Some Aspects of Reducing Sedimentation Rate of Refractory Fillers in the Investment Casting Process

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Abstract
This paper highlights the reduction of refractory filler sedimentation in the dip coating slurries used for the investment shell moulds. The methods employed are viz: the use of low density filler, the use of high level silicon radicals in the binder and continuous stirring of slurry.

Introduction

In the manufacture of ceramic shell moulds by the investment casting process a multi-layered ceramic shell is build up by repeatedly dipping a wax pattern in a slurry; draining and sprinkling with a coarse stucco grit. Each individual coat is hardened prior to applying the next coat.

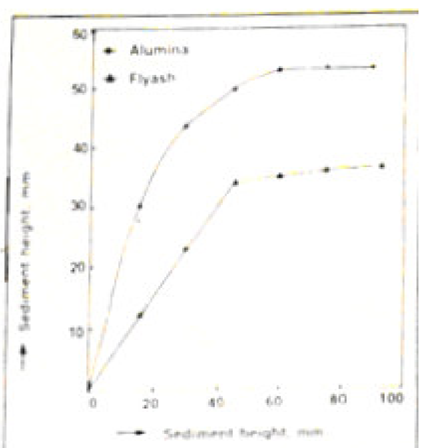

Fig.1: Effect of standing time on sedimentation in the unagitated slurry.

Slurries for shell making are refractory materials dispersed in a binder. The refractory materials include fused silica, alumina and zircon powder. In the shell making process, the slurry prepared will be used over a period of 8 to 12 hours depending on the number of coats given to the pattern. Therefore, during the standing time of slurries, the refractory filler will settle down. The highest sedimentation is attained by zircon powder and the lowest by fused silica. This is in relation to their densities: zircon powder, 4.6; alumina, 4.0; and fused silica, 2.6. Slurries are very important to insure a consistent strength of shells (1).

These facts led to the search for methods of reducing the sedimentation rate of refractory materials in their slurries. The sedimentation rate of refractory materials was reduced by grinding with unburnt betonite or titanium oxide. The method of grinding resulted in decreasing the refractoriness of materials. In another trial, addition hexantrol or polyxypropylentrol to the slurries was tried to reduce the sedimentation rate of refractory filler materials. Using this method, the strength of shells was decreased (2).

A change in the binder chemistry alone is not enough (3); change in binder (4); refractory filler and a method of process maintenance are needed. In the present work, some strategies have been developed to reduce the sedimentation rate of refractory fillers in their slurries as described below:

Method-I	The level of colloidal silican radicals were increased in the binder. The binder is colloidal silica.
Method-II	A low density refractory material was used to prepare the dip-coated slurry. For this purpose coal flyash, a solid waste from thermal power plants was employed. (5,6). The chemical composition of coal flyash is given in table-1. The results of coal flyash were compared with those of alumina.
Method-III	The dip-coated slurries were stirred for different intervals of time for the process maintenance.

Experimental set up

Materials used:

Refractory filler materials: Alumina and coal flyash (particle size = 45 μm)

Binder: Colloidal Silica (20%, 25% and 30 % SiO_2)

Table-1 Chemical analysis of coal flyash

S.No.	Particular	% Weight
1	Sio_2	60.43
2	$Al_2 0_3$	33.02
3	$Fe_2 0_3$	2.03
4	Tio_2	1.64
5	Mn o	0.03
6	Ca o	0.22
7	Mg o	0.43
8	$P_2 0_5$	0.26
9	So 3	0.05
10	Na 2°	0.50
11	K2°	0.76
12	Loss on ignition (LOI)	0.63

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Stucco materials: Primary stucco (AFS 120) and Secondary stucco (AFS 50) sands.

Slurry Preparation

Dip-coated slurries were prepared by adding the refractory filler material to the binder liquid, using sufficient agitation to break-up agglomerates and thoroughly wet and disperse the powder. The filler to binder ratio is 0.65.

