EFFECTS OF MECHANICAL VIBRATION ON GRAVITY DIE CASTING OF ALUMINIUM ALLOYS - A REVIEW

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ABSTRACT

An Aluminum alloy casting mainly used in industrial engineering as the technique can fabricate the products with complex shape in lower superheat in a simple processing run. As the use of Aluminum alloy is more it is required to improve its mechanical properties and grain structure. In this review study the influence of mechanical vibration on the mechanical properties and micro-structure of Aluminum Alloy during gravity die casting has been discussed. Gravity die castings of AC4C Aluminum alloy (AlSi7Mg) under mechanical vibration (0-120 Hz) were conducted using the actual casting machine.

A part of mold (vibrating mold) was oscillated by a vibrator. Mechanical vibration imposed before pouring, and stopped at 40s after pouring. Columnar rod specimens (25 mm in diameter and 210 mm in length) were cast to investigate the effects of mechanical vibration on grain size, inner defect, and mechanical property. The grain size of columnar rod specimen decreased from 1800 µm (0 Hz) to 750 µm (100 Hz) by imposition of mechanical vibration. The internal defect of specimen decreased by mechanical vibration of frequency 70 Hz or less. But the vibration of 80 Hz or more led to increase of internal defect. As a result, specimens cast with the vibration of frequency 70 Hz showed higher UTS (ultimate tensile strength) compared with the specimen cast under other vibration conditions.

Keywords: Gravity Die Casting, Mould, Mechanical Vibration, Aluminum Alloy, and Microstructure

INTRODUCTION

Gravity die casting method is competitive casting method when production quantity is relatively small or when heat treatment is needed to improve the mechanical properties. This casting method gives better tolerances and surface finish than sand casting. The tooling costs are somewhat higher than by sand casting. In gravity die casting molten Aluminum is poured into a metallic tool. The casting temperature is about 750°C.The tolerances and surface finish is 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 mold. The mold 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 mold. Once solidified, the die is opened and the casting removed either by hand or with the use of pins in automated processes.[8] Excess material including the gate, runners and 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. Mechanical properties of castings strongly depend on its solidification structure. In general, it is know that many properties of castings such as yield point, ultimate tensile strength (UTS) and elongation are improved by reduction of their grain size.[2][8]

The grain refining agents are very effective to refine the grain size of castings. So, the grain refining agents are widely used in usual casting process. Titanium, boron, carbon, and mother alloys including these elements are well known as the grain refining agents for aluminum alloys. However, in recycling, these grain refining agents are considered to be impurities. Recently, the concern for resource saving, energy saving and recycling increases rapidly. Therefore, a new grain refining process that does not use grain refining agents or other additives is required. It is well known that the vibration and agitation of melt during solidification process can refine the grain size of castings.[2] So, many new processes using vibration and agitation have been developed and reported. These processes are effective for refining the grain size of castings, but have been hardly put to practical use. Because, these processes need special and expensive equipment's, indicating increment of product cost. Furthermore, it is difficult to fabricate the complicated and large products by these processes. Our previous work reported that reduction of the grain size, internal defect, and scattering of mechanical properties of castings was achieved by imposition of mechanical vibration on metallic mold using very simple equipment's. We also investigated that the effects of mechanical vibration on cooling rate and dendrite arm spacing of castings using an actual casting machine, and it has been reported the cooling rate increased and the dendrite arm spacing decreased by addition of the mechanical vibration. In present study, gravity die casting of AC4C Aluminium alloy (AlSi7Mg) with mechanical vibration was carried out using the actual casting machine to investigate the effects of the mechanical vibration on grain size, internal defect and mechanical property.[3]

LITERATURE REVIEW

In 2010, Naoki Omura, Takuya Tamura1, Kenji Miwa, Hideki Furukawa, Masayuki Harada and Tadatsugu Kubo, 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. However, 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. Furthermore, the UTS of specimen vibrated at 70 Hz was independent of the mold temperature.[6]

