Interfacial Reaction between Magnesium Alloy and magnesia Ceramic Shell Mold

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Abstract: The ceramic shells were fabricated with ceramic slurry containing magnesia as filler material and colloidal silica binder. The shell characteristics in terms of hot bending strength, thermal expansion and hardness were measured. The non–linear nature of thermal expansion in the ceramic shells is on account of phase transmission of stuccoing sand. The MgO was found at the interface of magnesia investment shell mould and AZ91E alloy.

Keywords: Investment shells, magnesia, hot strength, thermal expansion, metal-mould reaction.

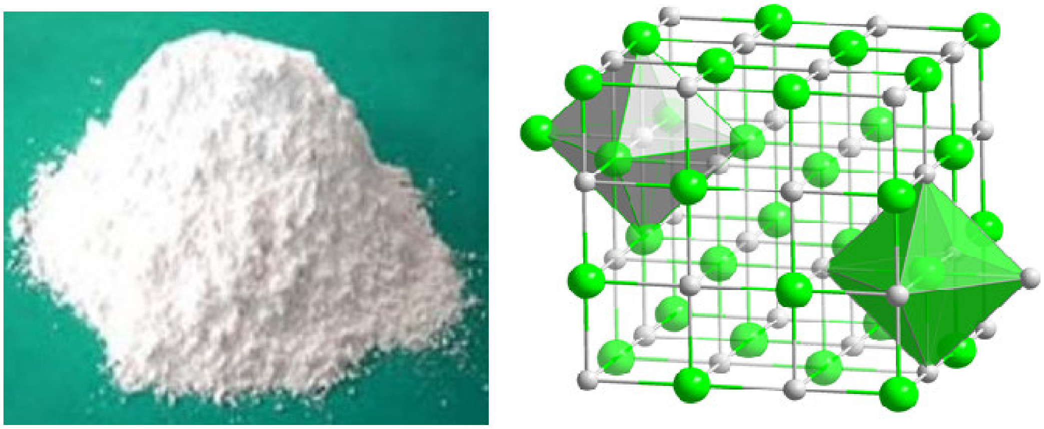
1. Introduction

Magnesium is the lightest of all commonly used metals. Due to its excellent damping capacity, which provides vibration absorption ability, corrosion resistance and excellent machining characteristics, use of magnesium in industry, particularly in automobile industry is consistently increasing [1]. The suitability of ceramic moulds to be used for making Aluminum – Lithium castings was investigated [2]. The lost wax process made molds. Visual inspections of the as – cast casting surfaces indicated that there were large gas bubble defects due to melt –mold interaction when those were cast into conventional moulds consisted of SiO2 center dot ZrO_2 filler. X-ray microanalysis showed that the main product of that interaction was Li_2 Co_3. However, good quality Al-Li castings were obtained when cast into ceramic moulds which consist of MgO filler, TiO_2 binder and Al_2 O_3 stucco under an argon atmosphere. The ultimate tensile strength ceramic mould castings of Al- 2.5% Li- 2% Mg- 0.15% Zr- 0.12% Ti alloy was lower by around 85% than that of the metal mould castings, while its elongation was 5%. The materials used to build the investment shell moulds, especially refractories, play a vital role in the production of quality castings [2-7]. The properties of refractory fillers, which affect the shell quality, are melting point, thermal expansion, and metal - mould interaction. During the casting process, molten zirconium alloys can easily react with the mold materials and produce a surface contamination layer.

In the present work, magnesia was used as refractory filler material to fabricate investment shell moulds for casting of magnesium alloy AZ91E alloys.

2. Materials and Methods

The colloidal silica binder was used to fabricate the ceramic shells from magnesia (MgO) as a reinforced filler material. Magnesium oxide is produced by the calcination of magnesium carbonate (figure 1). The specifications of colloidal silica binder and magnesia are, respectively, given in table 1 and table 2. Two grades (primary and backup sands) of stuccoing sand were employed in the present investigation. Finer grade silica sand having AFS grain fineness number 120 was employed for primary coats. This is 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. Coarser grade sand having AFS grain fineness number 42 was employed for back up coats. This is river sand. The backup sand was employed to develop more thickness to the shell walls with minimum coats.



(a) (b)

Figure 1. Magnesite: (a) powder and (b) crystal structure

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

Table 2. Specifications of magnesia

Property	Magnesia
Density, g/cc	3.58
Refractoriness, ^0C	2852
Chemical composition	MgO
Sieve analysis	200-mesh (74 μm)

2.1 Manufacture of ceramic shells and Mg-alloy castings

The investment 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 magnesia 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. The pre-heated investment shells were poured with Ti-alloy.

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 (figure 2). 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. 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.

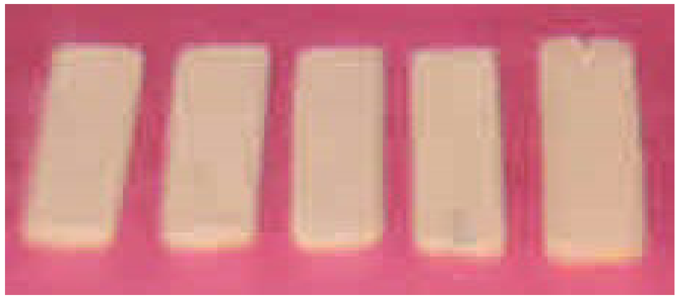


Figure 2. Specimens for bending tests

2.3 % thermal expansion of ceramic shells

It was measured in terms of %volume expansion of the investment shells. The length, width and thickness of the shells were measured using vernier calipers before and after sintering in the electrical oven. The % thermal expansion was computed using the following formula:

$$\% \text{ thermal expansion} = \frac{V_2 - V_1}{V_1} \times 100$$

where, V_1 is the volume of the shell before sintering and V_2 is the volume of the shell after sintering.

