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Effect of addition of 2%Al2O3 for grain refinement of Al-16Si Hypereutectic Alloys at 770°C.

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Abstract— Presently light weight Al-Si alloys are recognized as excellent candidate, which will replace the traditional use of cast iron in automobile engine in order to promote fuel economy & improvements in vehicle emission in engineering applications. The microstructure of hyper-eutectic Al-Si alloys is composed of primary Si crystals having several morphology such as star like, polygonal, plate like & feathery shape along with eutectic phase (α-Al + eutectic Si). The morphology of eutectic Si is also complex, including coarse acicular and flake like shape. During conventional casting process the size, morphology and distribution of primary and eutectic Si phase in Al-Si alloys play a critical role in determining the mechanical properties and wear behaviour.

The Al-16Si-2%Al_2O_3 alloys have significant improvement in hardness and wear resistance as compared to Al-16Si alloy melted at the temperature of 770°C. The presence of Al-rich intermetallic compound in Al-Si-Al_2O_3 alloys was reported in the XRD analysis which accounts for improvement in both hardness and wear resistance. In SEM images, it is observed that the larger feathery, star and plate like shape of the primary Si and coarse acicular and flake like shape of eutectic Si were modified by addition of Al_2O_3 content. The fine spherical & uniformly distributed primary and eutectic Si phases found to improve mechanical and tribological properties of hyper-eutectic Al-Si alloys.

Index Terms— composite, Al-Si-Al_2O_3 alloy, Al-rich intermetallic compound, Al-16Si-2%Al_2O_3 alloys, tribological behavior, $Al_{3.21}Si_{0.47}$,wear rate.

1 Introduction

A fine equiaxed grain structure is normally desired in Al castings as fine and equiaxed grain offers the best combination of strength and ductility [1]. The type and size of grains formed are determined by alloy composition, pouring temperatures, solidification rates & the addition of grain refiners containing intermetallic phase particles which provide sites for heterogeneous nucleation [2]. Grain size is refined by increasing the solidification rate but it is also dependent on the presence of grain refining elements in the alloy [3 - 5]. Apart from wrought alloys grain refinement has a several benefits in cast alloys like improved mechanical properties that are uniform throughout the casting, distribution of second phase and micro porosity on a fine scale, better feeding to eliminate shrinkage porosity, improved ability to achieve a uniform an oxidized surface, better strength and fatigue life [6].

2 Materials and Experimental Methods

The materials used for Al-16Si and Al-16Si-2Al_2O_3 composite samples are i) 99.97% purity (Cp) aluminium ingot, ii) Gamma alumina (γ-Al_2O_3) and iii) Al-50%Si master alloy. Al-16Si-2Al_2O_3 composites have been made by stir casting process and the samples were tested for their physical, mechanical and tribological properties.

2.1 Manufacture of Al-16Si and Al- 16Si- 2Al_2O_3 composites.

Commercially pure (Cp) aluminium and Al-50 wt% Si master alloy were melted in a graphite crucible in a pit type melting furnace at 770°C to prepare Al-16Si alloy and Al-16Si-2Al2O3 composites were manufactured by conventional stir casting method by adding the Al2O3 particles. Fig.2.1 shows the (a) mould for casting and (b) Casting of Al-16Si-2%AL2O3.

(a) (b)

Fig.2.1: (a) Mould for casting of AMC, (b) Casting of Al-16Si-2%AL2O3 alloy by stir casting method.

2.2 Characterization

Different phases present in the samples are examine by the XRD analysis of the samples (10mm x 10 mm x 2mm) which was carried out with Cu-Kα target and matching of peaks with JCPDS data files.

2.3 Hardness and Density

For the measurement of the hardness value measured in Microvicker's hardness tester having diamond pyramid (square base) as indenter with 1kgf applied load for 15 seconds. The samples were taken care to make the horizontal faces of the test sample to be parallel by polishing. The measurement of the two diagonals of the impression at five different locations to get the Vickers Hardness number (VHN) of the samples.

