ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 9, September 2017

Dry Sliding Wear Characteristics of Hypo-Eutectic Aluminum Alloy Subjected to Grain Refinement

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***Abstract:* --Grain refinement studies on Aluminium, silicon and magnesium alloys have attracted considerable attention in the last five decades. The properties of aluminium alloy castings predominately depend on the grain structure formation that takes place inside the material during solidification process. In the present investigation, a device has been designed and developed, which will induce high frequency ultrasonic vibrations to the molten metal during solidification process inside mould. In this study, frequencies varied were 10, 20, 30, 40 and 50 kHz.amplitude of vibration kept constant .From the studies it is seen that the size of the grains has been reduced (from coarse to fine grains) equiaxed grains are seen. Hardness value has also increased considerably (56.6%) by subjecting the metal to grain refinement Wear resistance properties of LM25 alloy in dry sliding conditions has considerably improved. Wear studies in the dry sliding conditions has been carried out in detail. Wear studies has been carried out using standard pin on disc machine for different speeds viz,300,600,900 and 1200rpm.The study indicate that there is a considerable improvement in the wear resistant of the alloy subjected to grain refinement.**

Keywords— Aluminium Alloys, grain refinement, ultrasonic vibration , solidifications.

I. INTRODUCTION

crest. Bauxite ore is the source of aluminium; Aluminium is remarkable for low weight, low density, offers corrosion resistant due to the phenomenon of passivation. The parts or structural components made from aluminum and its alloy,are vital to the aerospace industry and are very important in transportation and building industries[1].Properties of the aluminium alloy castings predominantly depends on the grain structure formation that takes place inside the material during casting process(solidification process). Better improved properties are achieved when fine grain structures are formed. The formation of dendritic and fine equiaxed grain structure depends on solidification process, type of grain refiner alloys [2, 3]. For refinement of grains in aluminium alloys many methods are employed.Among those methods, inducing vibration during solidification which gives enhanced properties of cast alloys [4] has attracted considerable attention. Two factors that contribute to the formation of grains are; there must be the presence of suitable substrates in sufficient amount to act as heterogeneous nucleation sites. Secondly there has to be sufficient undercooling to facilitate the survival and growth of nuclei [5].The object of the work is to study the effect of inducing high frequency ultrasonic vibration to LM25 alloy and assess the mechanical proeperties and wear resistance properties. Research work regarding the effect of grain refiner addition has been carried out by a number of investigators. Details pertaining to the mechanical properties, structure are available, however less information is available on the development of an apparatus to induce different level of vibrations to the solidifying metal, the properties assessment due to the resulting microstructure. Frequency in the range of 10 to 50 kHz has been varied .Results of the investigation indicate refinement in the structure improved hardness value and wear resistant values upon subjecting the alloy to different levels of vibration

II. EXPERIMENTAL PROCEDURE

The Alloy selected is LM25 aluminum alloy. The composition of alloy is chemically determined by optical emission spectrometer

Table 1: Composition of LM25 alloy

Elements	Si	Mg	Mn	Cu	Fe	Ni	Zn	Pb	Ti	Sn	Al
% by wt	7.041	0.437	0.003max	0.021	0.345	0.02	0.04max	0.01max	0.007	0.003max	Rem

Melting was carried out in a graphite crucible which was

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 9, September 2017

placed inside an electrical resistance melting furnace; degassing was carried out (hexachloroethane degassing tablet). Dross formed on the top layer of molten metal was skimmed off and clean molten metal was poured into the mold.Different levels of ultrasonic vibrations and at constant amplitude were induced to the molten metal during solidification process for 3 minutes duration.The studies were carried out for the following conditions

- Without inducing ultrasonic vibration to the melt (as cast)
- Inducing different levels of ultrasonic vibrations to the mold during solidification process

2.1 Circuit for Ultrasonic vibration

To induce the ultrasonic vibration a special setup/apparatus was developed.It is schematically illustrated in figure- 2

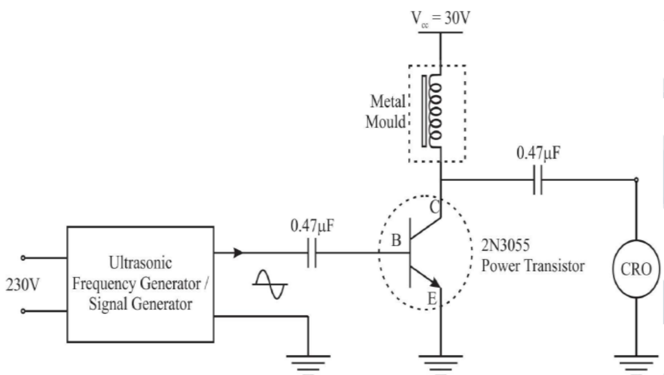


Figure- 2 Circuit diagram of ultrasonic vibration system with necessary connections

