Design and Development of Excitation Source to Process Functionally Graded Material Through Directional Solidification

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***Abstract*— Functionally graded material (FGM) is defined as the dissimilarity in structure and arrangement over volume. Directional solidification describes the solidification in a desired path. The FGM area of research work got concentrated on vibrations for the mold during casting, to improve mechanical and tribological properties. Al-18%wt Si alloy is used to produce FGM. The objective of proposed work is design of an excitation source to produce FGM, and comparison of mechanical properties for with and without vibrations. Due to microstructure variation and concentration gradient is achieved by the material produced with lateral base excitation have the higher mechanical properties as compared to the material produced without base excitation. In present work microstructure, hardness, wear and tensile strength for a specimen at different lengths are examined.**

Keywords*— *FGM; Directional solidification; base excitation; Al-18%wt Si alloy.

INTRODUCTION

In modern technology the modern science, energy and the materials are the three pillars. The research towards new material expansion leading the discovery of materials of high-tech field in 21st century. A fast growth has been took place in the materials at recent years [1], the reason is new experimental techniques and introduction of cross-penetration of new theories. In current engineering applications the tradition of pure metals are abridged because the introduction of alloys and functionally graded materials (FGMs), pure metals are in the homogeneous form so the properties are same for complete module, but for functionally graded material is in non-homogeneous form so material properties are different across the material. The aluminium-silicon alloy is having high tensile strength and other characteristics when compared with the different alloys like high carbon steel, and also enhanced ultimate tensile strength in aluminum and constituents are predisposed from the microstructure. These are some of the factors made us to work Al-Si as a functionally graded material in our work [1]. If the silicon is having more than 12% in Al-Si alloy then it is named as hypereutectic aluminium-silicon alloy. The hypereutectic Al-Si alloy is extensively used because of its fluidity, low thermal expansion, and decent wear resistant properties. The high temperature properties can be enhanced by adding some alloying essentials like copper, nickel, and magnesium and the hypereutectic Al-Si alloy is heat treatable one. The aluminium dendrites are formed in the melt for the period of the solidification.

FUNCTIONALLY GRADED MATERIAL

The practical problem arising from production will be solved by functionally graded materials, it is a new type of composite materials. Due to multi-functional role and its high performance, the FGMs are used in the new generation of space craft's [2] so in material science research for functionally graded materials is emerging with great potential in the recent years. The materials are expected to satisfy high performance requirements like space shuttle and other high-tech development [4]. Because of multi-functions in a single component the traditional homogenous materials are powerless. Thus formation of phase distribution, gradient of chemical composition and microstructure represents a new concept in the engineering applications [3]. So for this the main challenge is to combine a different properties in the same component, such as at low temperature require a structural toughness and at high temperature with high hardness is required this is achieved through functionally graded materials (FGM).

DIRECTIONAL SOLIDIFICATION

Solidification is phase conversion in which liquid goes into a solid when its temperature is lowered its freezing point. In directional solidification heat dissipation occurs only in one direction. The mold used for the casting is insulation brick, a hole is made at the center along its length and it made into two equal parts along the length for easy removal of specimen after solidification. The copper chill is used to get the directional solidification, copper chill is used because it is having higher thermal conductivity than other materials so it

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will help to get a better precipitation of primary silicon. The mold is placed on top of the chill and these two are packed with sand to avoid heat loss.

MOLD AND CHILL

The insulation brick is used for mold, a through hole is made at the center of brick. The insulation brick is used to avoid the heat flow. The insulation brick is made into two halves at the center for easy removal of specimen. Copper is used for chill material because it is having high thermal conductivity. For directional solidification the mold is placed at the top of the copper black. The copper block is of flat shape. These two are packed with the sand to avoid heat flow. The solidification rate of melt depends on the thermal properties of chill material.

