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Mechanical Vibration Technique for Enhancing Mechanical Properties of Particulate Reinforced Aluminium Alloy Matrix Composite

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Abstract. The effects of subjecting solidifying particulate reinforced aluminium alloy matrix composite to various sources of vibration on the resulting casting quality, a mechanical vibration technique for inducing vibration resulting in enhanced mechanical properties, such as impact properties is devised. TiC particulate reinforced LM6 alloy matrix composites are fabricated by different particulate weight fraction of titanium dioxide and microstructure studies were conducted to determine the impact strength and density, respectively. Preliminary works show that the mechanical properties have been improved by using vibration mold during solidification compared to gravity castings without vibration.

Introduction

A number of literature surveys have been reported on the influence of mechanical, electromagnetic and ultrasonic vibration to metals. It is generally accepted that in certain circumstances different sources of vibration during processing of metals can enhance metallurgical and mechanical properties. Applying mechanical vibration during the solidification process it's a fairly simple technique that does not require complicated procedure or expensive setup. It can be applied for the current existing processes and does not require extensive modifications on the design of the equipments used. It requires less energy as compared to electromagnetic vibration and semisolid processes and less expensive. The low energy requirement made it the most environmentally-friendly process than any other grain refinement methods. There are three practicable methods of application of vibration; vibration of the whole of the mould, vibration of liquid, and electromagnetic induction [1-3].

Moreover, many researchers have found that mechanical vibrations of sonic, electromagnetic and ultrasonic character, when applied during solidification of metals and alloys, modify conventionally obtained macrostructures and microstructures, hence effecting its mechanical properties [4-10]. The well-documented beneficial effects of subjecting a solidifying ferrous or nonferrous melt to vibration shown in Table 1.

The objective of the present work is to study the effect of mechanical vibrations on mechanical properties of the Titanium Carbide (TiC) particulate reinforced aluminium-silicon alloy matrix composite.

Table 1. Researchers review using mould vibration to enhancing mechanical properties

Materials	Types Vibration	Influence of vibration
Aluminium LM6	Mechanical vibration [1]	Uniform distribution and refinement of primary Al Primary grains contact/connect each other forming Improvement in tensile strength with increasing amplitude of vibration
Al–18 wt%Si, Al–12% Si, A356 aluminum alloy Al-Si Alloy, Al 11.8%Si Alloy	Mechanical vibration [2-9]	Coarsening of eutectic Si, reduced of eutectic cell size, uniform distribution and refinement of primary Al, improve the density, hardness, UTS and % elongation. Decrease of porosity with increasing intensity of vibration Reduced eutectic cell size as well as primary dendrite size
Al alloy Mg composite Zn-SiC particulate	Ultrasonic [10-13]	Degassing, The refined effect enhances with the increase of vibration time, grain refinement
AZ91 alloy A356 alloy	Ultrasonic vibration [14-16]	Improve of compressive strength, ultimate compressive strength and fracture strain. Initial hydrogen concentration and reduction in porosity and shrinkage concentration in a spot achievement of uniform grains Reduced solidification time and eutectic temperature
Al-5Ti-1B	Ultrasonic [17- 19]	The narrower particle size spreads significantly improve the grain refining performance of the master alloy.
Al-Si alloy	Ultrasonic irradiation [20]	Improvement of mechanical properties Promotion of grain refinement Ductility enhancement Reduced solidification time and eutectic temperature
Al–Si alloys, Al-6%Si alloy, A356	Electromagnetic Stirring (EM) during continuous Casting [21,22]	Reduce of porosity, increase of UTS and modulus Modified eutectic only in EM mould
Al-Si Alloy Al alloy 7150 A356 Al alloy, Al-Zn-Mg-Cu-Zr ingot	Electromagnetic stirring [23-26]	Reduction in Si segregation in hypereutectic alloy Dendrite fragmentation Promotion Uniform distribution and refinement of primary Al Reduced solidification time and eutectic temperature Lest dendrite or net-global grains
Al–5Mg AZ80 Mg	Electromagnetic field [27]	Reduced diffusion layer thickness in front of the solidification front Increased concentration of alloying elements in solid solution Decreased volume of nonequilibrium eutectics Refinement of dendritic microstructure and fine distribution of nonequilibrium eutectic phases
Al–5Mg , Al–4.5Cu	Electromagnetic generator at 30 and 150 Hz, 0.05–5.52mm amplitude, 1–120 g peak acceleration [28]	Extensive grain refinement especially with high accelerations