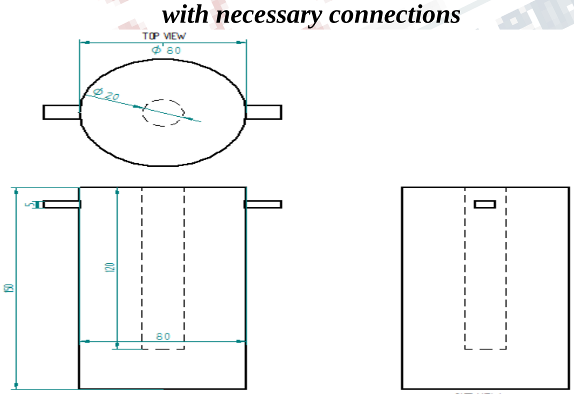


Figure-3 detailed drawing design of the mold in 2D Model

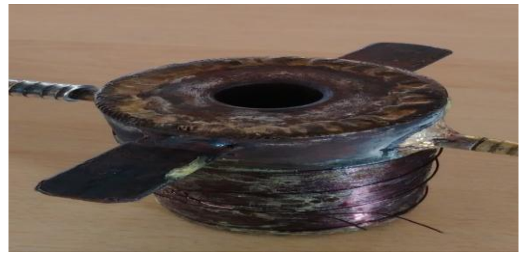


Figure-4 Working model of the mould

Die is designed in such a way that the ultrasonic vibrations are directly induced into the moltem metal present in it. Permanent mold made of EN19 steel is wound with electrical wires which supply ultrasonic vibrations from the signal generators and signal controllers to the mold (when power is supplied to the setup). The necessary connections are made before pouring the molten metal into the mould. A facility is available to control the frequency and amplitude as per the requirements. Frequency is varied from 10 to 50 kHz in steps of 10 kHz. The setup is equipped with a power supply unit, signal generator, CRO and Transistor. The circuit diagram as shown in fig.2.The power supplied to the circuit is 230V AC current; the signal generator or frequency generator, generates reiterating voltage wave forms; the signal generator can yield more than one type of signals. The cathode ray oscilloscope delivers accurate time and amplitude measurement signals over a diverse range of frequencies.

2.2 Experimental Procedure

The ultrasonic vibration system operates at a frequency of 10 to 50 kHz and can generate different ultrasonic vibration of frequency and different amplitudes. In the present study the different levels of ultrasonic vibrations selected were 10, 20, 30, 40, and 50 KHz and amplitude selected 10volts. The molten metal was poured at a temperature 7230C into the metallic mould and then ultrasonic vibrations were induced to the mould for period of 3 minutes duration. The system is provided with different levels of frequencies and amplitudes.

Steps involved

- Make the necessary connections as per circuit diagram
- Check for the required frequency level and amplitude in respective device and adjust the vibrations level by operating the respective knobs.
- check connections of the die prior to pouring the molten metal into the die;
- Transfer the molten metal into the die, duration of the application of ultrasonic frequency is 3 minutes; after treatment disconnect supply from the system.
- After solidification and cooling the specimen is

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 9, September 2017

ejected out of the die.

Experiments hardness tests were carried out were conducted using (MITUTOYO) micro hardness testing machine,wear studies were carried in dry sliding condition. It is capable to check the hardness very accurately and directly gives the hardness value after finding the indentation diameters d1 and d2 .Load selected is 0.3kg and 10 second dwell time. The machine automatically applies the load for ten seconds. An average three hardness values at different location across the cross section has been employed for the analysis. An instrumented type of Pin on Disc wear testing machine has been used to carry the wear tests.Weight loss method has been carried for the analysis. Wear studies has been carried by varying speed, load, keeping track radius constant. An 8mm diameter pin (specimen) is made to slide against a rotating wear disc has been used and the wear assessments has been carried out. Specimen for microstructure examination, Hardness studies and wear studies were machined as per requirements from the ascast alloy and the alloy subjected to vibrations.

