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INNOVATIVE CASTING USING MAGNETIC MATERIALS

Basavarajappa V N[*1], H B Niranjan[2] & Manjunatha A R[3]

[*1]Assistant Professor, Department of Mechanical Engineering, Sambhram Institute of Technology, Bangalore, India

[2]Professor, Department of Mechanical Engineering, Sambhram Institute of Technology, Bangalore, India

[3]Assistant Professor, Department of Mechanical Engineering, Jain Institute of Technology, Davangere, India

ABSTRACT

Casting is a manufacturing process, which is used directly or indirectly in almost every industry. It is a primary process having effect on the properties of resultant product. The history of molding and casting traces back to earlier century. It has been observed that in first and oldest generation mold was made by means of squeezing/jolting green sand, second generation binders were used in sand molding process, i.e., clay or organic resins to enhance the properties. It progressed to the third generation where physical means like gravity, vacuum, lost foam were adopted. Of the late the magnetic field is being attempted which has observed to stabilize free flowing dry molding materials. This development of unbounded casting process is to improve flexibility and enhances mold ability. The concept of unbounded casting is to change the kind of binder or to avoid substantial binder. Magnetic molding uses an expandable pattern surrounded by steel shots which are bound together by the action of an induced magnetic field. The present work has been carried to study the effect of the magnetic field and on properties of the casting. A preliminary study was carried with the 'sand cast', 'die cast' and Magnetic molding of Aluminum alloy. It's observed that the magnetic mold casting exhibited reasonably enhanced 'yield strength' compared to other molding processes, with fine grain micro-structure monitoring the properties of casting, process being environment friendly and materials are reusable.

Keywords: Magnetic molding, lost foam process, Mechanical properties, Aluminum alloy

I. INTRODUCTION

The magnetic mold consists of steel shots which are free-flowing during the molding stage and rigid during the casting and the solidification stages. The steel shots can be compacted by vibration. After compaction, the mold becomes rigid by the application of magnetic field that induces magnetic bonds between the steel shots [2]. Fig. 1 shows the main experimental steps of the magnetic molding process.

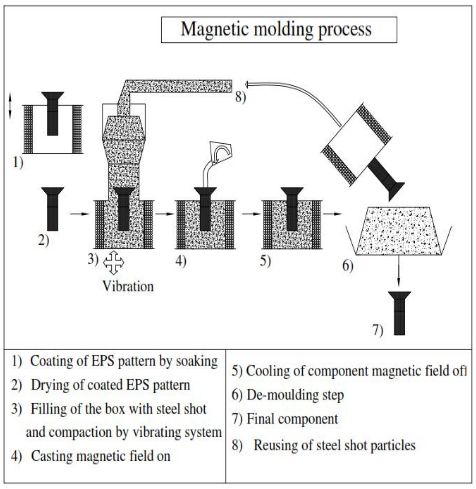

Fig-1: Schematic view of the magnetic molding process

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Besides, the magnetic molding process could offer improvements in the dimensional tolerance of products, better compaction and rigidity of the mold when compared to the conventional sand casting and die casting process. In total, the magnetic molding process is an innovating and promising process for the production of complex components, and presents very interesting aspects from the point of view of an environment and working conditions (no chemical additives, absence of sand or ceramic slurry wastes and ease of de molding).

Pierre-Marie Geffroy et al [2] in their study on "thermal and mechanical properties of grey cast iron and ductile iron castings using Magnetic molding and lost foam processes the mold made of steel shots leads to higher cooling rate of liquid metal, tend to finer microstructure, which results in enhanced properties.

A study on the performance of the mold materials on the castings is presented as follows.
'Sand casting' generally adopts silica based material which tends to render advantage such as inexpensive production cost, particularly in low volume; enable to fabricate/cast large parts both for ferrous and nonferrous castings. However, the sand as the mold material leads to the castings to be of lower degree of accuracy, and poor surface finish.

Investment Casting (lost wax or lost foam) uses disposable wax or foam pattern for each cast part. It is very precise but more expensive and being cost – efficient only when sand or plaster castings cannot be used.

Die casting is a method of using meal molding materials under high pressure and usually preferred for nonferrous alloys such as zinc, tin, copper, and aluminum. Due to the high tool costs, die casting tends to be reserved for high volume production runs as it would be uneconomical for smaller quantities. Also, the die cast components cannot be used as structural parts because of poor mechanical properties of the part.

A study on the "influence of changes caused by forced convection in solidification conditions on columnar crystal zone and its limitations" carried out by J. Szajnar [4] analyzed the relation between thermal and concentration conditions, in connection with crystallization front, stability loss. They observed that, after simplification the same can be considered as columnar crystal growth.

