALYSIS OF HOT CERAMIC SHELL BEHAVIOR AT CASTING CONDITIONS

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Abstract
This paper presents the behavior of ceramic shells prepared from flyash at casting conditions. The hot modulus of rupture of the ceramic shells is influenced by the recrystallization of silica into cristobalite in flyash. The hot permeability decreases with the sintering and thermal expansion of filler and stucco particles. The ceramic shells at casting conditions experiences surface cracks.

Key words:
Hot ceramic shells, flyash, casing conditions

1. INTRODUCTION

The ceramic shells are poured at high casting temperatures depending upon the type metal to be cast [1]. These casting temperatures generate thermal stresses owing to expansions of refractory materials used to manufacture ceramic shells [2-6]. When a liquid metal is poured; the metallostatic pressures exert on the walls of ceramic shells. The ceramic shells should withstand the induced thermal stresses and metallostatic pressures to counteract the break and distortion. When the ceramic shell is broken, there will not be any casting; or, when it is distorted, the dimensions of casting will be affected.

This paper focuses onto the behavior of ceramic shells at casting temperatures. SEM was used to reveal the cracks, which were generated due to thermal shocks in the shells.

2. MANUFACTURE OF CERAMIC SHELLS

The ceramic slurry was prepared from coal-flyash as filler material and colloidal silica as binder. The ceramic shells were made of applying a series of ceramic slurry to the wax patterns. The pattern was first dipped into the ceramic slurry bath. The pattern drain 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 [8].

3. TESTS ON THE CERAMIC SHELLS

The important characteristics of the finished ceramic shells studied are:

- Hot modulus of rupture
- Hot permeability
- % thermal expansion

3.1 Hot modulus of rupture of the ceramic shells

The test of hot modulus of rupture was conducted on the universal sand- strength-testing machine with attached electrical oven as shown in Figure 1. 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 [9].

3.2 Hot permeability

The specimens used for permeability test are shown in Figure 2. The internal diameter of the permeability specimen is 36mm. The standard permeability meter with attached electrical oven was employed to measure the permeability number of the ceramic shells. 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. The permeability number was calculated using the standard procedure.

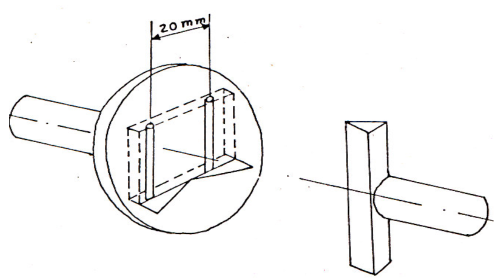

Figure 1. Hot modulus of rupture test

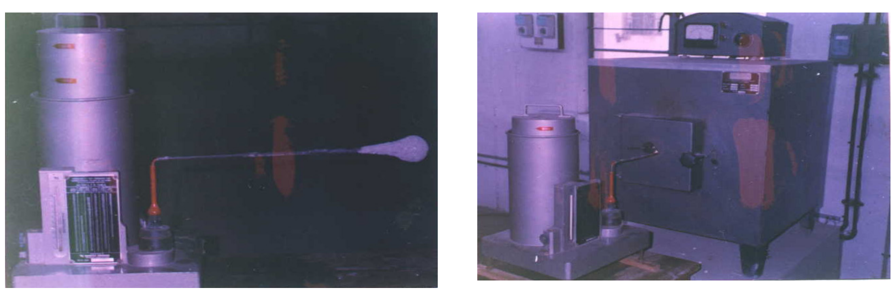

Figure 2. Hot permeability test

3.3 %thermal Expansion

It was measured in terms of %volume expansion of the ceramic shells. The length, width and thickness of the shells were measured using vernier calipers before and after sintering in the electrical oven.

4. RESULTS AND DISCUSSION

4.1 Hot Modulus of Rupture of Shells

The effect of sintering temperature on the hot modulus of rupture of ceramic shells is shown in Figure 3. The modulus of rupture of flyash shells increases with increasing temperature upto 500 °C and latter on the modulus of rupture starts decreasing with increasing temperature. This is due to the partial conversion of silica content in the coal flyash to cristobalite. The recrystallization of silica to cristobalite results in softening of the ceramic shell.

