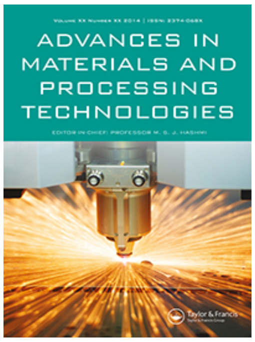

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Impact of metal mould vibration on the mechanical properties of aluminium 6082 t6 alloy

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ABSTRACT

Casting is a technique used to prepare machinery parts. Casting during vibration is one of the techniques used to improve the properties of material. In this paper, the effect of mould vibration on the properties of gravity die casting alloys is studied. This process decreases the porosity, holes and increase in the grain refinement of cast alloy. Aluminium 6082 T6 alloy is made by casting process, with and without vibration. The frequencies varied from 0 Hz to 45 Hz. The material is tested on electronic tensiometer and vickers hardness to check its tensile strength and hardness. The outcomes showed improvement in grain refinement and properties when vibration is applied during casting. With this improvement, it can be widely used in trusses, bridges, cranes and transport applications.

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Vibration casting; Aluminium 6082 T6; Electronic tensiometer; vickers hardness; SEM analysis

1. Introduction

Metal casting is a manufacturing process in which a molten metal is poured into a mould that contains a cavity of required shape and allow it to solidify and the solidifying process is known as the casting. Among all the manufacturing process, metal casting is oldest and widely used due to its simplified process. Nowadays, 70% of all the parts are made of metal casting. The commonly used metals for casting are aluminium, tin, lead, bronze and copper. Casting is most commonly used to create complex shapes. The quality of casting depends on flow behaviour and solidification time of a material.

Factors such as pouring temperature, mould conditions, vibration frequency and other variables of the process have the particular effect on properties and microstructure of castings [1]. Premvrat Kumar and Sandeep katyiar [2] found that mechanical properties changes during vibrating sand casting. Ashwe abugh and Ikpambese kumanden kuncy [3] found that casting during vibration increases the quality and can be used for industrial applications. Nagaraju Tenali et al. [4] found that there is an increase in mechanical properties using mechanical mould vibration with Aluminium 356 alloy. M.E Moussa et al. [5] studied about effect of ultrasonic vibration treatment on microstructure and mechanical properties of brass alloy. X.Jian et al. [6] used Aluminium 356

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alloy in refinement of eutectic silicon phase using high intensity ultrasonic vibration. S. Varun et al. [7] found that there is an increase in tensile strength and decrease in elongation while using LM25 aluminium alloy using gravity die casting by graphite mould vibration. Dommaschk [8] investigate and reported the effect of vibration on pure aluminium, Alwt%SiMg alloys along with other non-ferrous alloys. He focused on the study grain refinement process and reported that the casting wall thickness dependency on characteristics of casting could be minimised using mechanical vibration. Pillai [9] used very low-frequency vibration to the study the effect on A356 and Al12Si alloy and concluded that mechanical vibrations improve the density and elongation of the cast component. Bobba et al. [10] has performed research on the consequences caused in the casting aluminium alloy (A-1050) samples due to mechanical mould vibrations and the results showed that there was a substantial grain refinement and maximum rise in tensile strength combined with hardness. Zhao et al. [11], tested the outcomes of mechanical vibration on the microstructure, thermal fatigue behaviour and impact toughness of hot worked cast die specimen. The die was treated with mechanical vibration with a maximum frequency of 50 Hz in the course of time during solidification operation. The experimental results indicated that the mechanical vibration specimens reduced the growth of cracks forming from mould wall towards the centre of the steel during solidification. Adegbuyi et al. [12] found that the consequences of pouring and vibration on cast condition of aluminium and copper alloys depends upon the crystal grains, vibration within casting materials were purified; solidification structure of the resulting structure was much finer than that produced without vibration. Vijayaram et al. [13], examined the consequences of vibration on the mechanical properties, microstructure of titanium carbide particulate reinforced LM6 alloy composite casting. The composites were fabricated by vibration moulding sand casting technique at frequencies of 10.2, 12 and 15 Hz. Outcomes replicated that the hardness and impact strength of the composites have raised with a rise in persistence of vibration and rise in titanium carbide particulate build up in the LM6 alloy matrix composite. Maximum tensile strength was also noticed at the frequency of 10.2 Hz when contrasted with the gravity die-casting without vibration.

