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Experimental Investigation on the Effect Due to Mould Vibrations on Mechanical and Metallurgical Properties of Aluminum Alloy (A-1050)

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ABSTRACT

In the current research work performed, the consequences caused in the casting aluminum alloy specimen due to mechanical mould vibrations are examined. Mould vibration throughout the casting provides decreased rate of shrinkage, good morphology, surface finish and lesser probability of hot tear. In this research work, the effect of mould vibration during solidification of Aluminum A-1050 alloys for dissimilar values of wavelengths at a permanent pouring temperature has been investigated to understand the modification in microstructure and mechanical properties after casting. The Al A-1050 casting has been made in a metal mould with different vibrations. The frequencies are varied from 15Hz to 50 Hz during the casting process. A casting has been made with different vibration as well to compare the results of castings with vibration frequencies. The experimental outcomes exhibited substantial grain refinement and significant increase in tensile strength and hardness of the castings with mechanical mould vibration during the duration and after solidification.

KEYWORDS

Aluminum A-1050 Alloy, Hardness, Microstructure, Mould Vibration, Ultimate Tensile Strength, Vibrating Table

1. INTRODUCTION

Aluminum alloy is one of the most widely used on-ferrous metal structure materials in the current industries. It is widely used in aviation aerospace, automobile, machinery manufacturing, shipping and chemical industries. With a rapid development and advancement in the science, technology and industry economy in recent years, the demand for welded structural parts of aluminum alloy is increasing day by day which makes the research of weldbility of aluminum alloy deepen. The wide applications of aluminum alloy have promoted the development of welding technology of aluminum

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alloys. At the same time, the development of welding technology has expanded in the application field of aluminum alloys. Therefore, the welding technology of aluminum alloys is becoming one of the hotspots of research. The peculiar properties of aluminum A-1050 alloy which make it more versatile like the weight, high machinability, high corrosion resistance, good conductivity and high thermal conductivity. A mixture of tribological, mechanical properties and low density are exhibited by aluminum alloys which made the alloys highly suitable for complicated metal manufacturing. Aluminum alloys can be operated for packaging functions in food industries, pistons production, making sumps of internal combusting engines, heads of the cylinder and electrical cables (Chapman, 1975) (Lancer, 1981)

Metal casting is the best technique used in the manufacturing process in which the liquid metal is teemed into the mould cavity and then allowed to cool or solidify in that cavity. Amongst each and every single manufacturing process, the casting procedure is reasonable due to its basic procedure. The casting feature is being influenced by the flow behaviour of the molten metal and other considerations of the process. Extra than 80% of the manufactured goods made nowadays days practice the casting methods (S.S. Mishra et al. 2015). The heat produced during casting of aluminum alloy varies between 650°C – 750°C. To know the subsequent pouring temperature required for the metal and alloy information on their melting temperature is required (Jain, 1986) (Dieter, 1981). Likewise, pouring temperature has a substantial outcome on the attribute of the cast achieved. Inferior pouring temperature than the ideal value, mould cavity will not be stopped because of the quick solidification of the riser and this leads to the disturbance in steering solidification. As soon as the pouring temperature is greater than the optimum rate, it will cause consequences such as casting contraction and wrapping of the mould (Grill, 1982) (Llewellyn, 1997) (Lancer, 1981). Most of the researchers implement ultrasonic and electromagnetic vibrations for their findings on the effects caused in the casting product and material (Abugh A et al. 2013) and (Jian X, 2016). Aspects such as mould surroundings, pouring temperature, vibration frequency and other parameters of the procedure have a specific outcome on the properties and microstructure of castings (Jackson K.A, 1958). Sokoloff et al. (2005) examined the mechanical vibration influence on the grain refinement and the development of the grain structure. Cambell et al. (1981) have researched the factors that can improve in the corrosion and mechanical properties on an alloy which that can be achieved by mechanical vibration only. Dommaschk et al. (2003) investigated and described that the consequences produced due to mechanical vibration on pure aluminum, Al-Si-Mg alloys along with other non-ferrous alloys. The researcher concentrated on the analysis of the grain refinement procedure and stated that the casting wall width will have reliance on characteristics of casting and could be minimized by using mechanical vibration. Pillai (2004) used extremely little frequency vibration on the study to find the effects on A356 and Al12Si alloy due to mechanical vibration. The researcher determined that the mechanical vibrations will tend to develop the density and elongation of the cast element. In appendage, the mechanical vibration can increase the composition circulation within the alloy and confine the expansion to a little extent (Zhu J, 2014) (Xie J et al.,2016)