Experimental Procedure

Material. The material used in this work was aluminium-11.8%silicon alloy. This matrix was chosen because of excellent combination of strength and damage tolerance at elevated temperatures. The reinforcement was Titanium carbide particles of size 44 microns (µm), were used as the dispersoid, respectively. Casting method was used for processing of the composite.

Fabrication of Composites. In this investigation, large ingots of aluminium-11.8%silicon alloy material weighing approximately 4 kgs were cut into small pieces for accommodating into the graphite crucible. The mechanical vibration of the mould was applied to the aluminium alloy matrix composite with and without vibration at a frequency 0 Hz and 10.2 Hz with 0.120mm amplitude. The titanium carbide particulate used as a second phase reinforcement in the alloy matrix was added on by different weights fraction 0.2, 0.6, 1 and 2% wt.

In this research work, the particulate were preheated to 200oC in a heat treatment muffle furnace for 2 hours and was then transferred immediately in the crucible containing liquid LM6 alloy for mixing by an impeller blade of the vortex stirring machine. Next, the composite liquid material was poured into the mould, which was attached on the system that provides the mechanical vibration with 10.2 Hz and 0.120 mm amplitude (Fig. 1a) and without vibration or normal position (Fig. 1b). Then, the casting was ejected from the mould after solidification and gating system was removed to get the specimens. In the final stage, the specimen was prepared to the accurate dimensions according to the standard. The actual specimens prepared for the impact tests are shown in Fig. 1c.

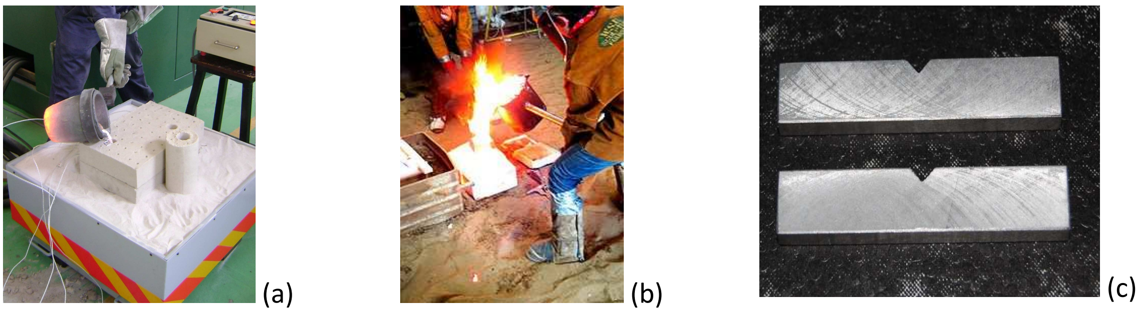

Fig. 1. (a) With vibration mould , (b) Normal Position, (c) Finished specimen for impact test.

Testing. The impact test was conducted in accordance with ASTM E 23-05 standards at room temperature using izod impact tester, Fig. 2 and Fig. 3 show the machines used to conduct the impact tests and A&D-GR 200 – Analytical Balance for density measurement, respectively.