The consequences of the mechanical tests are noted down to verify if it has any rise in mechanical properties and characteristics of different vibrations produced Al 6082 T6 alloy.

2. Material selection

To investigate the effect of mechanical mould vibration, Aluminium 6082 T6 alloy is examined. The basic composition is tabulated in Table 1.

Aluminium 6082 is a medium strength alloy. Among 6000 series, 6082 has highest strength and it is corrosion resistant. It is also called as structural alloy. Aluminium 6061

Table 1. Aluminium 6082 T6 alloy composition as per ASTM Standards [14].

Component	Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Al
%Wt.	0.7–1.3	0.0–0.5	0.0–0.1	0.4–1.0	0.6–1.2	0.0–0.2	0.0–0.1	0.0–0.25	Balance

Table 2. Mechanical properties of aluminium 6082 T6 alloy [14].

Property	Tensile strength	Shear strength	Hardness Vickers	Elongation
Value	340 MPa	210 MPa	100 HV	11%

has been replaced by 6082 after its arrival due to its immense properties and it is most commonly used for machining purpose.

Aluminium 6082 T6 alloys are commonly used for trusses, bridges, cranes, milk cans, beer barrels and transport applications. The mechanical properties are tabulated in Table 2.

3. Methodology

In this research work, rectangular blocks were made by casting of with and without vibrations. The base block of Al 6082 T6 is cast material without vibration to compare with cast material with different frequencies. Here, we have used gravity die casting. There are three steps to prepare the specimens as shown in Figure 1 below.

At first rectangular mould is prepared with the dimensions of 18 × 12 × 10 mm. The rectangular mould is made of mild steel. The main purpose of using mild steel is that its melting point is very high when compared to Aluminium 6082 T6 alloy. So, there is no

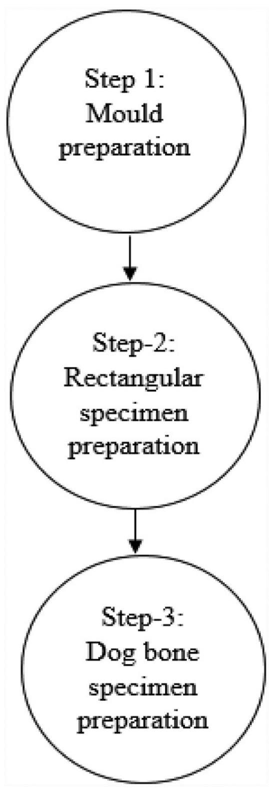

Figure 1. Sequences of steps involved in the preparation of Al 6082 T6 alloy specimens.

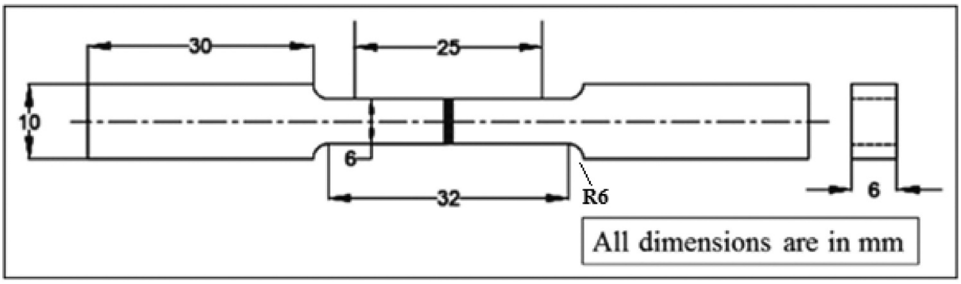

Figure 2. Dog bone specimen specifications as per ASTM E8 standards [15].

