International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 12 | Dec 2019 www.irjet.net p-ISSN: 2395-0072

A Review on Microstructure and Mechanical Properties of Aluminium Alloy using Mold Vibration

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Abstract: *Al-Si based alloys are the most important non-ferrous alloys. These alloys were enormously used in various sectors like marine, aerospace and automobile industries because of their excellent mechanical properties such as corrosion resistance, low density, low coefficient of thermal expansion, excellent wear and good strength. These are used in areas that require a combination of light weight and high wear resistant. But all these performances of these alloys depends on the grain refinement and modification particularly dendrite arm spacing, primary and secondary eutectic silicon particles. These applications demand the study of techniques to improve mechanical properties and grain structure of these alloys. Present work shows the effect of mechanical mold vibration on grain size, dendrite arm spacing, inner defect, and mechanical property of aluminium alloys. As a result, this review will provide the improvement in mechanical properties and grain structure of LM-13 alloy by applying mechanical mold vibrations during the gravity die casting process.*

Keywords: Gravity Die Casting, Mould, Mechanical Vibration, Aluminium Alloy, Microstructure, Mechanical Properties.

1. INTRODUCTION:

Aluminium is the third most common element and the most abundant metal in the world. It comprises 8% of the earth's crust. Due to its versatility, aluminium is the most widely used metal after steel. Per year around 29 million tons of aluminium is demanded worldwide. It is commonly alloyed with zinc, silicon, magnesium, copper, lithium and manganese. Aluminium has over 300 wrought alloys in which 50 are used commonly. The various properties of aluminium and its alloys make aluminium most economical, versatile and attractive material to be used for wide range of purposes i.e. from highly ductile and soft foil to the other demanding engineering applications. Some of the properties possessed by aluminium are high thermal conductivity, resistance to corrosion, electrical conductivity, fabrication ease, lightweight and bright colour and texture [1].

In gravity die casting molten aluminium is poured into a metallic tool. The casting temperature is about 750°C. The tolerances and surface finish are good. The use of sand cores in gravity die casting enables casting of very complex components. A metal die is manufactured, usually in 2 parts, to form a mould [2].

- The mould is heated and a lubricant is sprayed into it to assist in controlling temperature and in removal of the casting.
- Molten metal is poured into the mould.
- Once solidified, the die is opened and the casting removed either by hand or with the use of pins in automated processes.
- Excess material including the gate, runners, sprues and flash can be removed using a trim die in a power press or by hand.
- Scrap metal is then re-used in the production cycle by re-melting.

2. LITERATURE REVIEW:

Premvrat Kumar, Sandeep Katiyar [1], Effect of Mechanical Mould Vibration on the Properties of Sand Casting Aluminium (A-1100) Alloy was carried out to investigate to increases the quality and decreases the porosity and inner defect of moulding alloy or metal. The effect of mechanical mould vibration on casting characteristics of Al-based alloys was evaluated. Aluminium alloy A1100 is chosen to the study the effect of mechanical vibration on hot tearing, grain refinement, and mechanical properties and on the morphology of eutectic silicon of A1100 alloyThe following conclusions are drawn from results- Mechanical mould vibration during casting of A1100 alloy showed a decrease in porosity, hot tearing, and solidification time and pipe formation.

Vivekkumar R. Mishra, Gourav Purohit, Chetan Jaiswal, Nishant Vyas [2], A Review Paper on Effects of Mechanical Vibration on Gravity Die Casting of Aluminium Alloys was carried out to After studying above literature review it may be concluded that the effect of mechanical vibrations on various aluminium alloys under gravity die casting process can be observed as the mechanical properties like ultimate tensile strength and Hardness are increased at a particular frequency of vibration, further it can be observed that the micro grain structure of the aluminium alloy has improved at a particular frequency of vibration, the grain size has reduced and fine grain structure has obtained. Hence an experiment can be conducted on various other aluminium alloys to check the effect of mechanical vibration on their properties and grain structure.