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Mettler-Toledo density tester machine was used for measuring the density of the samples one by one.

2.4 Wear test

To investigate the tribological behaviour of the composite having sample with 10mm dia and 30mm height were tested in a pin on disc wear testing machine. The load was varied from 40 to 60N with rotation speed of 300, 400 and 500rpm (having 40mm track radius) for the duration of 5 minutes at room temperature without using any lubrication materials. The microprocessor controlled attached with wear testing machine gives real-time data for height loss (in micron) and coefficient of friction. The mass loss due to wear of each was calculated by the formula

$$V = KFS$$

Where, V = Wear volume (mm3)

K = Wear rate (mm3/Nm)

F = Normal load (N)

S = Sliding distance (m)

After the test, the role of applied load and RPM on wear behaviour of the prepared composites was studied.

3 Results and Discussions

3.1 XRD Analysis of Composite

The XRD test shows, major peaks obtained are mainly the presence of aluminium and silicon where as the minor peaks signify the existence of SiO2 and Al2O3 in Al-16Si matrix as shown in Fig.3.1 and Fig.3.2. It was observed that the addition of Al2O3 influences the peak intensity of the Al-rich intermetallic compound (Al3.21Si0.47) significantly as shown in Fig.3.2.

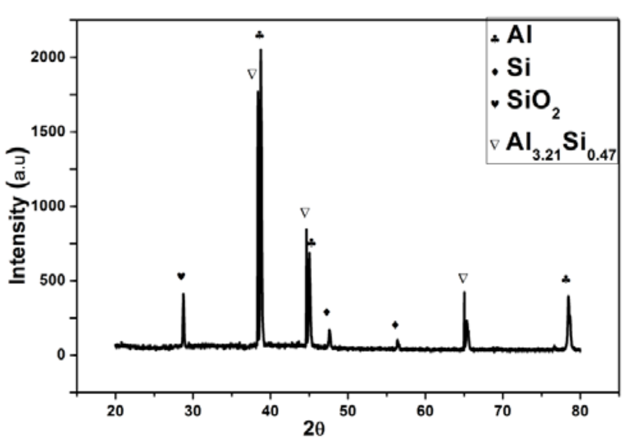


Fig.3.1: X-ray diffraction patterns of Al-16Si alloy melted at 770°C.

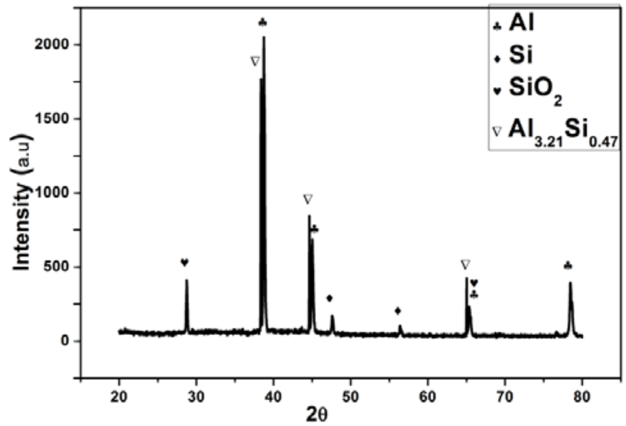


Fig.3.2: X-ray diffraction patterns of Al-16Si-2%Al2O3 alloy melted at 770°C.

3.2 Hardness and Density

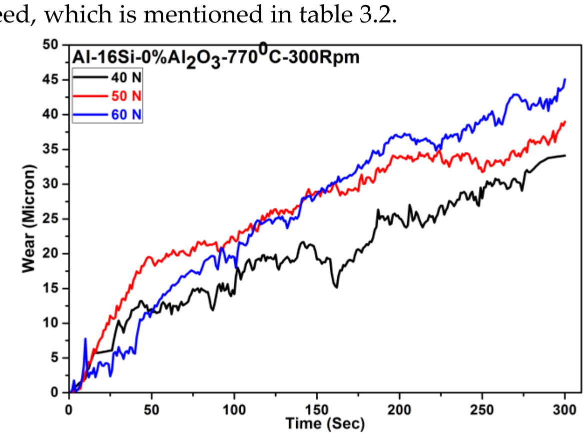
Table 3.1: The density and hardness of the different samples.