chance of melting the mould when molten Aluminium alloy is poured. The Aluminium 6082 T6 is heated in the induction furnace and it starts melting from 500 to 550 ℃. At the same time, the mould is kept on vibration motor. Here, we used a mechanical vibration motor with a frequency range of 15 Hz to 45 Hz. The vibration motor is kept with a frequency of 15 Hz and molten metal is poured into a mould during vibration. Here, the pouring temperature plays a key role in quality of casting. If the pouring temperature is too low, misruns and cold seals may occur. If the pouring temperature is too high, it may cause shrinkage pores and it changes the chemical and physical properties of a material. So, the pouring temperature should be maintained at optimum value. After solidification the rectangular block is ejected from mould. The process is repeated with different frequencies 30 Hz and 45 Hz. The cast rectangular sample is fed to the wire electric discharge machine (EDM). Here, the dog bone shape specimens as are fabricated according to the ASTM E8 standards as shown in Figure 2. ASTM E8 refers to the dimensions which is used to perform yield strength, tensile strength, elongation and reduction of area. These dog bone-shaped specimens are tested on electronic tensiometer, vickers hardness and SEM analysis as shown below.

4. Testing

The produced dog bone shape specimens are undergone various mechanical tests to find the strength, hardness and grain refinement.

4.1. Electronic tensiometer

To find its tensile strength, the specimens are tested in electronic tensiometer which is shown in the Figure 3 below. The load is applied on the specimen, at a particular time the specimen gets leads to fracture, i.e. fracture point. The values and graphs (Load Vs Deflection) are collected from computer connected to tensiometer.

4.2. Vickers's hardness test

To find the hardness of Al 6082 T6, Vickers hardness is one of the method as shown in the Figure 5. It is used to calculate the hardness of various different the metals. For each sample, three trails were performed to find the hardness.

Figure 3. Electronic tensiometer setup for experimental tests .

4.3. SEM Analysis

Scanning Electron Microscopy is a process that scans a sample with an electron beam to produce a magnified image for analysis. It is widely used to investigate the microstructure and chemistry in different range of materials.

5. Results and discussions

5.1. Tensile test results

Tensile strength results of non-vibrated and vibrated with different frequencies of Aluminium 6082 T6 are tabulated in Table 3 below. These results are used to compared with non-vibrated Al6082 T6 to show the increase in tensile strength when vibrated. The increase in elongation shows that there is decrease in brittleness of the material when frequency of vibration gradually increases. The load vs displacement graphs of different frequencies are shown in Figure 4 below.

Vibration analysis and treatment in the course of casting even though rises the tensile strength there is a depletion in ductility of the specimen as a proof from the easing in the percentage of elongation with the rise in the usage of vibration in various applications.

Table 3. Tensile strength of the specimens with different vibrations.

Tensile strength	Sample	Tensile strength(MPa)
0 Hz	Sample 1	90.2
	Sample 2	89.5
	Average	89.9
15Hz	Sample 1	101.56
	Sample 2	100.09
	Average	100.825
30Hz	Sample 1	117.5
	Sample 2	119.23
	Average	118.36
45Hz	Sample 1	115
	Sample 2	112.3
	Average	113.65