In this research work, the consequences of mechanical mould vibration on metal casting alloy A1050 are calculated. The A-1050 alloy is metal cast in the mould. The mechanical vibration is generated during the solidification process of the metal cast. After the process, the obtained alloy is dimensionally reduced and surface leveling is performed on the lathe machine. Universal testing machine was utilized for the test to obtain the ultimate tensile strength and ductility. Hardness and rigidity are analyzed by using Rockwell test machine. The outcomes of the tests are recorded down to examine if it has any increase in mechanical properties and characteristics of A1050 alloy, when mechanical mould vibration is operated during the casting process.

2. EXPERIMENTAL SETUP

2.1 A-1050 Alloy Casting

The casting of A-1050 alloy is done by using steel moulds. The steel mould is fabricated by the optimum grain size of the particular alloy by differing the pouring temperature, compositions and physical and chemical properties of the alloy which has an ultimate effect on the attributes of castings produced in the process.

2.2 Process of Preparation of the Test Specimens

A-1050 alloy is warmed in the furnace until it changes its form into liquid and reaches the maximum temperature of 650°C. The temperature is sustained till the end of the process as this temperature of 650°C is the pouring temperature of the alloy, then the liquefied alloy is teemed into vibrating metal moulds depending on the ultrasonic vibration produced. The vibration is created by using vibration motor which is induced in the metal moulds as shown in the Figure 1. The mould is maintained under vibration until the solidification state is obtained in the casted alloy, following solidification process, the casted alloy is removed out from the metal mould for additional processing and conducting experimental tests.

Finally, the casted alloy portions are machined for dimensional modification and surface finishing which done with the help of lathe machine to the make specimen of A1050 alloy for the examination of the mechanical properties. It is also being noticed that the amount of vibration with amplitude of 430 microns, frequency of 20 Hz and time of vibration 25 sec had some degree of effect on the ductility of the specimens.

2.3 Mechanical Properties Testing Process

The specimen of alloy A-1050 is secured on to the universal testing machine-UTM and tensile strength test is analyzed and stress-strain readings are selected until the specimens are fractured or ruptured as shown in the Figure 2. The stress-strain values are noted from the load deformation. The rupture load for each single specimen was observed and also the diameter at the place of rupture and the ultimate gauge length. The original diameter and primary gauge length for every single specimen was recorded in advance to the uniaxial load. Hardness of the specimens were examined with the help of the rock well harness testing machine. The hardness is examined at various locations of the specimen, the values are tabulated in the Table 2 and tests are performed at room temperature to show the real time condition of the Al-1050 alloy when it gets ruptured due to various factors in the day to day life.