Sample	Density(g/cc)	Hardness(VHN)
Al-16Si	2.6213	52.565
Al-16Si-2%Al_2O_3	2.644	55.69

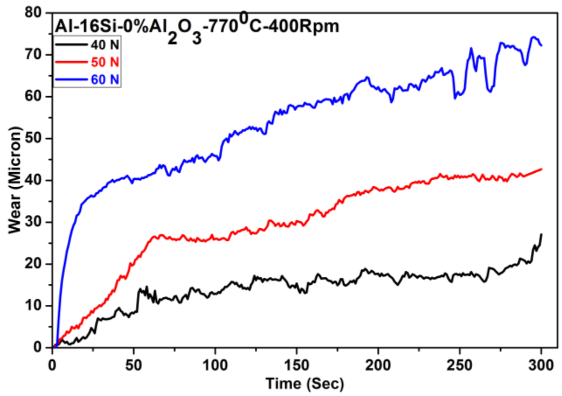
From the Table 3.1 shows that the density and hardness increase with addition of alumina. The density of Al2O3 is about 3.95g/cc. The formation of Al-rich intermetallic harder phase causes for increasing hardness with forfeit of increase in very small density.

3.3 Wear Test

The graphs of the wear plotted against time for Al-16Si alloy are shown in Fig.3.3 which indicates that wear of sample is more in case of higher speed. The gaps between lines of 40 N, 50 N and 60 N loads are increased with increasing speed (300 to 500 RPM) at particular time (250 sec). Similar tradition shows also in Al-16Si-2Al2O3 composite. It indicates that the total wear of the samples is more at higher load and high speed, which is mentioned in table 3.2.



(a)



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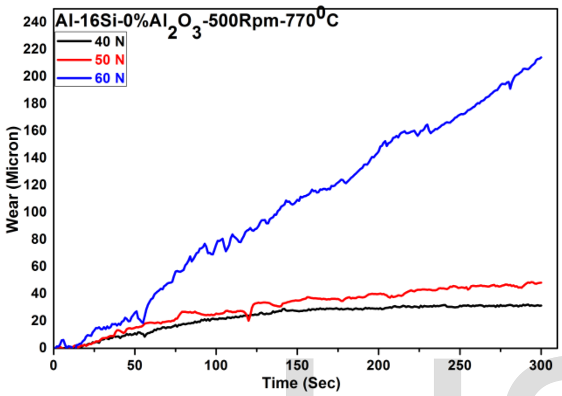


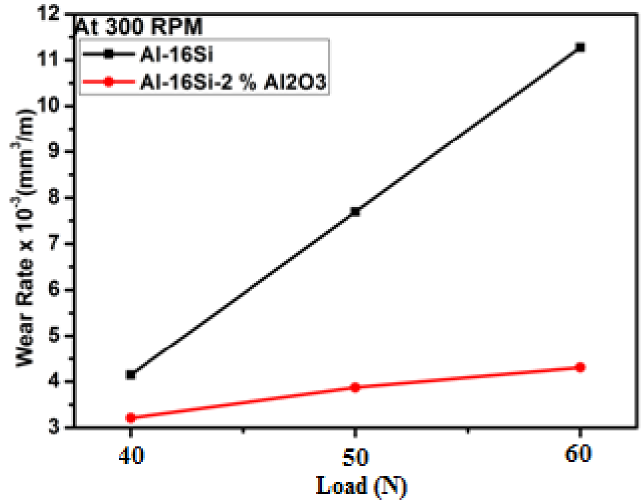
(c)

Fig.3.3: Effect of loads on wear of Al-16Si alloy at different RPM (a) 300, (b) 400 and (c) 500.