Y. Seetharama Rao, Rajana Vara Prasad, Sri Ram Murthy Paladugu [3], Experimental Investigations of Microstructure and Mechanical Properties of Aluminium Alloy Using Vibration Mold was carried out to investigate results showed improvement in mechanical properties with vibration when compared to without vibration, with vibration. Microstructure of the cast also improved when compare with, without vibration of the cast specimen. The microstructure image reveals that there is a fragmentation of silicon needles and no impurities when casted with vibration and there is an increase in grain refinement with increase in the frequency of vibration. The strength properties like hardness, tensile strength, impact strength, compressive and shear strength found increasing when casted with vibration and increases with increase in the frequency of vibration and found better than the properties when casted without vibration.

Sakendra Kumar and S.P. Tewari [4], A review on solidification of casting under oscillatory conditions of ferrous and non-ferrous materials was carried out to investigate finer grain size leads to high mechanical properties such as tensile strength, hardness, toughness, fatigue strength and yield. Grain refinement and enhancement in mechanical properties can be achieved by the mold rotation, mechanical vibration and electromagnetic stirring. This paper also reviews the cooling rate, nucleation presents, grain size, grain growth and change in solidification behavior under static and oscillatory casting conditions. Mechanical properties are dependent on these microstructural changes that take place during solidification of the melt. Mold vibration allows casting of typically difficult-to-cast alloys.

GUO Hong-min, et al. [5] was found the effects of vibration and grain refiner on the microstructure of semisolid slurry of hypoeutectic Al-Si alloy that the primary (Al) particles become finer and rounder with the increase of vibration frequency. Intense convection can be caused in melt by vibration, which is generated from the free surface of the bulk melt and spreads downwards, consequently leading to the convection in the bulk. Non-dendrite primary (Al) crystals become finer and rounder with the increase of vibration, and slurry can be prepared with EPD (equivalent particle diameter) of primary (Al) about 90 μm and ASC (average shape coefficient) above 0.5 under vibration of 20 Hz.

Chong LIN, et al [6] studied about the effect of Fe containing and ultrasonic vibration on Al−17Si−xFe alloys and suggested with increase of Fe content from 2% to 5% in the Al−17Si−xFe alloys, the amount of plate-like or coarse needlelike α-Al4FeSi2 phase increases while the amount of long needle-like-Al5FeSi phase decreases. The effect of USV leads to the formation and refinement of -Al4FeSi2 phase. Acoustic streaming and cavitations of USV homogenize the solute field and temperature field, and increase the start-freezing temperature of-Al4FeSi2 phase, thereby promoting the formation of fine α-Al4FeSi2 particles.

J. Hua et al. [7], grain refinement obtained under induced by the pulsed discharge vibrations the grain size of the β-phase of the Sn−Pb20% alloy under different pulsed discharge frequencies.

M. Li et al. [8], find the controlling microstructures of AZ31 magnesium alloys by an electromagnetic vibration technique during solidification. This may be responsible for the formation of coarse structures with dendritic morphologies.

W. Wang et al. [9], studied about the crystal nucleation and detachment from a chilling metal surface with vibration and find the exerting vibration to a chilling solid surface is an effective way to produce lots of nuclei for forming equiaxed grains microstructure by preventing the solidifying shell to form and promoting dendrites to break off and shower down not only from the free liquid surface but also from the chilling solid surface. To obtain finer equiaxed grains, it is necessary to increase synchronously vibration frequency as well as amplitude.

Kishor Pawar, Amitesh Kumar [10], Effect of Ultrasonic Mould Vibration on Microstructure & Mechanical Properties of Pure Aluminium Casting During Solidification was carried out 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 20 KHz to 30 KHz. 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.

Nagaraju Tenali, Dr. B. Karuna Kumar, K.Ch. Kishor Kumar [11], An investigation of Effect of Mould Vibrations on Mechanical and Metallurgical properties of Aluminum 356 Casting was carried out Providing Mould vibration during casting is one of the latest techniques employed in order to get better structure in the solidified casting. Mould vibration during casting gives reduced amount of shrinkage, better morphology, surface finish, and less chances of hot tear The Al356 casting has been prepared in a graphite mould with and without vibrations. The frequencies are varied from 0 Hz to 20 Hz during the casting process. A casting has been made without vibration as well to compare the results of castings with vibration. The experimental results showed significant grain refinement and remarkably improvement in compression strength and hardness of castings with mechanical mould vibration during solidification.