2.4 Estimation of Metal-Mould reaction

Vickers hardness was carried out to find the hardness of surface layers of the castings. Scanning electron microcopy was carried out to characterize the fine-scale topography and establish the microscopic mechanisms governing metal-mould reaction. The scanning was carried in IICT (Indian Institute of Chemical Technology - Hyderabad) S-3000N Toshiba shows Scanning Electron Microscope.

3. Results and Discussion

The effect of sintering temperature on the hot bending strength of magnesia investment shells is shown in figure 3. The filler to binder ratio was 0.75 cc/ml. The hot bending strength magnesia shells decreases with increasing temperature [10].

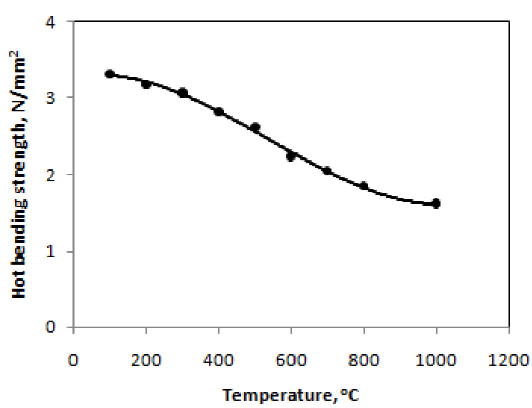


Figure 3. Effect of temperature on hot strength of ceramic shells.

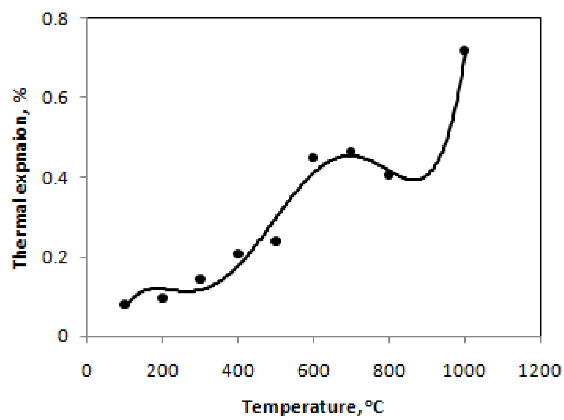


Figure 4. Effect of temperature on thermal expansion of shells.

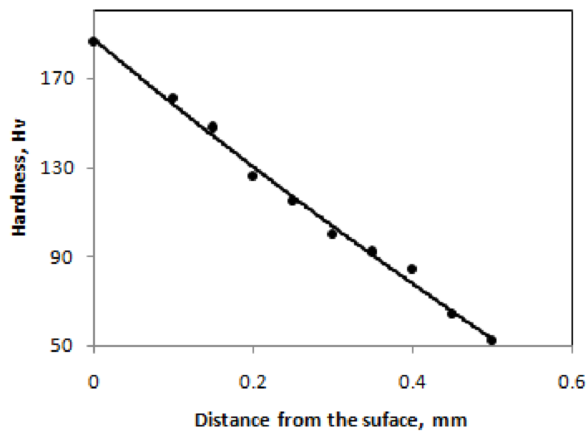


Figure 5. Hardness profile metal-mould interface.

The thermal expansion curve for investment shells is illustrated in figure 4. The fluctuation is on account of phase transition of primary and back up sand used for sprinkling of shells [11]. Figure 8 shows the hardness profile of a sample from 25mm thick AZ91E alloy casting made in magnesia investment shell mold. The hardness has a function of depth from the surface decrease with an increase in depth (figure 6a). Formation of a thicker magnesia (figure 6b) case in 25 mm thick casting is due to slower cooling rate experienced by the thicker casting.

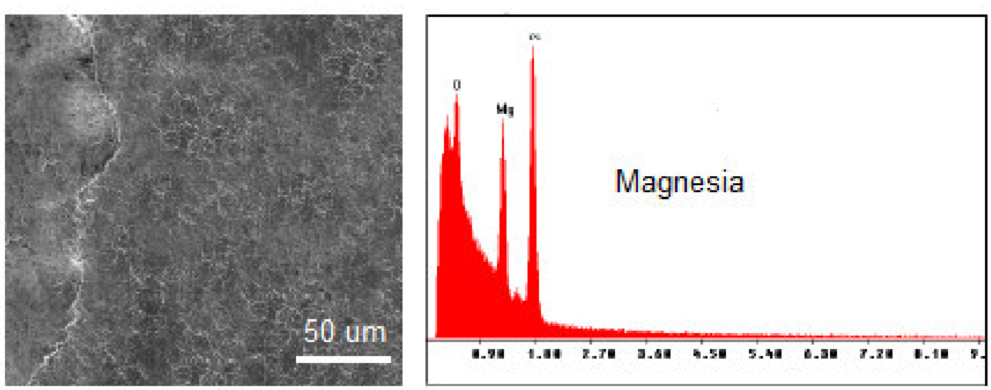


Figure 6. Metal-mould reaction (a) hardness variation and (b) formation of α phase

4. Conclusions

The hot bending strength fused silica shells increases with increasing temperature. The non–linear nature of thermal expansion in the ceramic shells is on account of phase transmission of stuccoing sand. The MgO was found at the interface of magnesia investment shell mould and AZ91E alloy.

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