In 2013, P. Sujith Kumar and E. Abhilash and M. A. Joseph , This investigation is a modest attempt made to understand the effect of vibration on α-aluminum dendritic morphology and porosity in gravity die cast A356 aluminum alloy solidified under air cooling (35oC) and furnace cooling (600oC to 35oC) atmosphere. Considerable change in Secondary Dendrite Arm Spacing (SDAS) is observed according to the change in cooling atmosphere which is characterized in terms of local solidification time/cooling rate. The SDAS value predicted with an available dendritic criteria function is found to be varied from that of experimental studies. The effect of low frequency vibration (15 Hz, 1 mm amplitude) on solidified alloy, quantified in terms of SDAS, is found to be much significant in the case of air cooling atmosphere compared to that in furnace cooling atmosphere. The reduction in porosity observed in the castings solidified under mould vibration asserts the advantage of using mechanical vibration in gravity die casting.[7]

EXPERIMENTAL PROCEDURE

The schematic of the experimental apparatus of vibration casting is shown in Figure 1. A vibrato was placed at the fixed base. The vibration generated by the vibrator was transmitted to a part of fixed mold

(Vibrating mold) through transfer rods and a transfer board. This vibrator generates the vibration by the high-speed rotation of eccentric pendulum. Thus, the vibration frequency and centrifugal force of the vibrator could be easily controlled by changing the frequency of the inverter current supplied. The commercially available (AlSi7Mg) was used in the test.[1]

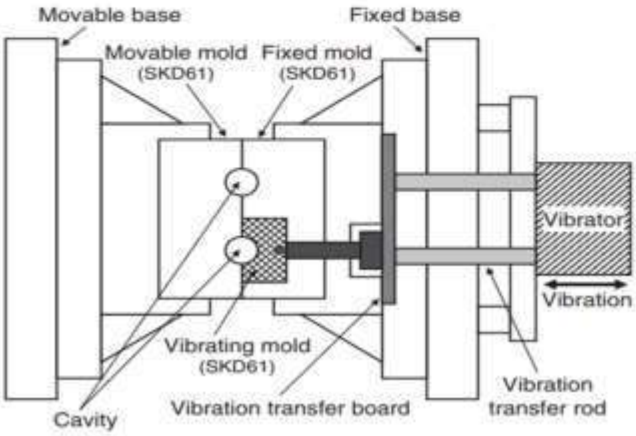

Figure 1: Schematic diagram of the experimental apparatus (top-view).

Figure 2 shows the shape of castings fabricated by mechanical vibration casting. Columnar rod specimens (25 mm in diameter and 210 mm in length) were cast using bottom gate plan. In this figure, the direction of the mold vibration is a vertical to the plane of this paper. Mechanical vibration casting was carried out at 1003 K of the melt temperature and 633-693 K of the metallic mold temperature.[4] The imposition of mechanical vibration (0-120 Hz) started before pouring, and stopped at 40s after pouring. Macrostructure and inner defect of the as-cast specimens was observed by an optical microscope (OM) and an X-ray CT system (SMX-225CT; Shimadzu, Kyoto, Japan).[1]

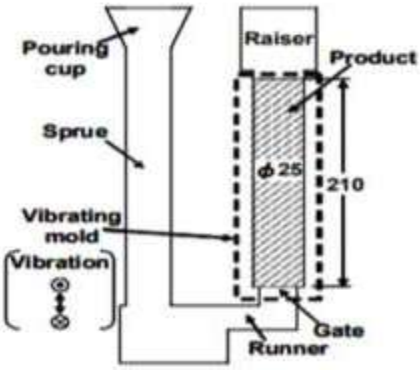

Figure 2: Schematic drawing of castings.

Tensile test specimens (14 mm in gauge diameter and 60 mm in gauge length) were machined from as-cast columnar rod specimens. Tensile tests were carried out at room temperature at a constant crosshead speed of 1 mm/min.. The chemical composition of this material determined by emission spectrometric analysis is shown in Table 1. The liquidus temperature of this material was 888 K.[7]

Table 1.Chemical composition of AC4C aluminum alloy (AlSi7Mg**).**

Si	**Mg**	**Ti**	**Fe**	**Ni**	**Cu**	**Zn**	**Al**
6.67	**0.200**	**0.005**	**0.052**	**0.003**	**0.000**	**0.014**	**Bal.**

EFFECT OF MECHANICAL VIBRATIONS

1.1 GRAVITY DIE CASTING OF AC4C ALUMINIUM ALLOY UNDER VIBRATION

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 internal defect of specimen reduced at the vibration frequency of 70Hz or less.[3] However, 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. Also, such experimental study can be carried out on other materials casted by gravity die casting process.[7]