III. RESULTS AND DISCUSSIONS

From the investigation carried out on grain refinement of hypo-eutectic aluminium LM25 Alloy casings subjected to different levels of ultrasonic vibration(10,20,30,40 and 50 kHz) and constant amplitude is 10Volts the following observations are made.

3.1 Microstructure examination.

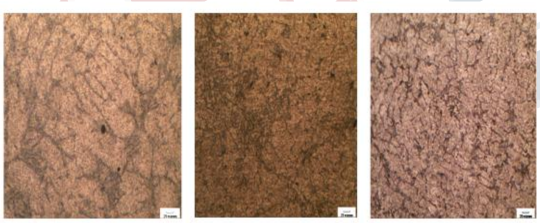


Figure-5 Microstructure of As-cast, 10, 20 KHz (10V) ultrasonic vibration, X200

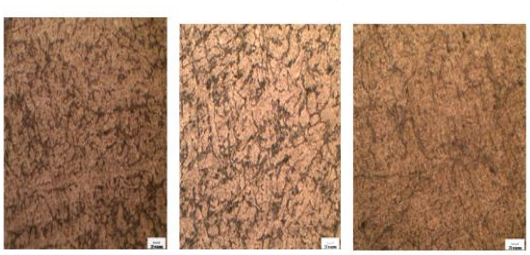


Figure-6 Microstructure of 30, 40 and 50 KHz (10V) ultrasonic vibration X200

Figure-5and 6 shows the micrograph images of the specimen (200x magnification for 10,20,30,40 and 50 kHz US vibrations respectively).As-cast Al-Si alloy (without the inducing ultrasonic vibration). It is observed that, the structure of alloy is composed of coarse aluminium matrix, it is strengthened by Si precipitates, and dispersion of eutectic silicon particles and inter metallic. Microstructure consists of network of inter-dendritic eutectic silicon in a matrix of aluminium solid solution. Porosity is observed. The dark black colour spots are seen in casting. Further upon subjecting the molten alloy to different levels of vibration, can be observed that very fine grains and equiaxed rose shaped dendritic structure, globular grains are found; absence of porosity in the specimen and equally dispersed silicon in the casting subjected to different levels of vibrations is seen.

3.2 Hardness Test Results (Vickers micro indentation tests)

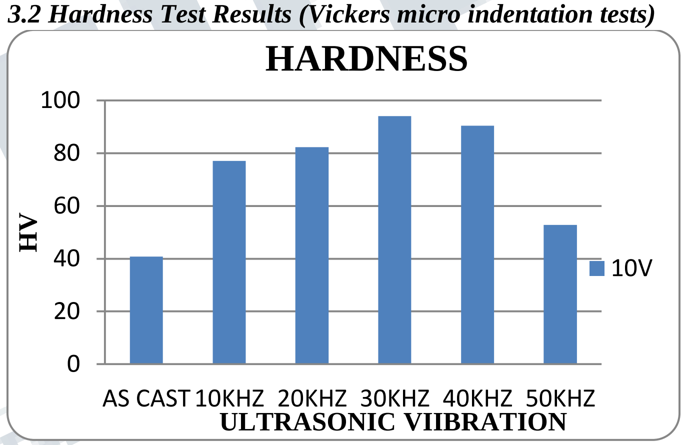


Figure-7 Variation of Hardness values with vibration levels (10V amplitude)

Figure-7 shows the variation of Vickers hardness value for the specimen for different conditions. It can be seen from the figure that as-cast specimen exhibits lowest hardness value 40HV. Increasing trend in hardness value is observed with increasing vibration levels; higher hardness value is noticed for the specimen subjected to 30 kHz frequency. This may be due to the refinement of grains, the compaction of structure and uniform dispersion of the silicon parts may be the reason for higher hardness value. With further increase in the vibration level beyond 30 kHz a decreasing trend in the hardness value is noticed. This may be due to the non-uniform dispersion of silicon particles in the matrix. Further increased vibration has let to decrease in the harness value. An increase of 56.63% in hardness value is noticed. This indicates that the specimen subjected to 30 KHz frequency level exhibits higher hardness value. The study indicates that