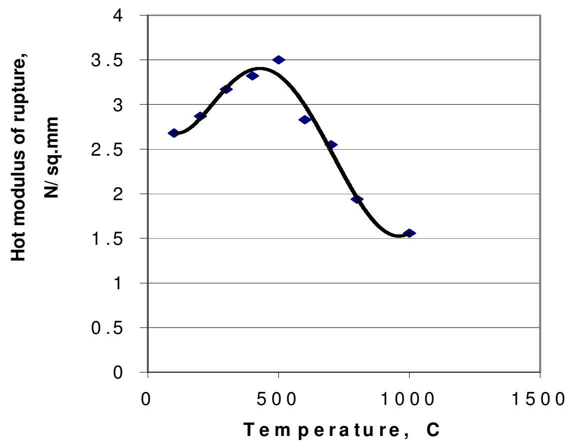

Figure 3. Effect of sintering on the strength of the shells

4.2 Hot Permeability of Shells

The affect of sintering temperature on hot permeability of shells is observed from Figure 4. 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 the ceramic shells. The flyash shells show grater permeability owing to the round (spherical) particle shape of coal flyash.

4.3 % Thermal Expansion of Shells

Figure 5 shows the thermal expansion curves for flyash shells. The thermal expansion curve for flyash shells is non-linear. The non – linear nature of thermal expansion is due to mixed expansions of the constituents of coal flyash and phase transmission between 500 to 600°C.

4.4 SEM Analysis

The SEM photographs of ceramic shells are shown in Figure 6. The ceramic shells which were sintered at 700°C were observed under scanning electron microscope (SEM) for cracks. The intensity of cracks in the flyash shells is high. This is mainly due to various thermal expansions of different constituents of coal flyash. The thermal expansion causes the filler and / or stucco sand particles strain against each other, and thereby debonding the particles. The debonded particles on further heating dislocate or slip one over other and results to opening of cracks in the ceramic shells. The cracks in the ceramic shells are only limited to surface. This is supported by the reduction of permeability in the ceramic shells with prolonged heating.

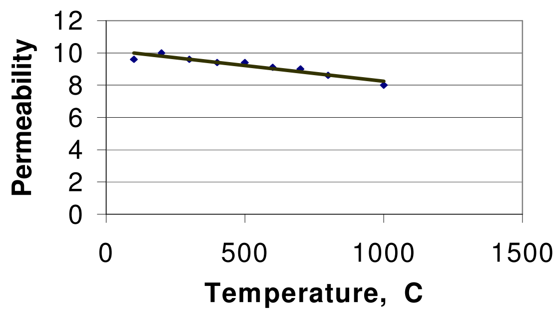

Figure 4. Effect of sintering on the permeability of the shells

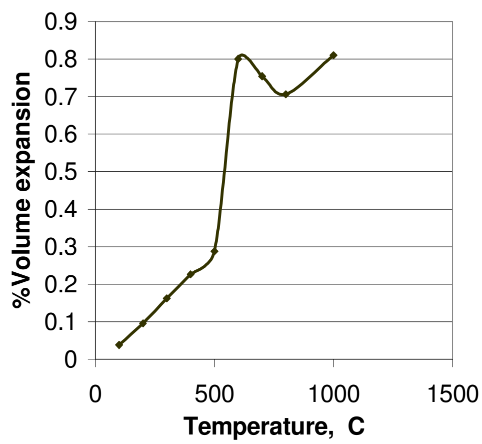

Figure 5. Effect of sintering on the thermal shock of the shells

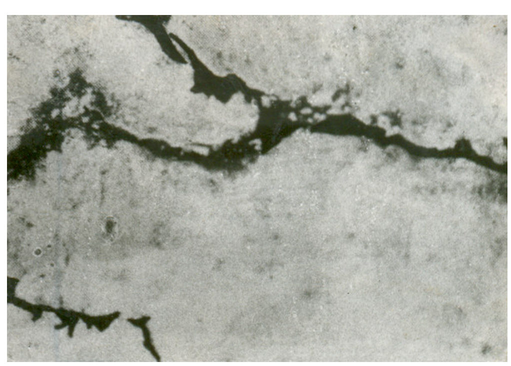

Figure 6. SEM photomicrograph of the ceramic shells sintered at 700^0C. Dark areas represent surface cracks. Magnification is 1000X.

5. CONCLUSIONS

The following conclusions are drawn

1. The strength of flyash shells has increased with the increase of temperature (due to sintering) upto 500 °C, and latter on it decreased due to recrystallization of silica into cristobalite in flyash. The maximum hot modulus of rupture for was 3.50 N/mm^2 at 500 °C for flyash shells.

2. Initially the permeability of liquid medium during heating and latter on it has decreased owing to sintering and closing of voids resulted due to expansion of filler and stucco particles. The maximum hot permeability values for flyash shells were respectively 10.0.

3. The heating of shells during sintering operation has caused the opening of surface cracks due to non-linear and mixed expansion and contraction of flyash constituents.

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