Figure 1. Vibrating table and cast mould experimental setup

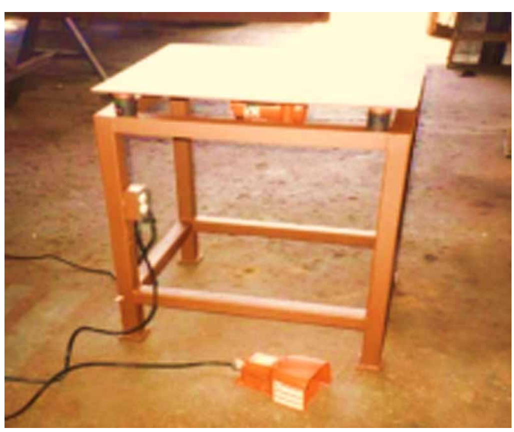
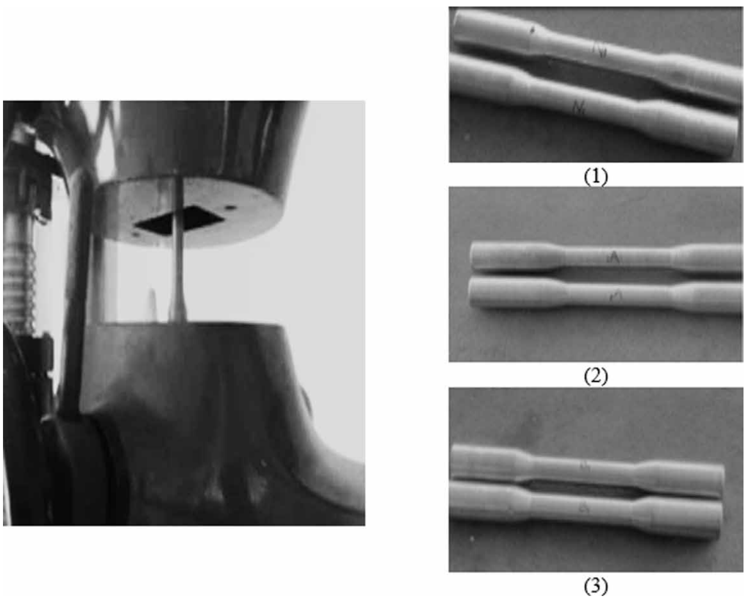


Figure 2. UTM machine showing sample specimen of A1050 tested for tensile and ductility, (b) Test specimens with (1) 15 Hz, (2) 30 Hz and (3) 50 Hz mould vibrations



A total of five test specimens (two for ultimate tensile test, three for hardness test and microstructure) were casted out for each different frequency of vibration. Castings were made for different vibration frequencies as from 15 Hz, 30Hz, 50 Hz. After the casting process, all the specimens are handled for heat treatment process. Around two for each frequency were heat treated and then converted into essential tensile test specimen as per standard. The standard used in the experimental analysis of the aluminum alloy A-1050 is E8.

After the ultimate tensile tests, the specimens are arranged for the hardness test and microstructure checkup. These hardness and microstructure specimens are prepared into four equivalent parts all along its total length. Hardness specimens are only grinded on the surface by belt grander and then followed by polishing. The development of wear resistance is with the increase in the hardness, to find the grain size reduction value mathematically, Archard's law (Shen L. Y et.al, 2000) is implemented.

3. RESULTS AND DISCUSSIONS

3.1 Tensile Test

Graphs were mapped from the Ultimate tensile test results which were obtained from the stress and strain values as shown in the Table 1. As observed from the Figure we can make out that the tensile strength increases by the rise in the metal mould vibration frequency. Generally, as stated that the

Table 1. Tensile test results at various frequencies of mould vibration and the Average Results of mould Vibration

Trail	Trail-1	Trail-2	Trail-3	Average
Ultimate tensile strength (N/mm^2) **– 15 Hz**	320	327	328	325
Ultimate tensile strength (N/mm^2) **– 30 Hz**	356	360	362	359
Ultimate tensile strength (N/mm^2) **– 50 Hz**	410	412	411	411

tensile strength and compressive strength are reciprocal to each other and as the tensile strength decreases the compressive strength increases.

The maximum values of tensile strength are at vibration frequency of 50 Hz of 412 N/mm^2 and the minimum value is at vibration frequency of 15 Hz of 320 N/mm^{2,} by this reading it can be found that the strength of the aluminum A-1050 decreases with the mechanical vibration frequency after casting process. So based on that we can predict that if mould vibration increases the compressive strength of the component increases. Tensile results of vibrated and more vibrated test samples are shown in Table-1 and Figure-3 below.

