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Effect of Mould Vibration on Microstructure and Mechanical Properties of Casting During Solidification

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***Abstract*— The effect of mould vibration during solidification of Al-Cu alloys was investigated to understand the modification in microstructure and mechanical properties of casting. The casting was done in a graphite mould. Frequencies were varied from 40 to 150 Hz. A casting was also was also made without vibration to compare the results of castings with vibration. The experimental results showed significantly grain refinement and remarkably improvement in hardness of castings with mechanical mould vibration during solidification.**

Keywords*— Solidification, mechanical mould vibration, microstructure, hardness.

I. INTRODUCTION

The mechanical properties of fine and non dendritic grain structure of casting are superior to the dendritic and coarse cast structure. The non dendritic structure is obtained by rheocasting and thixocasting [1-3]. In this process grain becomes golublar leads to increase in strength as well as ductility. It means toughness of globular grains will be higher than the dendritic structure. Application of mechanical vibration during solidification of melt is one of the techniques of grain refinement. This is simpler than any semisolid processing like rheocasting and thixocasting. There are number of methods for producing vibration, like electromagnetic vibration, ultrasonic vibration and mechanical vibration, however, mechanical vibration is easy to produce and control over it. A number of researchers investigated the effect of electromagnetic vibration and ultrasonic vibration on the microstructure of castings [4-8]. However, mechanical vibration is easier and economical than ultrasonic and electromagnetic methods for production of castings. By mechanical vibration during solidification, dendritic structure gets break into very fine cellular structure. Abu-Dheir et al. studied the modification of Si in Al-Si alloy for a constant mechanical mould vibration at a frequency of 100 Hz and variable amplitudes [9]. However, he has not focused on the variation of frequency of vibration. Olufemi and Ademola studied the effects of mechanical vibration on the mechanical properties of Mg-Al-Zn alloy; however he has not investigated microstructure changes due to mechanical vibration [10]. Sayuti et al., reported variation of tensile strength with respect to the frequency of vibration, but he has covered a very narrow range of frequencies viz. 10.2, 12 and 14 Hz [11]. Campbell observed improvement in corrosion resistance along with mechanical properties of alloys too [12].

In the present work, effect of mechanical vibrations to the mould during solidification of Al-6wt%Cu alloy and their effect on microstructure and mechanical properties were studied. Microstructure and mechanical properties were also compared with casting of without mould vibration. Grain refinement and increase in mechanical properties obtained due to the mechanical vibration of mould.

II. EXPERIMENTAL PROCEDURE

A VERSATILE-VGH-9043 mechanical shaker with the specifications as frequency ranges from 40 Hz to 150 Hz, amplitude 4 mm and maximum pay load 8 Kg was used for the experiment. A fixture was fabricated to hold the mould. Cylindrical graphite mould was made from the cylindrical electrode of arc furnace. The diameter of the mould was 15mm and depth of mould cavity was 15cm. The mould was robust to with stand the vibration. The schematic sketch of experimental set up is shown in the Figure 1. There are two knobs to control frequency of vibration and another is timer to set the vibration time.

The Al-6wt%Cu alloy was prepared by melting relative mass of 99.6% pure Al and 99.99% pure Cu in air atmosphere using an induction furnace. The molten alloy was cast in a metallic mould coated with zircon paint. From each casting small pieces of samples were cut for chemical analysis to confirm the composition. The chemical composition of each sample was tested by ARL 3460 METALS ANALYSER Optical Emission Spectrometer (Spark Spectrometer). The ingots of Al-6wt%Cu were cut into smaller pieces and these pieces were used in the experiments for vibration mould casting.

A required amount of master alloy of Al-6wt%Cu alloy was melted in an induction furnace. The pouring temperature of molten metal kept constant at 650oC. The molten metal was poured into the vibrating mould. The vibration was applied till the solidification of molten metal. Five numbers of test samples were cast for each frequency of vibration. Five numbers of test samples were also cast without vibration named as casting with 0Hz.

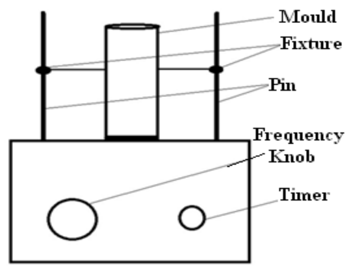

Fig. 1. Schematic Sketch of Experimental Set up of Vibration Mould Caster

Castings were made for different vibration frequencies as from no vibration or 0 Hz, 40, 80 and 150 Hz. After casting, all the samples are collected for analysis.