Shell Preparation

Ceramic shells for bending test were made by applying a series of ceramic coating to the patterns. A wax pattern was dipped into an investment slurry bath. The pattern was then withdrawn from the slurry and manipulated to drain off excess slurry and tp produce uniform layer. The wet layer was immediately stuccoed with relatively coarse ceramic particles by sprinkling the particles on it from above. Each coating was allowed to dry before the next was applied. The operations

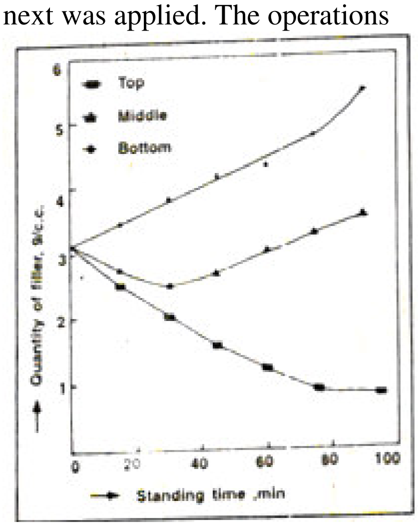

Fig. 2: Effect of standing time on alumina particle distribution in unagitated slurry.

of coating, stuccoing and hardening were repeated six times. The first two coats were given with primary Stucco sand and next four coats with secondary stucco sand. The final coat was left uncoated in

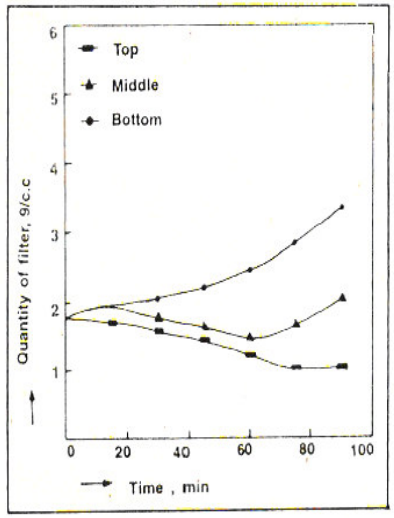

Fig.3: Effect of standing time on coal flyash particle distribution in the unagitated slurry

order to avoid the occurrence of loose particles on the shell surface.

Tests Conducted

Measuring of sedimentation was executed on the principle of determination of the sediment height in certain time intervals. This was performed in a glass tube of 25 mm dia. 400 mm high with 1-mm scaling. Viscosity of the slurries was measured by a ford cup with a 5 mm dia. nozzle. For performing particle distribution of refractory filler materials the slurries were tapped from top, middle and bottom of the container. The slurries were then allowed for drying in the open air till the entire liquid content was evaporated. The residue was weighed and considered as the amount of filler particles distributed at a particular lay. The bending strength of shells was tested on a universal sand strength machine (of Versatile Equipment Pvt. Ltd.) (7).

Results and Discussion

Effect of standing time of slurries

It can be seen from fig.1 that alumina exhibits high sedimentation rate than coal flyash. During the standing time of slurries, the water content starts evaporating, thus the slurry becomes denser. The refractory filler will also start settling down in the slurry owing to its density (higher the density greater the gravity force). The density of alumina is 4.0 p/cc and that of coal flyash is 2.01.

There may be gradient of filler particle content along the standing column (from top to bottom) of slurry in the container. In fig.2 and 3 the distribution of alumina and coal flyash particles respectively, at three different locations of the container is given. The size of filler particles is 45μm. the silica content in the colloidal silica binder is 25%. The filler to binder ratio is 0.65. Relative humidity and maximum temperature of atmosphere are 56.8 and 37.4^{o}C respectively. Initially the amount of filler particles was same at all the top locations. With the progress of time, the slurry near the portion of container gets depleted of filler

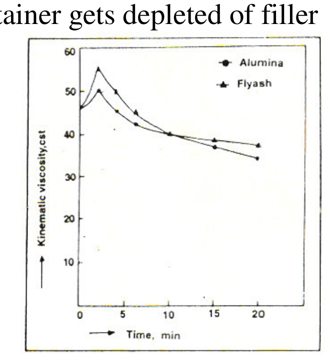

Fig.4: Effect of stirring time on viscosity of slurry

where as the lower portion gains further amount of filler due to sedimentation.