3.2 Hardness Test

Hardness results of the metal cast samples are presented in Table 2. It is evident that the hardness of metal casting increases with the rise in vibration frequency because vibration produce refinement of grains and grain structure. The maximum hardness was attained at the boundary in the graph for each single specimen, because the maximum cooling rate and utmost intensity of the metal mould vibration was noticed at the margin of specimen as evident from the microstructure also shown below from the Figure. Additional cooling rate stimulates the creation of fine grain and at the same the vibration procedure produces fine grains, that means additional grain boundary can produce more hardness (Ahagaki T. et. al, 1981). So we may be state that due to the mutual outcomes obtained from both cooling rate and intensity of vibration, there are remarkable changes of hardness in the metal cast product. The changes in the hardness with metal mould vibrations are shown in the Figure-4 and Table-2 below. From the below Figure-4, rise in elongation proportion exhibited that the brittleness of A-1050 alloy is reduced. This indicated that the mechanical vibration though metal casting of A-1050 alloy develops its mechanical properties. Vibration produced throughout metal casting of alloy A-1050 resulted in the grain refinement which in advance lead to compactness and increase in hardness of alloy as compared to A-1050 alloy casted with vibration of 15 Hz.

Figure 3. Graph representation of different frequencies (Hz) vs ultimate tensile strength(N/mm^2)

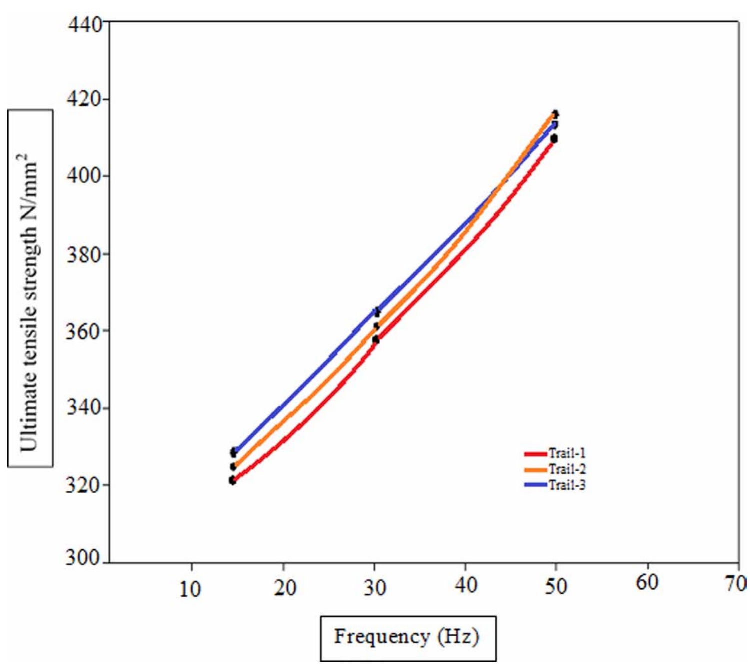
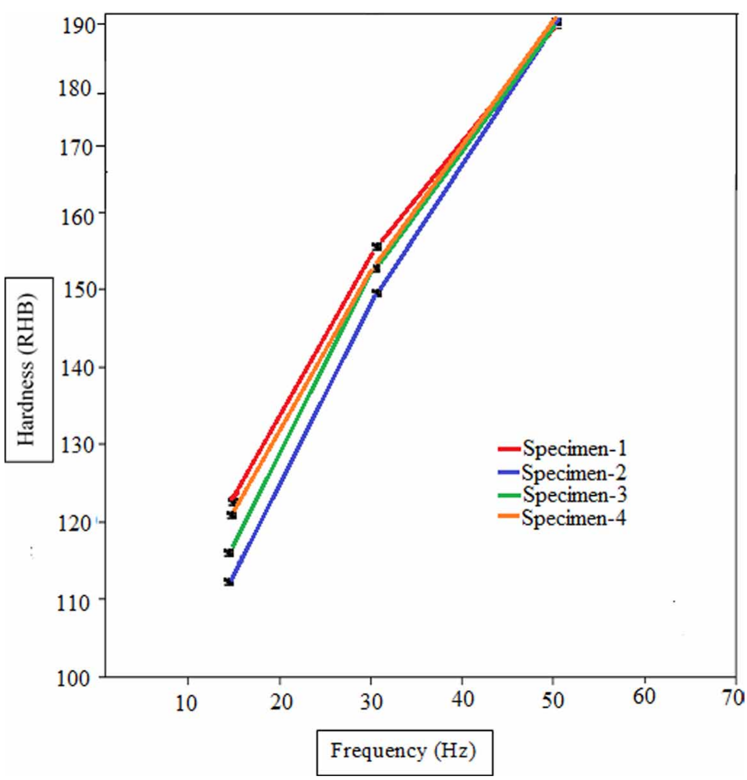