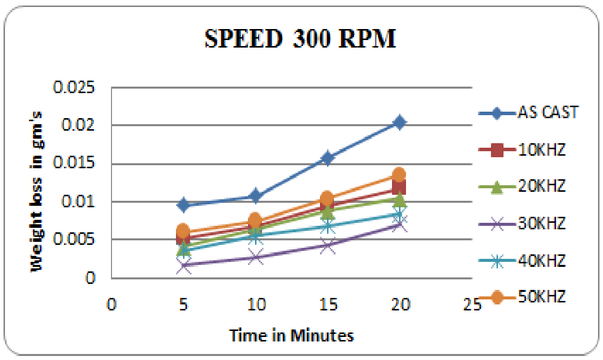
ISSN (Online) 2456-1290

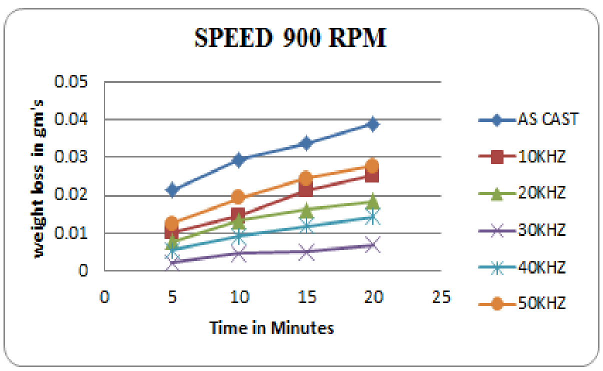
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 9, September 2017

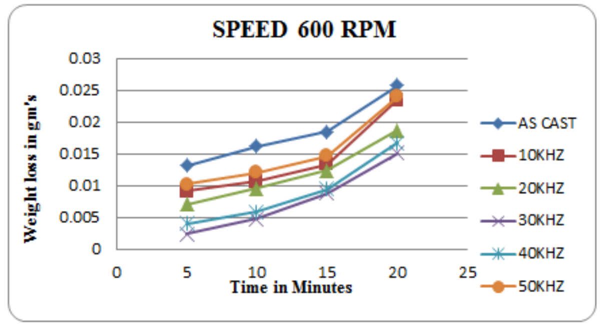
increase in frequency level upto 30 kHz will increase the hardness values and there after hardness value decreases.

3.3 Wear tests

Dry sliding wear tests were carried out using pin on disc type wear testing machine. The specimen was tested for constant load of 1 kg for different speeds viz.300, 600,900 and 1200 rpm for time duration of 20mins.Weight loss method has been considered for the analysis.







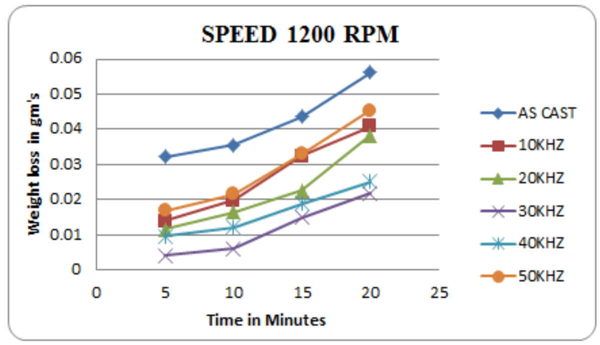


Figure -8 Weight loss v/s time (10volts)

Pertaining to figure-8 shows it can be seen from the figure that with an increase in speed the weight loss also increases. Maximum weight loss seen in the as-cast specimen. An improvement of 45% in wear resistance is noticed upon subjecting the alloy to ultrasonic vibrations

IV. CONCLUSION

The results of the investigation carried out indicate the following.

Microstructure Examination

- As-cast condition; structure exhibits coarse aluminium matrix eutectic silicon parts and inter-dendritic structure, porosities are also observed.
- Specimen subjected to ultrasonic vibration- fine grain structure, reduction in grain size is observed compared with as cast condition.

Hardness test results

Following table summersies the results of the Vickers hardness values carried out on the as cast specimen and specimen subjected to ultrasonic vibration.

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ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 2, Issue 9, September 2017

Condition	Hardness	
	HV	%Increase
As-cast	40.775	
10 kHz	77.075	89.02
20 kHz	82.225	101.65
30 kHz	94.025	130.6
40 kHz	90.425	121.76
50 kHz	52.75	30

Dry sliding wear tests

- As cast specimen exhibits less resistance to wear.
- Specimen subjected to ultrasonic vibrations exhibits more resistance to wear.
- Specimen subjected to 30 kHz vibration exhibits the least wear compared with other conditions.
- Hence from the above studies it is observed that inducing vibration to the alloy during solidification and cooling can be considered as one of the methods for the improvement of grain size,mechanical properties and wear resistance properties.
- The results of the investigation will be quite useful for selecting the vibration level for a suitable application.

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