Figure 1 Mold and Chill

EXPERIMENTAL SETUP & PROCEDURE

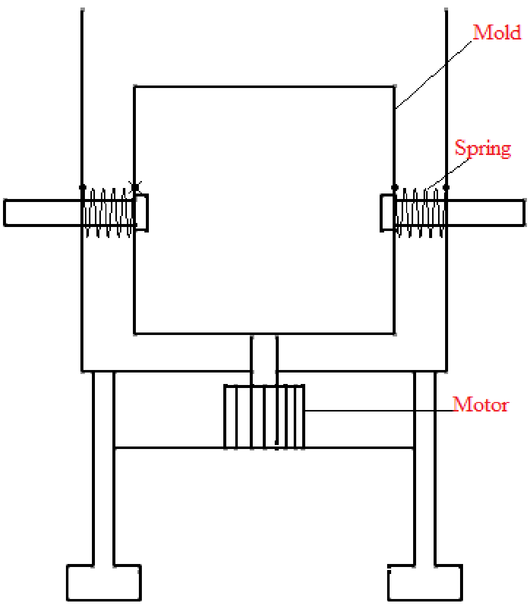

Figure 2 Vibrational set up

The vibrational set up is designed to carry out the casting, motor with eccentric cam is used to produce vibrations for the mold, the frequency of this is 50Hz with 1mm amplitude, and maximum pay load of 7kg. To hold the mold and chill arrangement a carrier is designed. The experimental set up is shown in figure 2. The vibrations are produced continuously up to the completion of solidification. After solidification the casted specimen is removed from the mold and made in to three parts that is top, middle and bottom. The specimen were prepared for hardness test and wear teat as per the ASTM standards. To find hardness Brinell hardness testing machine is used and for wear measurement ducom pin-on disc type wear testing machine is used. Wear test is carried out for three different loads i.e. 20N, 30N and 40N.

RESULTS AND DISCUSSION

HARDNESS TEST: the hardness values of the cast specimen is shown in table 1. The precipitation of silicon at the top is higher so it is having higher hardness value. The silicon present at the bottom will get precipitated and will move towards top portion hence the top portion has added up with bottom silicon results in higher particle size of silicon at the top.

Table 1 Hardness values (BHN)

	Without vibration	With vibration
Top	49.34	52.35
Middle	47.32	49.73
Bottom	44.52	46.32

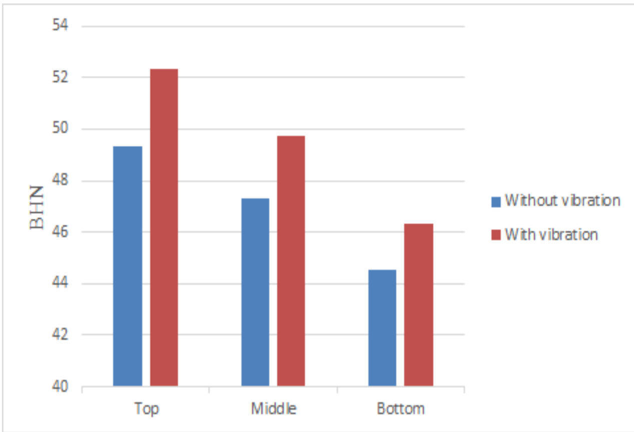

Figure 3 hardness value comparison

The hardness values increase with base excitation as compared to casting without excitation.

WEAR STUDY: FGMs will show distinctions in the properties from one portion to another. Hence it is significant to study the wear characteristics of the FGMs. wear test data in the form of specific wear rate is illustrated in figure 4. From the investigational data it is found that the wear is less at the top portion because of more silicon precipitation and specific wear rate is high. With growth in hardness progress in the wear resistance, this is because of grain size reduction is often expressed using Archard's law [5]. The wear resistance fully be influenced by upon dislocation and hardness [6]. The comparison is also made with without using vibrational set up and results showed a significant improvements in the sample which is casted with vibrations.

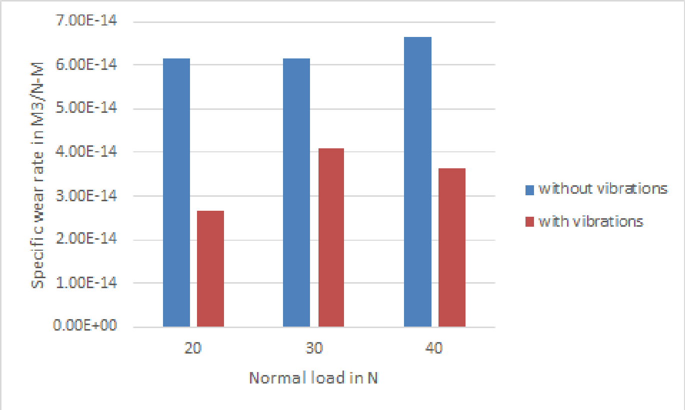

Figure 4 comparison of specific wear rate

CONCLUSION

The effect of mechanical mold vibrations on casting of Al-18%wt Si alloy was assessed. Al-18%wt Si was chosen to study the influence of mold vibration on casting features. It is originate that mechanical mold vibration has a major effect on the grain structure of casting. The hardness, wear resistance, were improved with casting in vibration. Ductility was reduced. In conclusion, with the mechanical mold vibration, refinement of the grain can be gained without use of chemical additives. Further study can be focused on the effect of poring temperature, effect of varying the frequency. Distant from the above, result of size variation of the casting and use of dissimilar materials can be studied as well.

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