Ashwe Abugh, Ikpambese Kumaden Kuncy [12], Microstructure and Mechanical Properties of Vibrated Castings and Weldments: A Review was carried out vibration during casting and welding on microstructure and mechanical properties of castings and weldments. In this paper, these effects are reviewed and discussed to provide a better understanding of the processes. Understanding of these processes and application of the procedures offer extensive scope for significant cost savings in design and fabrication of cast and welded products.

Guo et al. [13], investigated the microstructure character of AZ80 magnesium alloy ingots cast under electromagnetic vibration. Microstructure of the ingots cast with the conventional Direct-Chill method exhibited relatively fine dendritic grains at the surface area, but coarse dendritic grains at the ½ radius and large equiaxed dendritic grains at the center. However under electromagnetic vibration casting condition, the microstructure of the ingots was significantly refined, especially those at the surface and at the center.

Yao et al. [14], also studied the effects of ultrasonic vibration on solidification structure and properties of Mg-8Li-3Al alloy. Microstructure, corrosion resistance and mechanical properties of the alloy were investigated. Experimental results showed that the morphology of α- phase was modified from coarse rosette-like structure to fine globular one with the application of ultrasonic vibration. Corrosion resistance of the alloy with ultrasonic vibration for 90 seconds was improved compared with the alloy without ultrasonic vibration. Tensile strength and elongation of the alloy treated with ultrasonic vibration improved by 9.5 % and 45.7 % respectively.

Mitsuhiro Okayasu, Yuta Miyamoto and Kazuma Morinaka [15], also studied Material Properties of Various Cast Aluminum Alloys Made Using a Heated Mold Continuous Casting Technique with and without Ultrasonic Vibration. These microstructural characteristics made excellent mechanical properties. Using UV in the continuous casting process, more fine and spherical grains were slightly disordered, which was detected using electron backscattered diffraction. The mechanical properties of the UV HMC Al alloys were slightly higher than those for the related cast Al alloys without UV. Moreover, the severe vibration caused higher mechanical properties.

Naoki Omura [16], Gravity die casting of AC4C aluminum alloys with mechanical vibration was carried out to investigate the effects of vibration on the macrostructures, internal defect and mechanical property. The area of columnar structure expanded and the grain size of columnar structure decreased by the addition of the vibration. The internal defect of specimen reduced at the vibration frequency of 70Hz or less. The internal defect increased when the vibration frequency was 80 Hz or more. The specimens cast at vibration frequency of 70 Hz showed higher and less scattered UTS compared with the specimens cast at other vibration conditions.

Ashwe Abugh, Ikpambese Kumaden Kuncy [17], A number of methods utilizing external forces have been applied to induce fluid flow during solidification of molten metal in casting and welding processes. These include mould rotation, mechanical vibration and electromagnetic stirring. Many articles describe the benefits of vibration during casting and welding on microstructure and mechanical properties of castings and weldments.

V.P.Patel, H.R Prajapati [18] "Microstructural and mechanical properties of eutectic Al–Si alloy with grain refined and modified using gravity-die studied about the influence of the microstructure and mechanical property changes on sand casting and permanent die casting alloys by grain refinement, modification combined action of both (Al– 3Ti–1B + Al–10Sr) and without grain refinement and modification effect. The microstructures of the castings are studied by optical microscopes. The microstructure and mechanical properties (tensile strength, hardness and impact strength) was tested of as cast, treated (grain refined and modified) samples. The test results are shown improvement in mechanical properties in treated melt by sand casting and permanent die casting than cast alloy due to this change was due to improvement in grain size and microstructure, and comparison microstructure and mechanical property with each other.

3. CONCLUSIONS:

After studying above literature review it may be concluded that the effect of mechanical vibrations on various aluminium alloys under gravity die casting process can be observed as the mechanical properties like ultimate tensile strength and Hardness are increased at a particular frequency of vibration, further it can be observed that the micro grain structure of the aluminium alloy has improved at a particular frequency of vibration, the grain size has reduced and fine grain structure has obtained.

Several examples drawn from the literature suggest vibration during casting greatly benefits grain structure and mechanical properties of products. Dendrite fragmentation and detachment and total cooling rate have been identified as two major factors that contribute to the enhancement (refinement) of grain size of vibrated microstructures. Mechanical properties are dependent on these microstructural changes that take place during solidification of the melt. Vibration during casting and welding has now been fully documented and accepted as one important procedure for manufacturing high quality castings and weldments for commercial industrial use.

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