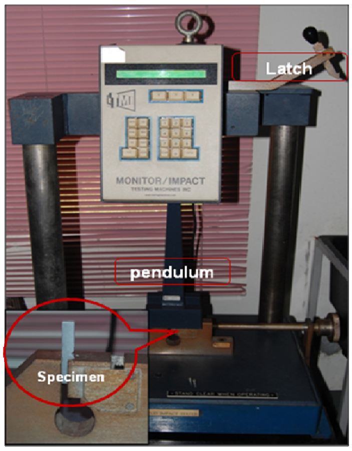

Fig. 2. Izod impact tester

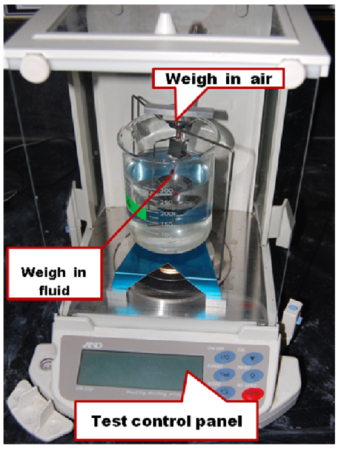

Fig. 3. Analytical balance

Experimental Results

The impact properties of particulate reinforced aluminum alloy matrix composite with and without vibration composite are given in Fig. 4. The mechanical properties of the composite with vibration are always better than that of correspondent without vibration. As shown in the figure, the impact energy value increases with increase in percent weight fraction of TiC and with using vibration during solidification. Mechanical vibration makes solidification microstructure of aluminium matrix composite fine and homogeneous and decrease the amount of defect such as shrinkage cavity and inclusions. The effect of vibration to help in the promotion of nucleation and thus reducing as-cat grain size, reducing hydrogen, reducing shrinkage porosities due to improved metal feeding, and producing a more homogenous composites structure [1,2,13]. These improved features lead to improve mechanical properties and lower susceptibility to cracking. Literature review on the effects of vibration on casting and reported an improvement of mechanical properties by as much as 40% [29]. It can be concluded that these effects play an important role on the improvement of impact energy. Fig. 5 offer the comparison of the mechanical vibration effect and weight fraction of the particles effect on the density. It is easy to draw a conclusion that, by mechanical vibration during solidification, the size of shrinkage cavity and inclusion are reduced and the amount of defects is also decreased. The densities of the samples are measured using A&D-GR 200 – Analytical Balance. It can be found that the density is higher in the sample with mechanical vibration mould than in without vibration mould. It is obvious that the amount of defect such as shrinkage cavity and inclusion is decreased and the compactness is enhanced due to applied mechanical vibration during the solidification process. The values of density in composites also increase with increasing weight fraction of the particles, because density of particles is higher than the Aluminium -11.8% Si Alloy (the density of LM6 is 2.65grs/c^3 and of TiC is 4.93grs/c^3) and hence the increase in wt.% of TiC will increase the density of the composite based on the role of mixtures [30].

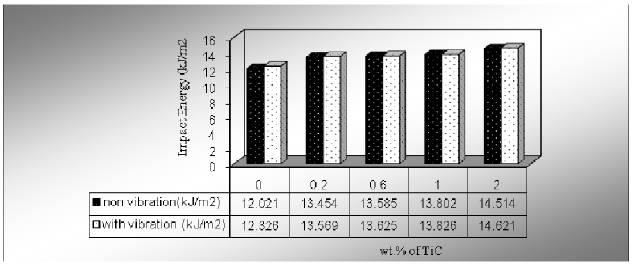

Fig. 4. Average of Impact energy vs wt.% of TiC

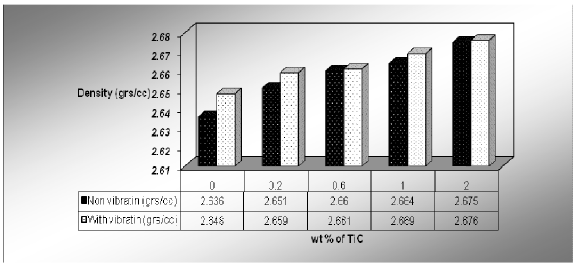

Fig. 5. Average of density energy vs wt.% of TiC

Summary

The optimum process was found in this study for production of TiC reinforced aluminium alloy matrix composite by casting technique using mechanical vibration during solidification. Density and impact energy of MMC were investigated. The following conditions have been drawn:

1. The impact energy increase with increasing in weight percentages of particles at room temperature.

2. It is possible to produce metal matrix composites having relatively better mechanical properties, by dispersing TiC in to molten aluminum alloy using mechanical vibration mould.

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