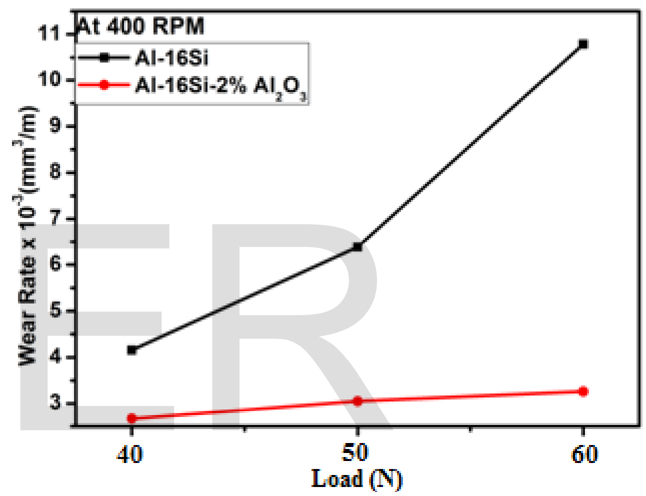
Table 3.2: Height loss of Al-16Si alloy with different loads and RPM at a particular time (250 sec).

Sl.No.	RPM	40 N	50 N	60 N
1	300	27.97644	31.74175	39.21802
2	400	17.54169	40.61199	60.40626
3	500	31.43255	44.68694	172.1039

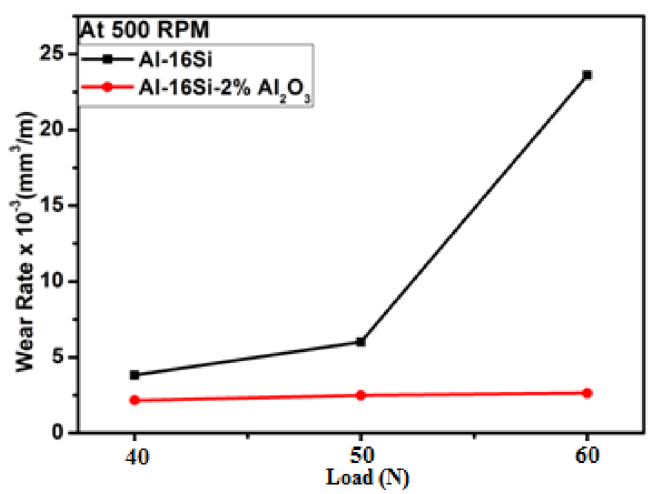
The wear rate increases with load but it decreases with addition of alumina as shown in fig. 3.4. In Al-16Si alloy it is noticed that the wear rate can be divided into two-stages. Stage-I consisting of wear rate under 40 N and 50 N where as stage-II contains wear rate under 50 N and 60 N. The graphs show that the wear rate in stage-I having nominal increase in wear rate over increasing load but it is shown that in stage-II, the wear rate significantly increases with increased in load because of the increasing temperature due to friction which causes for softening the base alloy.



(a)



(b)



(c)

Fig.3.4: Effect of Load on wear rate in Al-16Si and Al-16Si-2%Al2O3 alloys at 300 RPM, (b) 400 RPM and (c) 500 RPM.

Fig.3.4 reveals that the wear rates of the Al-16Si-2Al2O3 composite have minor increment in both the stages even if the load is increased. This is because of the formation of the hard in-

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termetallic compounds in this alloy which resist the wear rate and also compensate the temperature effect at higher load.

