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A Review on Characteristics and Mechanical Behavior of Metal Castings under Ultrasonic Vibration Technique

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Abstract- *The demanding problems for designers and engineers in the material science are to improve the quality of the castings. The several numbers of methods using external forces have been applied to introduce fluid flow during solidification of molten metal in casting process. These include mechanical, electromagnetic and ultrasonic vibration. Many technical journals describe the improvement in mechanical properties of castings under the vibration during solidification. In this paper, an attempt has been made to review the casting process to refine the microstructure of cast product during ultrasonic vibration technique. The awareness gain of these processes and application of the procedures offer the scope for better cost savings in design and manufacturing of cast products.*

Keywords: Ultrasonic Vibration; grain refinement; microstructure

I INTRODUCTION

Casting under vibratory conditions, moulds or work pieces are held rigidly on a vibratory table and the table is rigidly coupled to the vibration exciter which generates vibrations at different frequencies of oscillation and transmits them to the table and moulds which in turn vibrate at different frequencies of oscillation. The molten metal solidifies under these vibratory conditions. Inspection and testing of castings involve five main categories: casting ultimate, dimensional accuracy, mechanical properties, chemical substance and casting accuracy. Most of the research works are carried out to enhance casting soundness through micro structural analysis and mechanical property improvement for automobile and aerospace industries. During the process of solidifications, the vibration of moulding increases the properties of castings. In earlier studies, Campbell [1] noticed grain refinement to occur and mechanical properties improved in castings due to the application of vibration during casting. Fluidity is one of the most important factors in casting process. It is defined variously as the distance covered by quality liquid metal in a channel of fixed geometry before solidifying. That is the ability of a melt to flow and fill very narrow spaces, whether in a mould cavity grooves [2]. A coarse grained structure may result in a variety of surface defects in alloys used in rolled or extruded form, while the size of defects such as micro-porosity may reduce as a result of fine grain structures since the solidification of smaller grains will allow the mould to fill more completely and avoid unfavorable micro and macro- porosity thereby producing sound castings.

This paper gives a comprehensive review of the methods used for Ultrasonic vibration process with different materials, experimental investigation of vibration techniques, characterization such as microstructure examinations and mechanical properties.

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II PROCESSING

As can be seen in "Fig. 1," the experimental apparatus for ultrasonic treatment used in this study mainly consisted of a resistance furnace, an iron crucible, and a metallurgic ultrasonic system with power ranging from 0 to 2000 W. The ultrasonic system included an ultrasonic generator with a frequency of 20±2 kHz, a transducer, and a mild steel-made acoustic radiator [3].

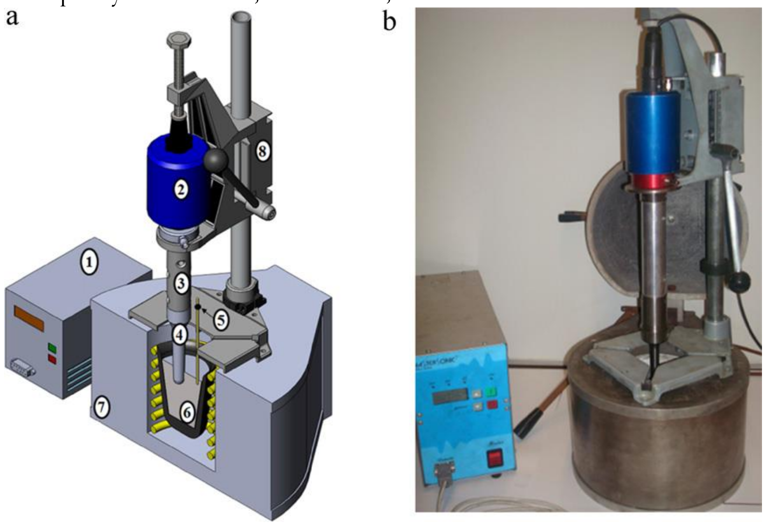


Figure. 1. Experimental set-up: (a) conceptual model: 1 – US supply unit, 2 – US converter, 3 – waveguide, 4 – acoustic radiator, 5 – thermocouple, 6 – liquid alloy, 7 – melting furnace, 8 – positioning device; (b) laboratorial unit.

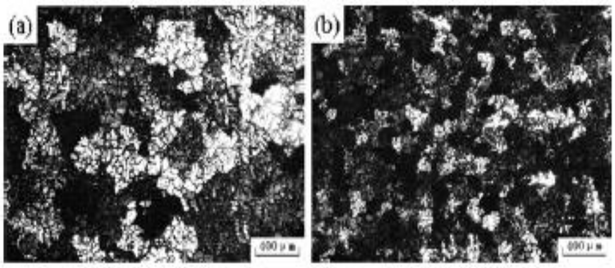
Al-Si alloys with 2%Fe materials were melted in a resistance furnace at 820-850º C. The melt was cooled down to a temperature of 750-780º C after degassing. The metal cup was preheated to 530-550º C by the heating furnace. Subsequently, about 600 g liquid metal was poured into the preheated metal cup. The USV was then applied on the melt with the ultrasonic vibrator immersed into the melt 15-20 mm in depth when the liquid metal cooled down to the predetermined temperature. The starting temperature of USV was 665º C, and ending temperature was 640º C. The USV treatment time was1.5 min [4].

The experimental setup for UST comprised a 5-kW ultrasonic generator, a 5-kW magnetostrictive transducer with water-cooling system and a niobium ultrasonic horn (sonotrode). Experiments were performed at the 4-kW generator power. The corresponding amplitude of vibrations was 40 μm, as measured by a contactless vibrometer. In each experiment, the amount of melt was 0.35 kg. The alloys were first molten in an electric furnace in graphite crucibles and then treated by ultrasound in different temperature ranges [5].