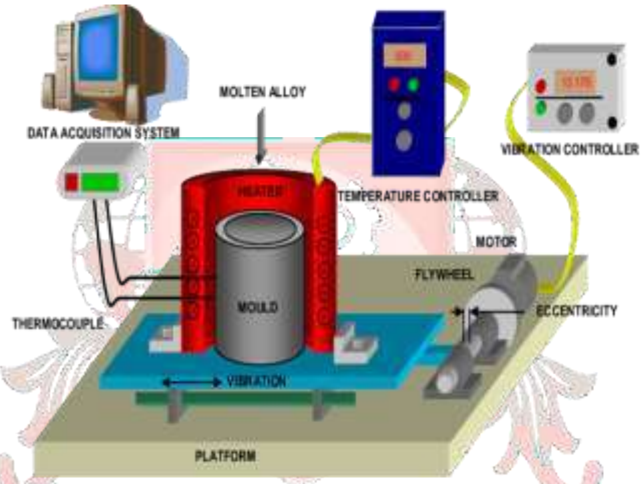

Figure 3.Cast under vibration

1.2 SPECIMEN CAST WITHOUT MECHANICAL VIBRATION

Columnar structure and granular structure are observed in their outer region and inner region respectively. A mean grain size of granular structure is about 1800 µm. Some internal defect is observed in the middle area of specimen cast of AC4C Aluminum alloy without vibration (0 Hz).[5][6]

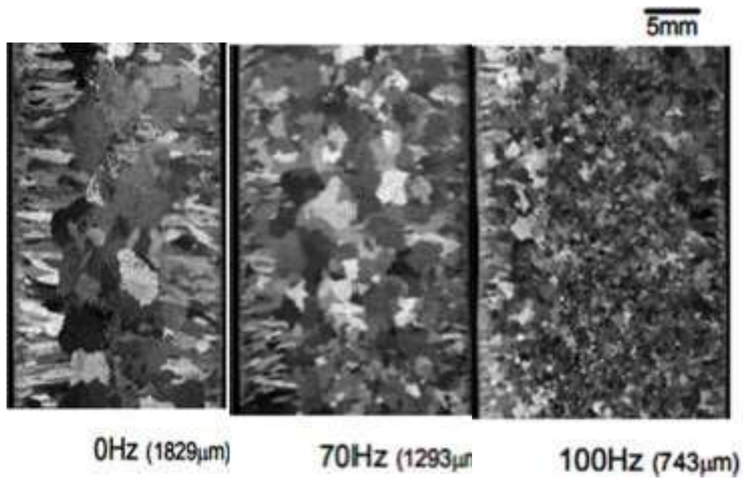

Figure 4.Effect of vibration frequency on the macrostructure of AC4C specimen cast at different frequencies

1.3 SPECIMEN CAST AT THE FREQUNCY OF 70 Hz

The specimen of AC4C Aluminum alloy vibrated at 70 Hz shows the least internal defect. Internal defect is minimized at the vibration frequency of 70 Hz. By addition of the vibration of frequency 70 Hz, the UTS increase to about 150 MPa. The UTS of these specimens is independent of the mold temperature[5][6]

1.4 SPECIMEN CAST AT THE FREQUNCY OF 100 Hz

Addition of the vibration of frequency 80 Hz or more, the internal defect slightly increases in the specimen of AC4C Aluminum alloy. Vibrations of frequency 80 Hz or more lead to decrease and scatter in Ultimate tensile strength.[5][6]

1.5 EFFECT OF VIBRATION ON COOLING RATE

Gravity die casting of AC4C aluminum alloys along with mechanical vibration was done to find out the effects of vibration on the temperature change of the melt and the dendrite arm spacing of specimen were measured to investigate the cooling rate of the melt, and following results were obtained.[4]

1. Due to imposition of the mechanical vibration, the cooling rate of melt increases.
2. The maximum temperature of vibrating mold during casting increases and the time to the maximum temperature shortens due to the mechanical vibration.
3. Because of the mechanical vibration the dendrite arm spacing in outer region of specimens decreases.
4. The specimen casted without vibration has smoother surface. but at high vibration frequency the surface of cast specimen becomes rough.