Table 2. Representation of variations in hardness in represent to different vibrations

Type	No of specimens	Hardness (RHB) Number of trails			Average (RHB)
		1	2	3	
Metal mould vibration at 15 Hz	1	118	125	124	122
	2	106	110	121	112
	3	110	115	121	115
	4	115	123	124	121
Metal mould vibration at 30 Hz	1	154	156	159	156
	2	145	151	150	149
	3	148	154	158	153
	4	144	149	153	149
Metal mould vibration at 50 Hz	1	189	192	191	191
	2	191	193	194	193
	3	187	190	193	190
	4	186	192	194	191

Figure 4. Graph representation of different frequencies (Hz) vs hardness (RHB)



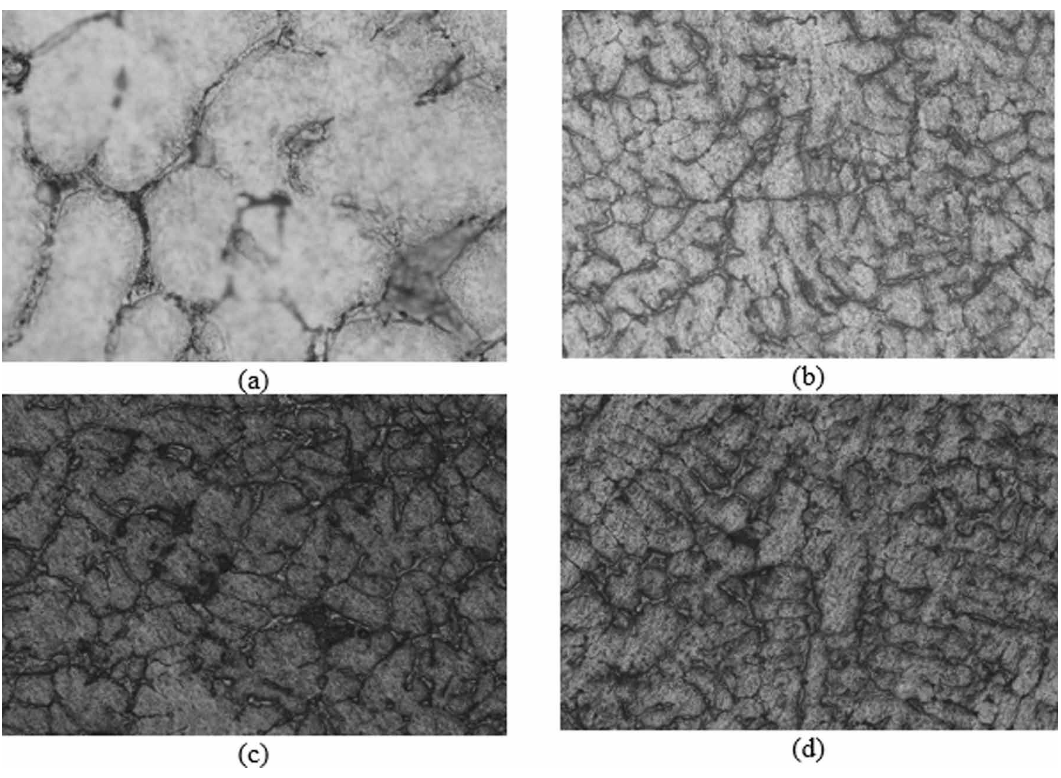
. Finally, after both the tensile and hardness tests, we can also justify that the application of the mechanical vibration can increase the flow of the liquid alloy in the procedure of solidification and filling, and decrease the resistance alongside the layer throughout the filling, which is beneficial in improving the filling volume also (Sun Y et al., 2017) (Li JQ et al., 2007) and from the micro structure analysis the vibration can also expand the composition dissemination in the alloy and reduce its growth to certain extent (Nie KB et al., 2014).