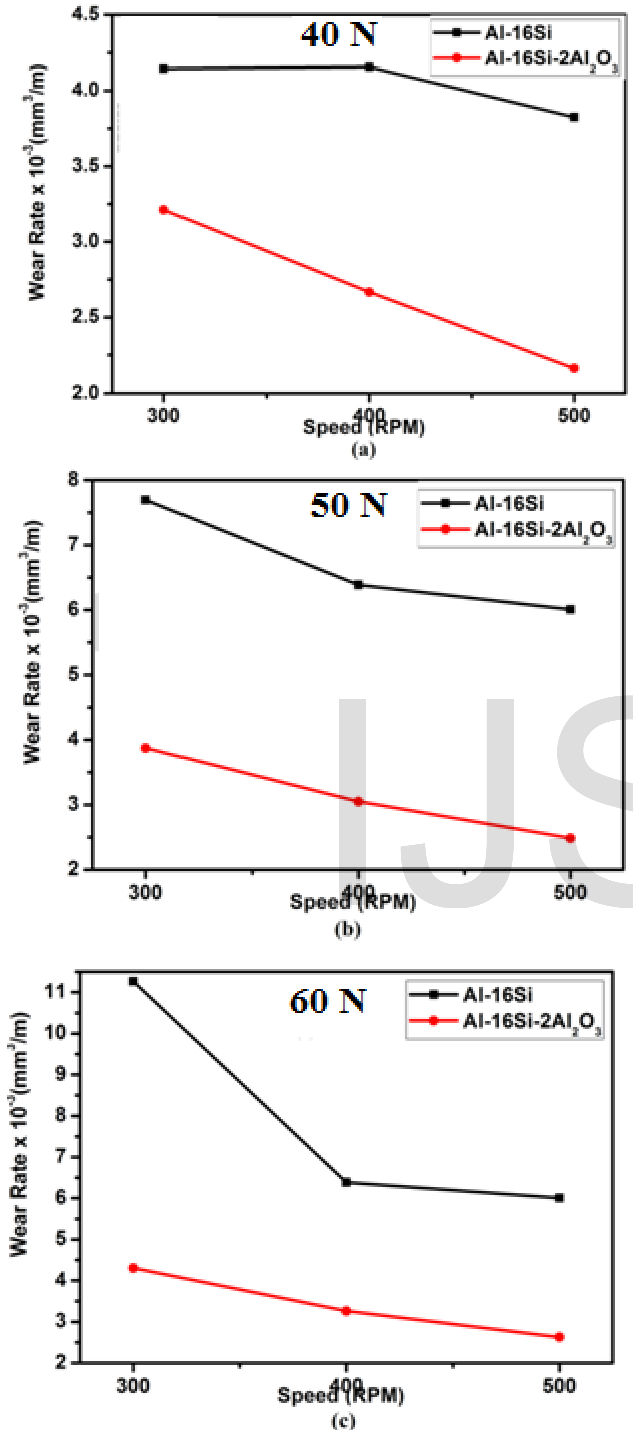

Fig.3.5: Comparison graphs of wear rate in Al-16Si and Al-16Si-2%Al2O3 alloys in different speed at different loads (a) 40 N (b) 50 N and (c) 60 N.

From fig.3.5, it is observed that initially the wear rate of the material decreases sharply with rotation speed and then it is nominal decreased with the RPM at constant load. The wear rate gap between two samples (i.e. Al-16Si and Al-16Si-2Al2O3) is more at lower rotation speeds (at 300 rpm) at different load; it indicates the effect of alumina particles have more in low speed as compared to that of higher speed.

4 Conclusions

- The XRD analysis shows the major peaks of aluminium and silicon and minor peaks of SiO2 and Al2O3 in Al-16Si alloy. Addition to these peaks, the peaks of Al-rich intermetallic compound (Al3.21Si0.47) also shown into the picture in Al-16Si-2Al2O3 composite.
- The formation of Al-rich intermetallic harder phase causes for increasing hardness with forfeit of very small increase in density.
- The wear rate of the alloys/composites was increased with increasing load and rotation speed where as less wear was detected in Al-16Si-2%Al2O3 sample.
- The wear rate gap between two samples (i.e Al-16Si and Al-16Si-2Al2O3) is more at lower rotation speeds at different load, it indicates the effect of alumina particle is more in low speed as compared to that of higher speed.

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