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Effect of Ultrasonic Mould Vibration on Microstructure & Mechanical Properties of Pure Aluminium Casting During Solidification

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Abstract: ***The objective of the research is to understand the effect of ultrasonic mould vibration on mechanical properties and microstructure of pure aluminium during solidification. In the present work, effect of ultrasonic vibrations to the mould during solidification of commercially pure aluminium and their effect on microstructure and mechanical properties were studied. Microstructure and mechanical properties were also compared with casting without mould vibration. Grain refinement and increase in mechanical properties obtained due to the ultrasonic vibration of mould. The purity of aluminium sample considered for the research was found to be 96.89%, and the range of ultrasonic vibration was kept between 20 KHz to 30 KHz. The casting was done in stainless steel mould of thickness less than 0.5 mm. It was found that the ultrasonic mould vibrated casting has fine grain and improvement in mechanical properties as compared to the casting without ultrasonic mould vibration.***

Keywords: ultrasonic mould vibration, pure aluminium, casting, stainless steel mould

1. 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. In this process grain becomes globular, which 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 [1].

The grain refinement can be achieved either when external forces are applied to induce fluid flow during solidification which include rotation of the mold, mechanical/ electromagnetic stirring of melt and rheocasting, or by imposing very large plastic strains through several techniques that include multi-axial forging and accumulative roll-bonding [2]-[4]. Increased frequency of mould vibration during solidification causes refinement of the grain in the alloy. This refinement of the grains results in an increased ductility, percentage elongation, UTS, impact strength and hardness of the said alloy samples. Increase in vibration intensities result in higher maximum values of these mechanical properties.

The mechanical mould vibrations increasingly improve the mechanical properties of the alloy [2]-[5]. During gravity and low-pressure die casting processing, melt is poured very quietly and slowly into the cavity of a mould to avoid including gases. As a result, the products fabricated by these two methods have far fewer inner defects than those by the high-pressure die casting. This small amount of inner defects in the castings allows heat treatment and welding in the subsequent processing.

A striking disadvantage is that gravity die casting requires a large volume of riser to prevent the shrinkage defects, resulting in the long curing time and low material yield. Furthermore, this low cooling rate enables the grain coarsening and the solute element segregation. Hence, the grain refining agent, such as titanium, boron, carbon, and mother alloys including these elements, are widely used in usual aluminium castings to refine and homogenize the macrostructure and the microstructure [6]-[10]. But, these grain refining agents induce some problems not only in production but also in recycling.

In production, both the grain refining agent and the addition process increase the cost of the final product. In recycling, on the other hand, the separation or removal of grain refining agents becomes difficult and it is a cost-added process. Because of the increasing concern on resource saving, energy saving, and recycling, a new process to refine and homogenize the cast structure is required. The increase in solidification rate and the imposition of vibration or agitation are known as a method to refine and homogenize the castings structure [6]-[11]-[12].

2. Experimental Procedure

2.1 Material

Commercially pure aluminium was used as the matrix material and its chemical analysis is shown in Table 1

Table 1: Composition of commercially pure Al

Element	Al	Other
Wt. %	96.89%	3.11%

2.2 Casting

The experimental set-up for this casting method has been illustrated in Figure.1. It consists of an ultrasonic chamber (Make–Model: RK–100H), which can vibrate at a frequency of 20 KHz to 70 KHz, a stainless steel mould and melting furnace. At the base of the chamber is a mesh on which the mould is fixed. The mould is surrounded by sufficient water so that effective transmission of ultrasonic waves to liquid metal could take place. The time period of vibration could be varied from 1 minute to 3 minute.

The mould was made of stainless steel that is stainless steel glass of thickness less than 0.5 mm and is shown in Figure.2. There is a heating system in ultrasonic chamber to heat the water at temperature 70 to 80 ^{o}C. The pure aluminium is kept into the furnace for melting. The melting is to be done till temperature reaches to approximately 750 to 850 ^{o}C. Then slag is removed with the help of slick and then graphite rod is taken out so that molten metal flow towards the mould.

The mould was subjected to vibration at a frequency of 20 KHz to 30 KHz. Then the liquid Al poured into the vibrating mould. The vibration continued for 3 minutes to ensure completion of the solidification. I have done another casting without ultrasonic vibration to compare the results of castings with ultrasonic vibration.

2.3 Microstructure

Samples were polished with emery paper of different grades. A mixture of 50% kerosene and 50% paraffin liquid supplied by MERCK was used on the emery paper during polishing. The surface was cleaned with water. Final fine polishing was done on cloth polishing. And 0.25 µm diamond paste was used during the cloth 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 etched with Keller's reagent (H2O: 95 ml, HNO3: 2.5 ml, HCl: 1.5 ml, HF (48%): 1ml) for 10 seconds than etched samples were cleaned in acetone and dried in hot air. Olympus (Model No.-C5060 ADL) was used for microstructure and FESEM (MODEL-Zeiss, Supra-40) was used for fractrography test.