3.3 Scanning Electron Microscope (SEM) for Image Examination

Scanning electron microscope representations of the Aluminum 1050 specimens which were experimentally tested are shown in the Figure 5 below and from the images represented below it clearly shows that by the rise in the frequency of vibrations the grain refinement increases. The grain refinement changed its structure as the vibration frequency increased from 15Hz to 50Hz. The microstructure samples were prepared by conducting different metallography steps like polishing on different silicon graded paper, fine polishing on double disc polishing machine and finally etching. After the tests when the microstructure was viewed, the grain size was more shrunken as the vibration increased and grain developed a compacted structure, grain was further in spheroidal form when casting is solidified and while being vibrated simultaneously changed its state.

Owing to the rise in the intensity of vibration, endorses the breaking of the dendritic structure and promotes high heat transfer, makes the grain finer (Radhakrishna K, 2011) Finally, we can notice from casting process, the cooling speed determines the assembly of casting product produced. If cooling rate phenomenon is quicker, microstructure will be better.

Figure 5. Microstructure of the Aluminum A-1050 specimen samples with different vibrations after different mechanical and metallurgical tests; (a) No vibration, (b) 15 Hz vibration, (c) 30 Hz vibration, (d) 50Hz vibration.



4. CONCLUSION

Aluminium alloy A-1050 was considered for the study on the effect of mechanical vibration on hot tearing, grain refinement and other mechanical parameters. The consequences due to mechanical metal mold vibration on the mechanical characteristics of Al-1050 alloy was evaluated in the research performed. Based on the experimental outcomes the subsequent conclusions we withdrawn:

1. Tensile strength increases depending on the metal mould vibration frequency during casting, as the compressive strength upsurges the tensile strength drops. The increase in the compressive strength is greatest sign in the strength of the casted product.
2. The ultimate tensile test of the A-1050 alloy over the effect of vibrations indicated an increase in ductility an d tensile strength of the alloy.
3. Increasing the mould vibration frequency of the casting product increases the hardness. which also very respectable sign of progress.
4. From the SEM images it can be noticed that the grain size was reduced by vibration and grain became more compact. The grain was more spheroidal shape when casting is solidified while being vibrated simultaneously.
5. As the frequency of the metal mould vibration rises with the grain refinement improves, which gives good strength of the casting process

Finally, it can be concluded that the mechanical vibrations induced during metal casting of A1050 alloy have a substantial role in refining the metallurgical and mechanical properties. This leads to the consumption of the alloy more efficiently and promptly in machinery of heavy scale industries.

Extended research can be concentrated on the consequences during high temperature, outcomes produced with the frequency more than 50 Hz. Distinct from the above, effects produced due to size variation during the casting process and implementation with distinct materials can be studied.

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