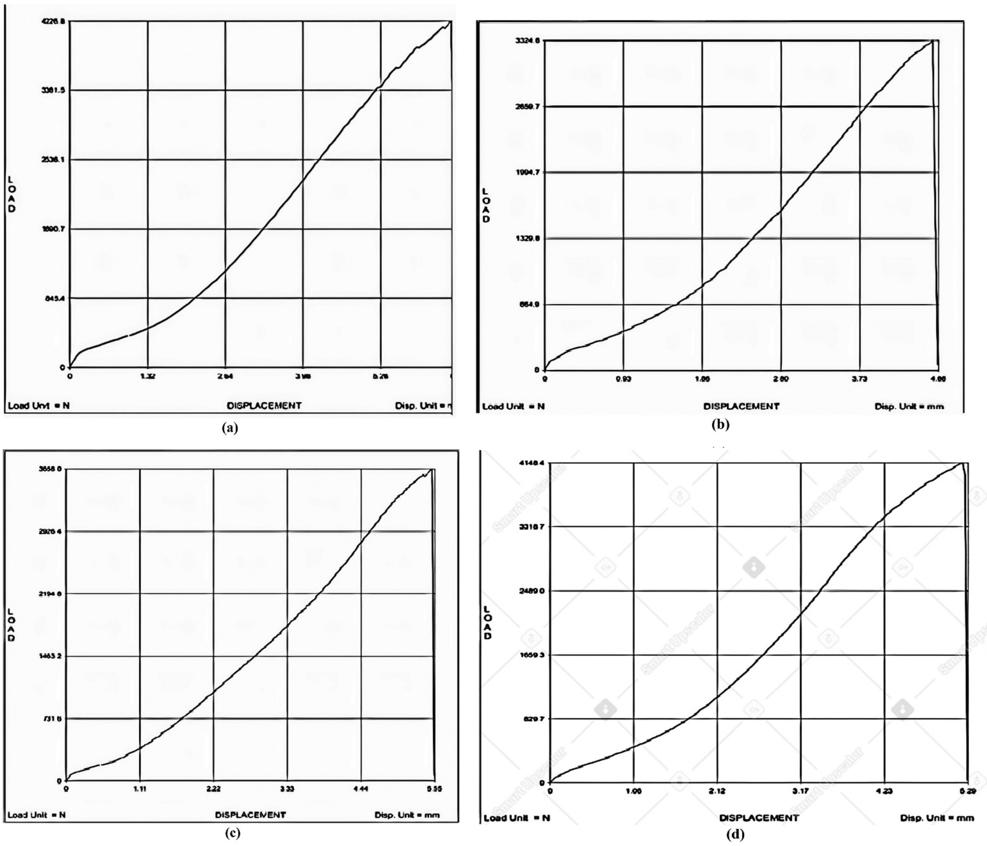

Figure 4. Load vs displacement of various frequencies sample (a)0 Hz (b) 15 Hz (c) 30 Hz (d) 45 Hz.

5.2. Vickers's hardness results

Vibration during casting helped in improving the grain refinement of Aluminium 6082 T6 alloy which helps in increase in hardness as shown in the Table 4. The average value of hardness for basic (0 Hz) no vibration sample was 77.98 RHB, as we noticed when the vibration frequency of the sample increased from 0 Hz to 45 Hz it reached to the maximum value of 87.8 RHB (45 Hz). So it can be noticed that as the hardness values increased with the increase in the intensity of vibration. As we increase the intensity of vibration the grains are closely arranged also, so there is a tremendous changes in hardness.

5.3. SEM analysis results

From the SEM pictures as shown below in Figure 5, it is noticed that vibration can produce remarkable improvements in the standard of castings due to lower the porosity and defects.

From the conducted research, due to the execution of vibration various holes and cavities are decreased. These holes and cavities happen when the reinforced metal is not obtainable to recompense for shrinkage in the course of metal crystallisation. Besides, raise in the