A work on "innovative design on fabrication of energy conservation in non-ferrous casting manufacturing process" with pattern made of expandable polystyrene material P. Gnanavel [5] observed that the development of unbounded casting process improves the flexibility and enhances the mold ability. The unbounded casting, avoids substantial binder/change of binder.

A review of literature review in developing Magnetic molding, reveal limited information lowers the process indicates an enhancement of mechanical properties of cast components by magnetic molding.

II. EXPERIMENAL PROCEDURE

The first stage of the technical approach is to design the magnetic molding facility and to define and to optimize the main process parameters such as the selection of the expandable polystyrene pattern (EPS) and its coating, the size and shape of the steel shots and the pouring temperatures. Then the cast materials obtained were compared with those obtained from the sand casting and die casting processes in the same conditions. These preliminary Aluminum alloy castings were analyzed to identify the influence of the magnetic field and the mold on the characteristics of the cast products, e.g. microstructure.

Magnetic molding procedure

Preparation of the patterns

The lost foam patterns of required size were prepared by using conventional machining methods and finishing the patterns.

Coating of expandable patterns

The refractory coating of the pattern plays an important role in the magnetic molding process. The coating used in the lost foam casting process forms a physical and thermal barrier to the metal poured afterwards. As a physical barrier, the coating prevent the diffusion of liquid metal through the magnetic mold

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surrounding the pattern and the loss of the final shape due to the mold collapsing during decomposition of the pattern[2]. The permeability properties of the coating also play an important role in the elimination of gas (foam) decomposition products during
the metal pouring step.

The coating slurry contains 300 g of zirconia, 86 ml of colloidal silica and 17 g of Disponil SN. Initially, 86 ml of
colloidal silica was put as a recipient; later 300 g of zirconia was added. To avoid the formation of agglomerates and bubbles, the zirconia was added little in
steps and the mixture was agitated by a mixer. The viscosity of the slurry was adjusted between 1000 to1100cP at 50 rpm with a Brooke field viscometer. This viscosity and thixotropic nature of the slurry allowed having a constant coating thickness on the EPS pattern.
The coated patterns were dried at room temperature for over 24 h; after the drying it showed lower permeability [2,5].

Magnetic Particles
The mechanical properties of the magnetic mold during the casting are mainly determined by the nature of the steel shot in the mold and the intensity of magnetic field.

The homogenous and good compaction of steel shot allows the mechanical properties of the magnetic mold to be improved [4]. Spherical particles are therefore currently used in the magnetic molding process for filling the flask. The mean diameter of steel shot is between 1.5 to 2 mm and the average bulk density, after compaction, was 4.5gm/cm^3.

Magnetic molding casting facility
The equipment used for the magnetic molding process includes either ‘’U’’-shaped electromagnets [5] or solenoid coil. The work performed showed that the magnetic field ranging from 0.2to 2 T enhances the mechanical properties of the mold. In this study a solenoid copper coil was used, with an internal diameter of 0.16m, a height of 0.2m and a magnetic field ranging from 0.02 to 1T in the center of the coil.

Dimmerstat
It is device used to supply continuously variable A.C voltage. The output is variable from 0-270 volts from main input of 240 volts. Contact between the winding and load is through a carbon brush which covers at least one turn of wire at all times. The area of winding swept by the brush is plated with metal which eliminates oxidation and ensures a long working life with negligible maintenance. So according to the calculation in our project we are selecting the 6 Amps variable voltage dimmerstat to producing the 0.1 - 2 tesla (T) of magnetic field intensity.

The foam pattern with the corresponding filling system was placed in the cylindrical mold. The mold, which contains the first layer of steel, is progressively filled with steel shot with the help of vibrating table. This cycle of compaction leads to excellent compaction of steel shot with minimal distortions of the EPS pattern. In the case of steel shot, mold filling is more homogenous than that performed with sand. In fact, steel shot density and shape (spherical) leads to excellent shot flow inside the cavities of foam patterns. The metal was melted in a ceramic crucible (2kg) using 20kW induction furnace. Fig.2 below shows the Magnetic molding procedure [5].

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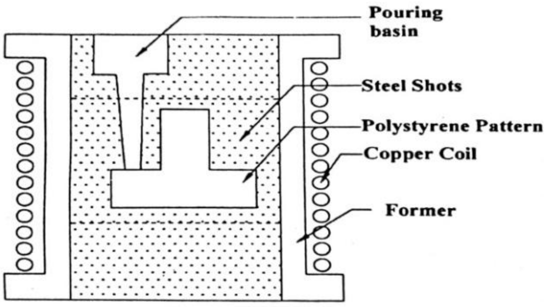

Fig.2 Schematic diagram of Magnetic molding

Fig. 3 Dimmer stat and mold with pattern

Fig. 4 Demagnetization of the mold

Fig. 5 The casting after demagnetizing

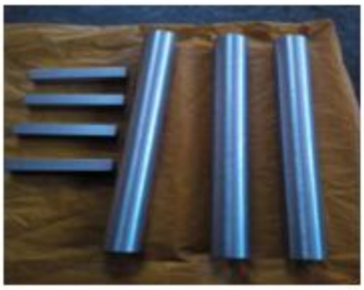

Fig. 6 The castings ready for testing

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III. RESULTS AND DESCUSSIONS

Measurement of mechanical properties

The tests were performed as per ASTM standards. The findings reveal that the yield strength and hardness (BHN) were reasonably got enhanced.