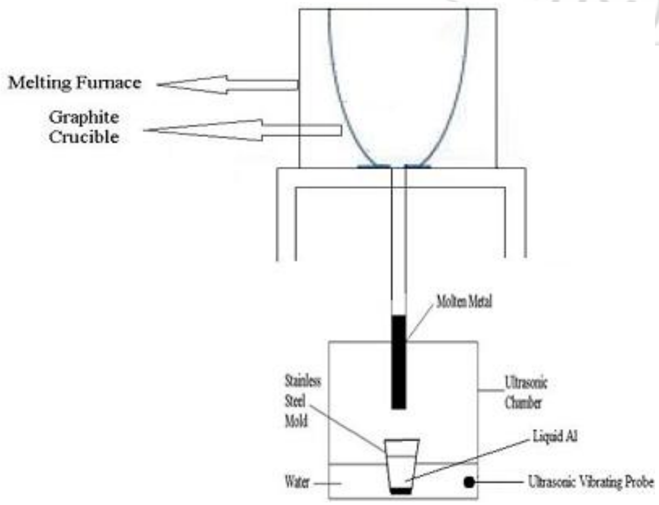

Figure 1: The experimental setup for ultrasonic casting (schematic).

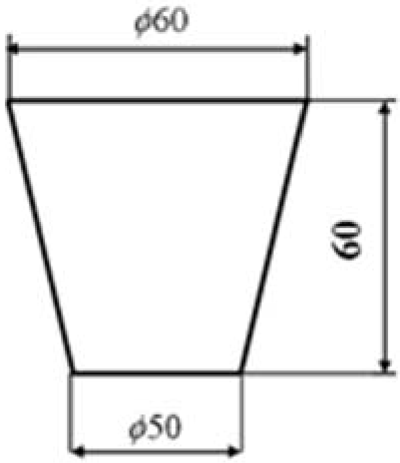

Figure 2: Stainless steel mould for ultrasonic casting (all dimensions in mm).

2.4 Microhardness

Microhardness measurements are performed on the polished samples using microhardness tester. The microhardness test was performed using a Zeiss UHL VMHT 0.001 Manufacture Technologies (Germany) Vickers indenter under a test load of 5 gf and a dwell time of 15 second and indenter speed was maintained at 25µm/s is used for this purpose. The variation in the microhardness values obtained for a particular specimen was ±3 Hv.

2.5 Tensile Testing

Tensile tests of the casting were carried out by an Autograph (Model:AG-5000G) tensile tester employing a crosshead velocity of 1 mm/min. The tensile specimens (Figure 3 and 4) were prepared as per ASTM standard.

Figure 3: Tensile specimen as per ASTM standard

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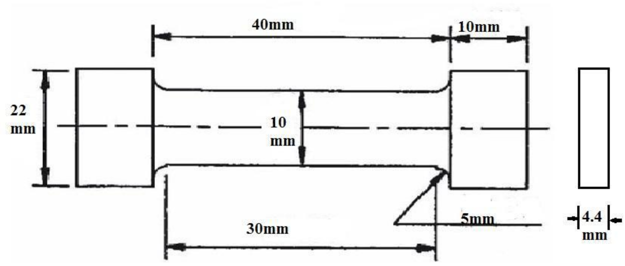

Figure 4: Sketch of tensile specimen as per ASTM standard (Lo / √Ao =4.5)

3. Results & Discussion

3.1 Microstructure Analysis

The micro structure has been taken at the outer surface of casting because outer surface of casting are more affected by ultrasonic vibration. Microstructure is shown in figure 5. Microstructure of casting without ultrasonic vibration is also compared with microstructure with ultrasonic vibration. The microstructure of casting without vibration is coarser than the casting with ultrasonic vibration as shown in the figure 5. Fine grain and non-dendritic structure are obtained due to ultrasonic vibration.

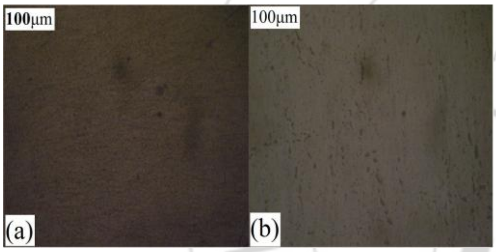

Figure 5: microstructure at 100X magnification
(a) Casting with ultrasonic vibration (b) Casting without Vibration

3.2 Microhardness

The microhardness has been taken at outer as well as middle part of casting then average value of both has been taken because outer have more hardness than inner because of fine grain. Microhardeness values were taken by Vickers hardness testing machine. The average value of microhardness is shown in figure 6. From hardness result, it was found that hardness of casting with ultrasonic vibration is greater than hardness of casting without vibration. This is because of grain refinement of casting with ultrasonic vibration as the coarser grains were found in the casting without vibration.