The various materials like AlSi9Cu3 alloy,7050 aluminium alloy,Mg-8Li-3Al alloy,AZ91 magnesium alloy ,A356 aluminium alloy were melted and applying Ultrasonic power source with different range[6-10] .

III CHARACTERIZATION

The below diagram referred to Microstructure of Ultrasonic vibration of castings with different frequencies. The implementation of ultrasonic vibration on the microstructure and mechanical properties of Al-17Si-2Fe-2Cu-1Ni alloys with 0.4% or 0.8% Mn were studied. The results show that the average grain size of primary Si in the alloys treated by USV could be refined to 21-24 μm[4]. Grain refinement (or) purification process of alloy with the help of Ultrasound the different powers was applied to treat AZ80 alloy melts to attain. The implement of ultrasonic powers from 0 W to 1400 W on microstructures of the AZ80 alloy with ultrasonic grain refinement treatment was investigated. The grain size of the alloy could be decreased from 387μm to 147μm after the ultrasound with the optimal power 600 W was applied to treat the melt [5].



(Before vibration) (After vibration)

Figure.2.SEM Analysis of AZ80 alloy

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The effect of ultrasonic treatment on the formation of microstructure was systematically analyzed in hypo-eutectic, near-eutectic and hypereutectic Al-Si alloys, inclusive commercial piston alloys. The results show that UST usually results in the refinement of grains and primary Si particles when it is applied in a proper temperature range, while ultrasonic treatment during the whole solidification processing leads to coarsening effect on eutectic Si phase. An effective MMM (Multi-frequency, Multimode, Modulated) ultrasonic (US) technology was used to change the cast microstructure of the samples was analyzed by optical and scanning electron microscopy and energy dispersive spectrometry. Ultrasonic vibration developed the formation of small globular grains, changed the molecule size and morphology of intermetallic compounds and distributed them equally entire the castings [6].

Investigated the microstructures of 7050 aluminium alloys. Compared to the normal cast alloy, the ultrasonic cast ingot (UI) was characterized with a finer microstructure than that in the conventional cast ingot (CI). It was observed that the Ultrosonic Ingot alloy can be aged faster and aging-strengthened easier than the Conventional Ingot alloy[7]. Studied the effects of ultrasonic vibration on solidification structure 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 [8].

The technique of ultrasonic vibration with different powers from 0W to 700W was applied during the solidification process of AZ91 alloy. The microstructures of alloy were characterized. Without apply to ultrasonic vibration (0W of ultrasonic power), the dendrites were coarse. Globular grains were obtained in AZ91 alloy subject to high intensive ultrasonic vibration. The grain size was reduced gradually from 202μm to 146μm with increasing ultrasonic power [9]. The impacts of high-energy ultrasonic field on the microstructure of A356 alloy are investigated. The result shows that the long dendritic silicon phases are split into number of particles [10].

IV MECHANICAL BEHAVIOR

A effective MMM (Multi-frequency, Multimode, Modulated) ultrasonic (US) technology was used to increase the mechanical properties of a AlSi9Cu3 alloy. Increased the value of Ultimate tensile strength and strain were to 332 MPa and 2.9%, respectively, which are 50% and 48% higher than the values derived for castings produced without vibration[3]. The implementation of ultrasonic vibration on the mechanical properties of Al-17Si-2Fe-2Cu-1Ni (mass %) alloys with 0.4% or 0.8% Mn were studied. With USV treatment, the UTS of A1 and A2 alloys are increased by 24.3% and 22.5% respectively at room temperature, compared to those of the alloys without USV treatment. The hardness of A1 and A2 alloys are also improved slightly after USV treatment [4].

Investigated the properties of ultrasonic 7050 aluminum alloys. When aged at 120 °C, the alloy attain its peak strength after 8 h, with tensile strength, yield strength and elongation of 602 MPa, of 547 MPa 12.7%,respectively. whereas the CI alloy plate had tensile strength of 536 MPa, yield strength of 462 MPa and elongation of 15.0%, after peak aged for 12 h [7]. The effects of ultrasonic vibration on solidification structure and properties of Mg-8Li-3Al alloy. Corrosion resistance and mechanical properties of the alloy were investigated. 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 [8].

The technique of ultrasonic vibration with different powers from 0W to 700W was applied during the solidification process of AZ91 alloy. Mechanical properties of the cured AZ91 alloy were characterized. The mechanical properties were improved by which the treated alloy. The ultimate tensile strength was increased from 145MPa to 195MPa and elongation to fracture from 2.3% to 5.2% correspondingly with increasing ultrasonic power [9]. The impact of high-energy ultrasonic field on the mechanical properties of A356 alloy is investigated. The acceptable improvement of mechanical properties can be reached due to the ultrasonic treating. The tensile strength yield stress and elongation are 293.85MPa, 207.34MPa and 6.98%, which are 1.55, 1.93 and 1.10 times to that of without high-energy ultrasonic treating, respectively[10].

V APPLICATIONS

The enhancement of mechanical properties due to the Ultrasonic vibration during the process of solidification has been widely applied in aerospace, automobile and industrial products. The composite materials are used in marine applications such as the construction of hull, connecting rod, and so on.

VI FUTURE SCOPE OF RESEARCH

The ultrasonic vibration technique may be used to improve the desirable characteristics of castings. By changing the process parameters such as frequency of vibration, time duration, pouring temperature, the castings can be fabricated thereby its mechanical properties and microstructure can be enhanced.

VII CONCLUSION

In this paper a review the effect of Ultrasonic vibration in various materials is discussed and its effects on the microstructure and mechanical properties are analyzed. Several researchers suggest vibration during casting with dendrite fragmentation, detachment have been identified as major factors which contributes the enhancement of grain structure and properties.

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