The refinement of solidification structure makes grain boundary increase significantly, which inhibits dislocation movement which contributes for enhancement in properties. At the same time, increase in grain boundary also promotes the lattice distortion. Both these factors contribute to the enhancement of strength and hardness.

Table-1: Mechanical properties

Sl. No	Mechanical Properties	Sand Cast	Metal Die Cast	Magnetic Mold Cast
1	Young's modulus (kN / mm^2)	0.893	0.915	1.175
2	Hardness (BHN)	72.56	89.89	110.14
3	Impact Strength (J / mm^2)	0.025	0.0375	0.0375

When the liquid metal was poured into the mould, the initially nucleation occurs near the mould wall. The nuclei are broken up into small fragments from the mould wall and dissociated into the melt due to convection caused by pulse magnetic pressure. This course lasts until formation of the solidification shell near the mould wall, which substantially increases the number of nuclei and suppresses the formation of columnar crystal.

It was observed that the microstructure (150X) of the current work revealed very fine grains.

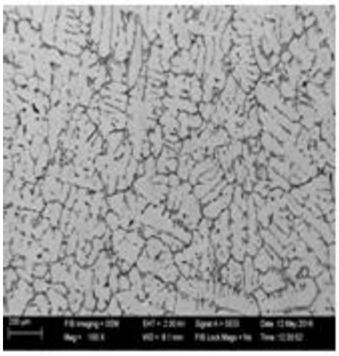

Fig. 7 Microstructure of Sand Cast alloy loy

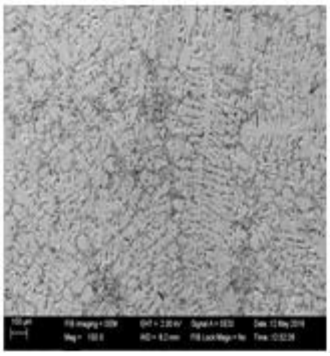

Fig. 8 Microstructure of Die Cast alloy

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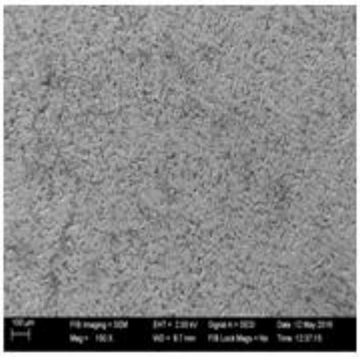

Fig. 9 Microstructure of Magnetic mold Cast alloy

1. In the sand casting the microstructure are not uniform and also have defects like porosity, blow holes, shrinkage defects etc., so this causes decrease in the strength of the cast and hardness(Fig. 7).
2. In the die casting the microstructure is reasonably uniform but grain boundary is smaller (Fig. 8) as compared to sand casting together exhibits increase in the properties
3. In the magnetic molding the microstructure is very fine and uniform (Fig. 9) as compared to other two and the grain boundary is good, which is likely to reduce the defects of the casting like porosity, blow holes etc. In this process the cast will undergo directional solidification; leading to improvement in the mechanical properties such as yield strength (31.6**%**), hardness (51.6**%**) of the material.

IV. CONCLUSIONS

It was observed that the **magnetic mold castings** exhibit better properties. Wastage of sand is completely eliminated making the process to be an eco-friendly.

From the technical point of view the main conclusions can be drawn as follows.

1. The application of the magnetic molding technology results in an improvement of the mechanical properties of ferrous and nonferrous alloys. The main aspect that can be accounted for this fact is the reduction of the grain size due to the finer microstructures obtained when compared to traditional sand casting and die casting process.
2. The magnetic fields applied do have a positive influence on dimensional tolerances of the castings. Furthermore it makes possible to apply different metal flow orientations and increase the flexibility of the lost foam process in terms of feeding and filling design.
3. The magnetic molding process is environment friendly, steel shots can be reused and recycled and the magnetic field has not any effect the health of workers
4. The investments needed to implement the technology are low cost and not any major change is needed in the facilities and equipment presently used in lost foam foundries. The process is economically feasible.
5. All kind of ferrous and nonferrous alloys can be cast.

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