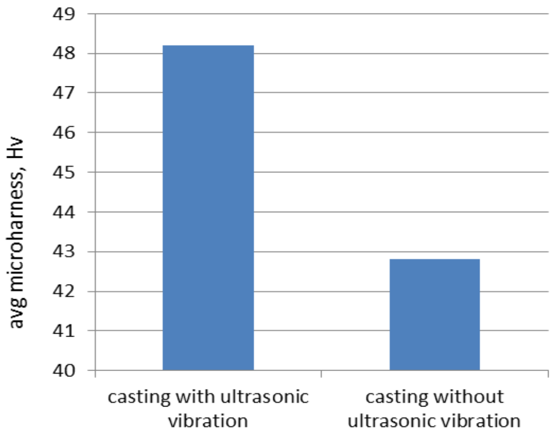

Figure 6: Microhardness result of castings

3.3 Tensile stress

The ultimate tensile stress of casting with ultrasonic vibration is more than ultimate tensile stress of casting without vibration. This is because of fine and no dendritic microstructure as well as less porosity in casting. The stress-strain curve for casting with ultrasonic vibration is shown in figure 7 and the stress-strain curve for casting without ultrasonic vibration is shown in figure 8. Fractography test shows the fracture of both casting is due to void nucleation and growth and ductile fracture shown in figure 9.

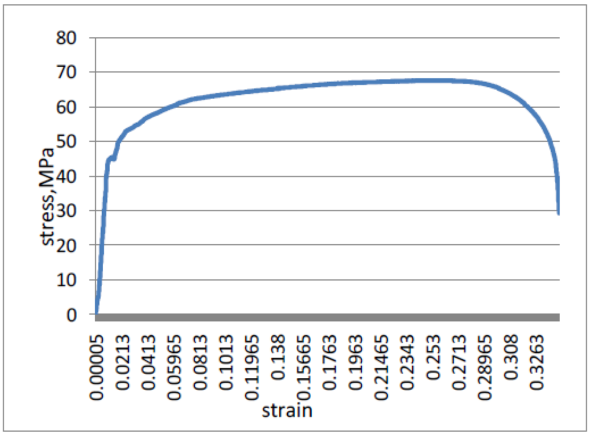

Figure 7: Stress-strain curve of casting with ultrasonic vibration

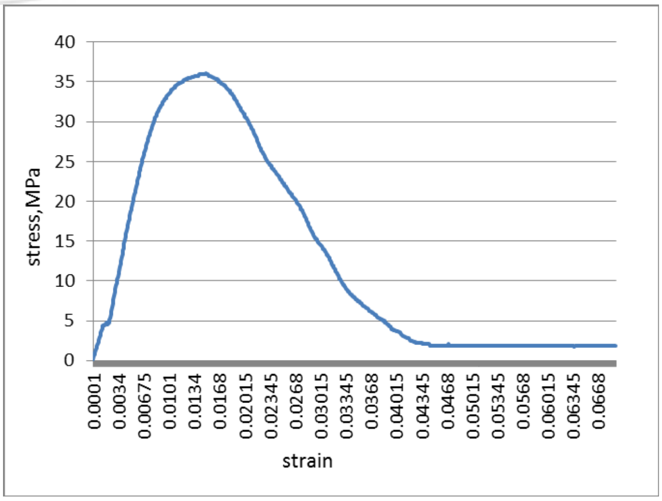

Figure 8: stress-strain curve of casting without ultrasonic vibration

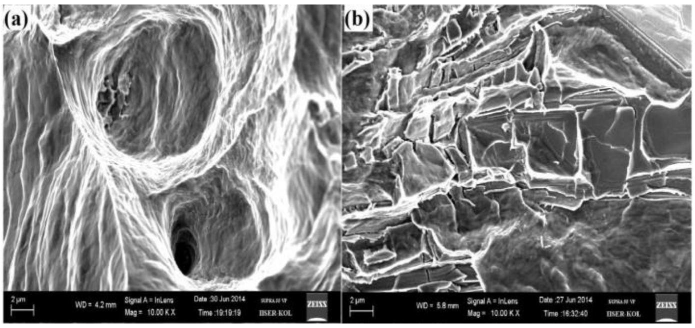

Figure 9: Fractrography image (a) with ultrasonic vibration (b) without ultrasonic vibration

4 Conclusion

Based on the above results and discussions, the following conclusions can be made as follows:

- Ultrasonic mould vibration has a good effect on the micro structure and properties of casting.
- Casting with ultrasonic vibration has finer grain than casting without ultrasonic vibration.
- Casting with ultrasonic vibration has microhardness value 48.21 Hv. whereas casting without ultrasonic Vibration has microhardness value 42.8 Hv.
- Casting with ultrasonic vibration has ultimate tensile stress 68.011 Mpa. Whereas casting without ultrasonic vibration 36.11 MPa.
- Casting with ultrasonic vibration and casting without ultrasonic vibration both have ductile fracture.
- We can also refine the grain without any chemical addition.

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