It can also be examined that the rate of sedimentation from the top layer was higher in the slurry of alumina; whereas the slurry of coal flyash has better retention of particles in the top layer. This may be due to the lower density of coal flyash and partly due

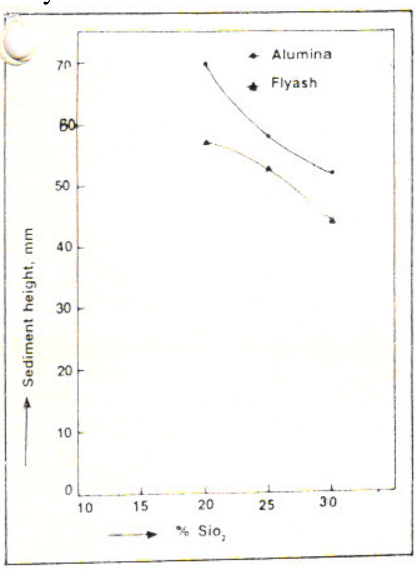

Fig.5: Effect of level of silica in binder on sedimentation (standing time = 60 min)

To the hollow spherical structure of flyash particles.

Effect of Stirring

In fig.4 the viscosity of the slurries made with alumina and coal flyash is shown. Viscosity initially tests excessively high because of air entrainment and lack of particle wetting. The tendency of air entrainment was more in the case of slurry containing coal flyash. Therefore, stirring was continued until the viscosity was fallen to its final level before the slurry was put into use. Stirring is required in production to keep the refractory powder from settling out of suspension. The slurries of alumina and flyash without stirring give respectively the shell bending strength of 2.05 and 2.82 N/mm^2. Whereas the same slurries with continuous stirring provide the shell bending strength values of 2.72 and 3.25 N/mm^2.

Effect of Silica Content in the Binder

The effect of silica content level in the binder on the sedimentation rate of filler is shown in fig.5. the density of the binder is directly proportional to the level of its silica content. The slurry prepared with a binder of high level silica content promotes greater buoyancy force to the refractory filler. The rate of sedimentation of filler is low in the slurries prepared with the binder of high level silica content. In fig.6 the bending strengths of shells made with alumina and coal flyash are shown. Strength of shells increases with increasing content of silica in the binder. This may be due to uniform distribution of filler and homogeneity of the slurry.

Conclusion

Refractory fillers possessing lower densities exhibit low sedimentation

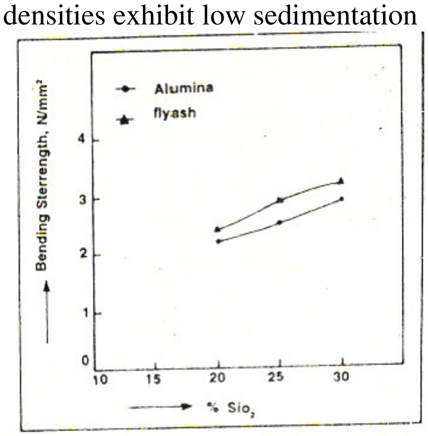

Fig.6: Effect of level of silica in binder on strength of shells (continuous stirring)

rate in the slurries and higher strength to the shells. Continuous stirring is required to keep the refractory filler from settling out of suspension in the slurry. The strength of shells is increases with stirring of slurries. Use of binders containing high level of silica content promotes higher buoyancy force to the refractory filler from settling down in the slurry and also provides greater strength to the shells.

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