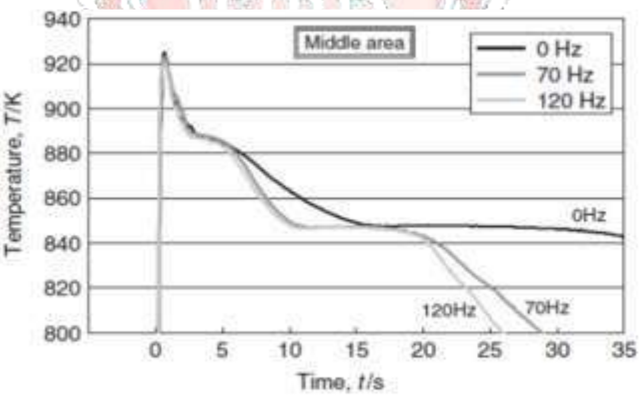

Figure 5.Cooling rates effect due to Mechanical Vibration (Melt at bottom area)

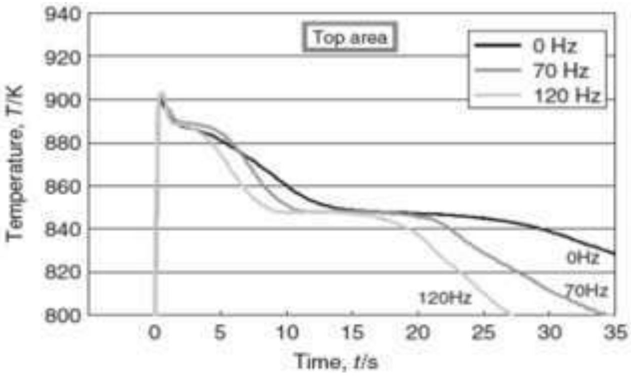

Figure 6.Cooling rates effect due to Mechanical Vibration (Top area)

1.6 EFFECT ON ULTIMATE TENSILE STRENGTH

Figure 7 represents the ultimate tensile strength (UTS) of as-cast specimen cast at various Mould temperatures and vibration conditions. When the vibration frequency is 0 Hz and 55 Hz, the ultimate tensile strength is low and scatters widely. Especially the specimens cast at low mould temperature (=633K) show very low and scattering ultimate tensile strength. By addition of the vibration of frequency 70 Hz, the ultimate tensile strength increases to about 150MPa.[3][5][6]

The ultimate tensile strength of these specimens is independent of the mould temperature, and hardly scatters. Vibrations of frequency 80 Hz or more lead to decrease and scatter in ultimate tensile strength. As we can see that at the frequency of 70 Hz, we get the best result is the ultimate tensile strength (UTS) increases to 150MPa.[5]

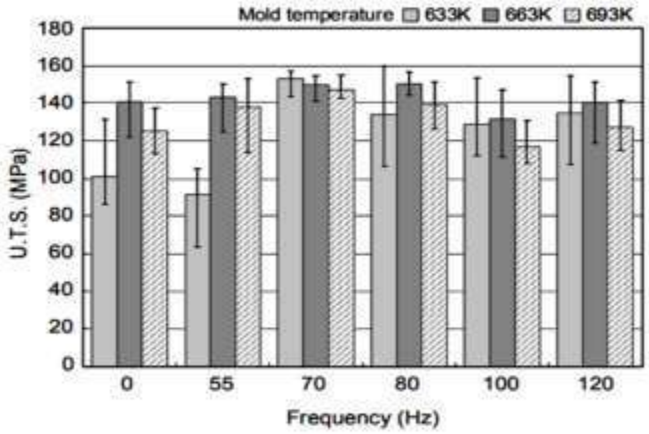

Figure 7.Ultimate tensile strength of as-cast specimens as a function of the vibration frequency

CONCLUSION

The effect of mechanical vibrations on various Aluminum alloys under gravity die casting process can be observed as the mechanical properties like ultimate tensile strength (UTS) and hardness are increased at a particular frequency of vibration, further it can be observed that the micro grain structure of the Aluminum alloy has improved at a particular frequency of vibration, the grain size has reduced and fine grain structure has obtained. Gravity die casting of AC4C aluminum alloys (AlSi7Mg) 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. However, 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 Gravity die casting of AC4C aluminum alloys (AlSi7Mg) 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. However, 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. Furthermore, the UTS of specimen vibrated at 70 Hz were independent of the mold temperature.

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