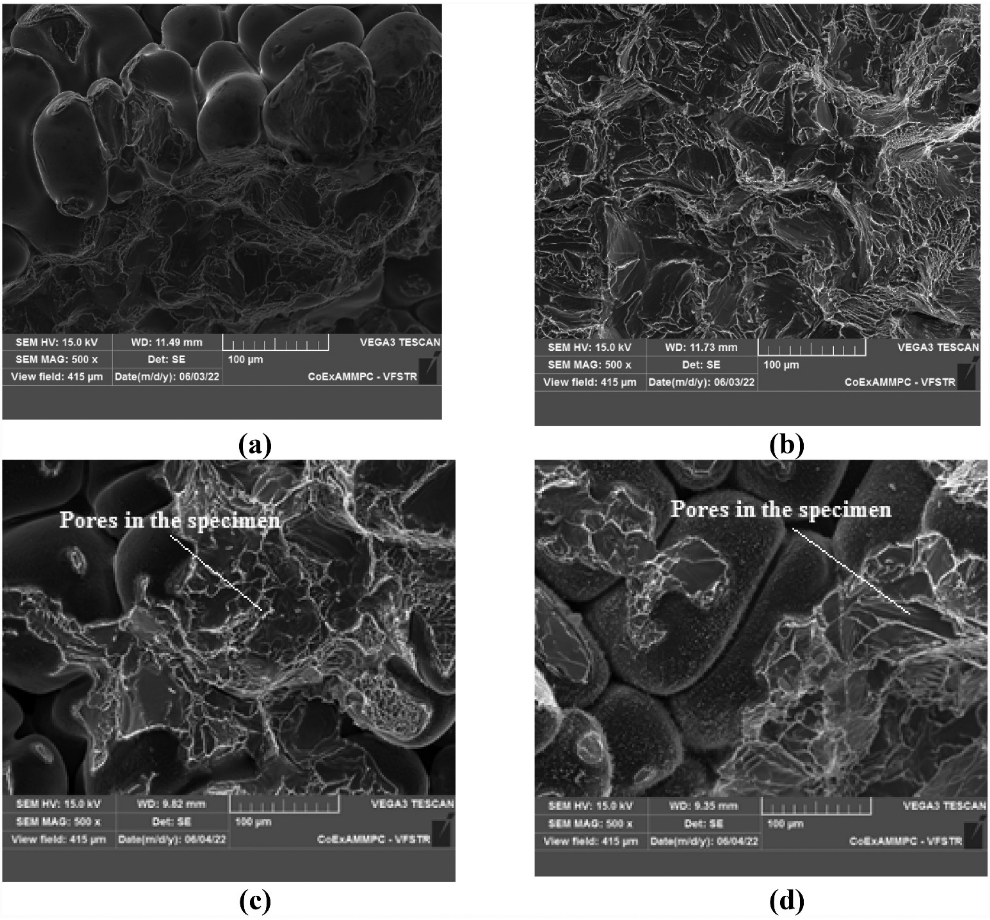

Figure 5. Microstructure images (X100) of different frequencies specimens after tests (a) 0 Hz (b) 15 Hz (c) 30 Hz (d) 45 Hz.

Table 4. Vicker's hardness test results after experimental analysis.

		Trails				
Frequency of a sample	Samples	Trail 1	Trail 2	Trail 3	Average of three trails	Average of two samples(Kg/ mm^2)
0 Hz	Sample 1	78.4	75.6	77.1	77.03	77.98
	Sample 2	79.5	78.4	78.9	78.9	
15 Hz	Sample 1	79.5	82.1	80.0	80.53	80.84
	Sample 2	82.7	81.2	79.6	81.16	
30 Hz	Sample 1	84.3	83.9	86.1	84.7	84.4
	Sample 2	86.4	82.7	83.2	84.1	
45 HZ	Sample 1	87.3	87.5	88.4	87.7	87.8
	Sample 2	89.2	86.8	87.6	87.8	

fragmentation process resulted in smaller grain size as observed in Figure 5 above. The grains are dispensed more consistently into smaller shapes. Minor fragmented grains increase the strength of the specimen by the raise in grain boundaries which is then retained by dislocations. Vibration disturbs the microstructure of the specimens in two different ways. Firstly, by producing periodic pressure tightness waves in the molten state alloy. During one half cycle of pressure tension cavitation event will take place. As these cavities grow, their surface temperature reduces due engagement of energy, offering a rise in the limited solid nuclei. Because of the other half cycle of pressure-tension, these cavities destroy, thus developing nucleation of solid part in the molten metal. Secondly, due to vibration differences, the heat convection of the liquid is gained by creating quick heat extraction. These two features enhance the nucleation rate over crystal growth speed resulting in good, fragmented, fibrous grains rather than coarse grain.

6. Conclusion

Based on the detections in the research conducted the following conclusions are recorded:

(1) The impact of mould vibration on the properties of aluminium 6082 T6 alloy is evaluated. Aluminium 6082 T6 is chosen to study the effect of mould vibration on grain refinement, tensile strength. It is found that mould vibration has significant impact on grain structure.
(2) The tensile strength and hardness are gradually increased as we increase the intensity of vibration during casting.
(3) Vibration created produced some beneficial consequences in clarifying the micro-structure by intensifying the solidification procedure to develop more good, fragmented and comparable microstructures. It also reduces the cavities, holes, porosities and faults such as depletion and addition.

Finally, it is concluded that mechanical mould vibration of Al 6082 T6 have an important role in improving the properties as compared to alloy without casting. This can be used to many more applications like railway doors and transport applications. Elongated research can be performed on the outcomes that occur in high temperature outputs, output with more than frequency of 50 Hz.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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