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Characterization of the refractory coating material used in vacuum assisted evaporative pattern casting process

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ABSTRACT

In the production of the casting using evaporative pattern of expandable polystyrene, the refractory coating applied to the pattern is an extremely critical factor. The coating is not required merely to prevent a direct contact with the sand and metal. But its main task is to support the sand during the brief interval between the gasification and replacement of pattern by the molten metal. In the present study, refractory filler material (flyash) has been used for coating the evaporative polystyrene patterns. Effect of temperature on the powder mixture containing zircon flour, filler material and binder was determined using Differentially Thermal Analysis (DTA) in the range from ambient temperature (20 °C) to 1000 °C. Powder particle morphology was analyzed by the scanning electronic microscope. X-ray diffraction analysis of the coating samples was carried out for 2θ values from 10° to 80°. Prepared slurry was applied on the polystyrene pattern of 20 kg/m^3 density. Coating thickness was maintained between 0.15 and 0.20 mm. Al–7% Si alloy was poured at the pouring temperature (700 °C). Microstructure of the casting was investigated. The result reveals that the sample 4 has less material loss. It contains large and small particles and fine pores. Particles of different grain size contribute to better uniform, continuous coating on pattern due to cohesion between the particles. The phases ($ZrSiO_4$, TiO_2, Fe_2O_3, Al_2O_3 and SiO_2) make the stable compound which leads to high temperature refractoriness.

1. Introduction

The Evaporative Pattern Casting (EPC) process, which employs expanded polystyrene pattern placed in unbonded silica sand, is increasingly gaining popularity in the foundry industry (Birkel et al., 1988). The great innovative potential of the EPC process was first recognized in the 1980 in the USA and Japan. This process offers many benefits such as flexibility in design configuration, reduced development time, cost and reduction or elimination of machining. About 140,700 tons of aluminum, iron and steel were cast using EPC process in 1997. It was estimated that EPC will account for 29% of aluminum and 14% of ferrous casting market in 2007 (Hunter, 1998).

At the present time, one serious limitation of EPC process is the formation of blow holes in the castings. The blow holes or gas porosities are generated due to the burning of polystyrene pattern in the sand mold. The gases evolve in the casting. To overcome the problem of blow holes, EPC process is combined with the Vacuum Sealed Moulding Process (V-process). The vacuum applied to EPC mould draws the decomposed gases and improves the casting quality. The developed hybrid process has been termed as Vacuum Assisted Evaporative

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Pattern Casting (VAEPC) Process (Kumar, 2006). Researchers have developed interest in utilizing unbonded sand mold to contain the pattern during introduction of molten metal. Special adhesives are utilized to bond the assembled pattern segments into a completed pattern. These adhesives are required to exhibit certain characteristics if acceptable defect free castings are to be produced. Clusters of individual patterns are then assembled and joined to a central vertical gating system utilizing similar adhesives. Refractory coating is then applied to the total surface of the pattern cluster and dried in a low temperature oven (Ballmann, 1988).

One of the most important steps in this process is coating. The coating is applied to the surface of the completed pattern assembly cluster. It produces a smooth, acceptable surface finish of the castings. It also provides the rigidity of the pattern assembly cluster after the coating has been oven dried. This rigidity minimizes distortion of the pattern shape during mold compaction (Ballmann, 1988). The coating should have a good wettability for foam material and should be durable and flexible during handling the patterns (Clegg, 1985). The coating should stabilize the area between the liquid metal front and the solid foam against the pressure of the sand and otherwise be permeable for the cracking products of the foam, e.g. liquid or gas phase (Dhafer et al., 2002).

There are several kinds of evaporative pattern coating with different thermo-physical characteristics, which are specially designed to meet number of requirements of the EPC process (Acimovic et al., 2003). Dieter (1965) used zircon flour coating for aluminum alloy while Acimovic et al. (2003) used kaolin and talc. Sodium silicate coating is not recommended because it lacks permeability and can lead to metal splashing during mold filling (Clegg, 1978). For the cast iron, a coating based on iron powder has been found successful in preventing metal penetration problems (Clegg, 1978). The high pouring temperature ranges of cast iron and steel usually dictate the selection of a silica or mullite type refractory. The binder is responsible for the cohesion of the amorphous particles as well as with the polystyrene of the pattern. For function of adherence there are multiple functional polysilances after acid hydrolysis band following condensation to interconnect the baking material as well as substrate (Dhafer et al., 2002).

Only a limited work has been carried out towards improving coating material characteristics. Zircon flour is an expensive coating refractory. In order to reduce the cost of coating aggregate, to be used on the polystyrene patterns, refractory filler material may be added as an additive to zircon flour. In the present study, refractory filler material such as flyash was added in the zircon flour. X-ray analysis of the coating samples was done. Morphology of the samples was analyzed by scanning electronic microscope (SEM). Differentially Thermal Analysis (DTA) was also done to measure the temperature effect on the samples. Microstructure of the casting was investigated.

2. Vacuum assisted evaporative pattern casting process

The VAEPC process starts with the pre-expansion of polystyrene beads, which contains pentane as blowing agents. After the pre-expanded beads are stabilized, they are blown into mold to form pattern sections. When the beads are in the mold, a steam cycle causes them to fully expand and fuse together; this process is followed by an in-mold cooling cycle. The pattern is made to the exact shape of required components, including all shrinkage and machining allowances. Feeders, runners and gating systems made in polystyrene are added at the suitable points (Sikora, 1978). The pattern coated with suitable refractory wash is embedded in dry unbounded sand which is vibrated to produce a rigid mold. On pouring, the molten metal replaces the polystyrene pattern, precisely duplicating all of the features of the pattern. After shake out, the casting requires minimal fettling because the expandable pattern requires no mold joint lines and cores may be eliminated entirely (Clegg, 1985).

3. Materials and methods

The choices of particular slurries will depend on the alloy and casting temperature being used. In the present investigations, slurries have been formulated using a mixture of zircon flour, flyash as a filler, and bentonite as binder. The water is used as a solvent. The specific refractory materials used in this investigation are (i) the zircon flour – 200 mesh (ii) flyash – 270 mesh (iii) bentonite – 270 mesh. The following combination of materials has been prepared for the analysis of coating materials, to be used in VAEPC process:

sample 1: zircon flour (20%) + flyash (70%) + bentonite (10%),
sample 2: zircon flour (40%) + flyash (52%) + bentonite (8%),
sample 3: zircon flour (60%) + flyash (34%) + bentonite (6%),
sample 4: zircon flour (80%) + flyash (16%) + bentonite (4%).

All the above materials were available in fine powder form. These powders were mixed in the ball mill for 8 h.

3.1. *Slurry mixer*

The main objective of slurry mixer is to produce stable viscosity of the slurry for a given set of parameters and to eliminate much common slurry problems. Slurry must be completely wetted as partially wetted slurry will not develop its full strength. As the slurry continues to mix and refractory is wetted and air is released, the viscosity will decrease. The actual stabilization time is dependant upon the mixing method and slurry composition. Slurries need to be applied in an even, uniform coat. The quality and consistency of the primary slurry decides the quality of the castings produced. Fig. 1 shows the schematic moderate shear propeller type slurry mixer equipment. This arrangement is equipped with a speed controller that provides adequate shearing action to breaks up agglomerates and strips the air off particle surfaces allowing the slurry to stabilize in a few hours. An additional beneficial feature is the use of a timer that turns the mixer on and off for a short period of time (typically 10 min on and 5 min off). This allows air trapped in the slurry to migrate to the surface and reduces the heat buildup in the slurry due to friction. Different combinations of slurries were prepared in a steel container at