Casting made using vibration mould cater was characterized for its microstructure. The specimens for microstructural study were prepared from the different sections (top, middle and centre) of test bar. Samples were polished with different grades of emery paper. A mixture of 50% paraffin liquid supplied by MERCK and 50% kerosene was used on the emery paper during polishing. The surface was cleaned with water. Final fine polishing was done on clothe polishing wheel. Hiffin Fluid and 0.25 µm diamond paste was used during the clothe polishing. The specimen surface was finally cleaned with distilled water. Finally polished surface was cleaned with acetone and dried in hot air. The sample was chemically etched with Keller's reagent (H2O: 95 ml, HNO3: 2.5 ml, HCl: 1.5 ml, HF (48%): 1ml) for 10 seconds. Etched samples were cleaned in acetone using an ultrasonic cleaner and dried in hot air. Average hardness of each polished samples were measured using Brinell hardness tester of indenter ball diameter of 10mm and load applied was 500Kg.

III. RESULTS AND DISCUSSIONS

A. *Microstructure Analysis*

Microstructures of different sections like top, centre and bottom of test samples were analysed. Microstructures are shown in the Figure 2.

Microstructure of without vibration also compared with vibration mould castings. The microstructure of without vibration is coarser than with vibration as shown in the Figure 2. The vibration causes grain refinement and non-dendritic structure. The refinement of grain size increases with the increase in frequency of vibration. Figure 2 shows refinement in grains with the increase in vibration frequency. It was also observed that bottom microstructures finer than the top and middle as shown in the Figure 2, because rate of cooling is faster at the bottom. The cooling rate decides the structure of casting. If cooling rate is faster, microstructure will be finer.

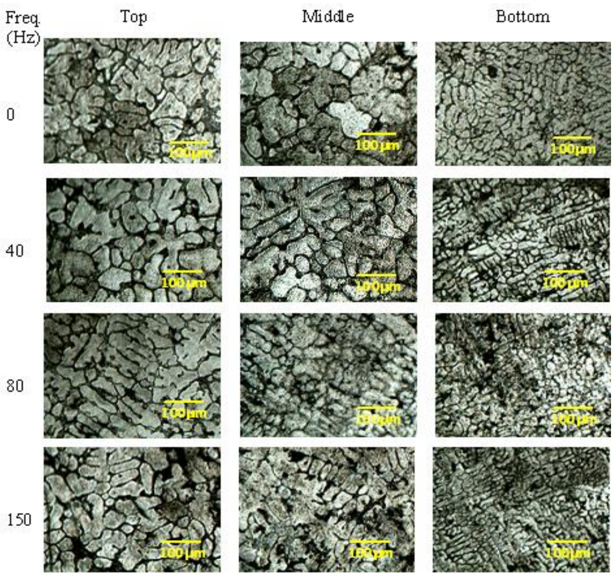

Fig. 2. Microstructure of different sections of castings at different frequency

Frequency (Hz)	Average Hardness (BHN)		
	Top	*Centre*	*Bottom*
0	67	68.8	76.3
40	78.3	82.6	89.7
80	95	104	107
150	107	115	121

B. *Hardness Test*

After taking the microstructure, harness tests were performed on the same test specimens. Hardness values were obtained using brinell harnes tester. For each samples three hardness values were obtained and final value was averaged over three readings. Average hardness results are presnted in Table 1.

From hardness results, it was observed that the test specimens of without vibration were having least harness among the specimens cast with vibration. This is due to the modification of microstructure due to vibration as the coarsest grains were found in the casting witout vibration. Table 1 shows bottom part of each specimens are having higher hardness compare to the another sections due to the cobined effect of cooling rate and frequency of vibration, it also proved from the obtained microstructure of Figure 1. Middle parts of castings were more hardness than the top as shown in Table 1 due to the effect of vibration causing more refinement at the centre than the top of the casting as shown in the Figure 1. Therefore, frequency of vibration also affects the harness of castings.

IV. CONCLUSION

A. The effects of mechanical mold vibrations on casting characteristics of Al-6wt%Cu alloy were evaluated mainly on microstructure and harness. Therefore, based on the above results and discussions, the following conclusions can be made as follows:

B. Mechanical mold vibration has a significant effect on the structure and properties of casting.

C. More refined and better mechanical properties can be obtained by mold vibration casting than the conventional casting without mold vibration.

D. As the frequency of vibration increases from 40 Hz to 150 Hz refinement of grains increase.

E. Hardness of casting also increases as frequencies from 40 Hz to 150 Hz.

F. Finally, it can also be concluded that grain refinement of Al-alloy is possible with vibration without addition of chemical additives.

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