Effect of Pouring Temperature in Al-16Si-1% Al_2O_3 Hypereutectic Alloys

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Abstract— In Al-Si hypereutectic alloys, the mechanical properties are affected by grain size, volume fraction and distribution of both primary as well as eutectic silicon. The instantaneous refinement and modification of primary and secondary Si particles in hypereutectic Al-Si alloys are very difficult through conventional processes. This paper investigates the effect of pouring temperature on Si particles during solidification in hypereutectic Al-16Si-1%Al_2O_3 alloys at particular rotation speed. It has been reported that the interfacial bonding between the dispersed phase and liquid matrix was good in the synthesized composites achieved in order to provide improved mechanical properties. The wear behaviour and hardness of the cast product of hypereutectic Al-16Si alloy significantly varies at different pouring temperatures. The dry sliding wear test has been performed on a group of specimens with varying parameters (at different temperature with different load and sliding velocities) in a pin on disc wear testing machine. However in XRD analysis of the samples depicted the formation of brittle phases like SiO2, Al_2O_3 and Al-rich intermetallic compounds. The hardness value of the materials increases with increasing pouring temperature where as it was again decreases with increasing higher pouring temperature.
Key words: Al-Si, gama-Al_2O_3, Al-16Si-1%Al_2O_3, $Al_{3.21}Si_{0.47}$, Wear Rate, Slope

I. INTRODUCTION

The familiar Al-alloy having high Si content have excellent properties over the conventional uses, which replace the cast iron in automobile engine in order to saving in fuel economy & development in vehicle emission in engineering applications. The determination of relationship between processing and performance are depends on the mechanical behaviour and wear resistance of engineering materials. Presently the modelling of engineering materials has motivated to developing a better and deeper understanding of mechanism and factors involved. The optimization of the aluminium based alloy was occurs through different processing or by using different grain refining elements. So the development of light weight metal matrix composites (MMCS) has been demanded and increases in automotive and aerospace sectors due to increase the fuel effectiveness and reduces greenhouse gas emissions [1]. Due to excellent characteristics of Al-Si cast alloy such as low cost of manufacturing, high specific strength, excellent cast ability and recyclability [2-4], it have been widely employed to fabricate automotive component working at ambient and reasonably high temperature (up to 200°C). Now a day the enhancement of physical, chemical and mechanical properties are the most raising area of aluminium matrix composites? The high Si-containing Al-alloys having low thermal expansion and high thermal stability of A390 is used extensively in engine parts of automobiles which is conventionally processed by casting routes [5]. In aluminium matrix composites (A356 and 6061), the addition of Al_2O_3 particles by gravity casting at a two-step mixing method improved the wettability of the Al_2O_3 particles and ensured good particle distribution. Al_2O_3 particles are located predominantly in interdendric regions as substrates of Si crystals in (A356-10%Si) composites. Increase in composition of Al_2O_3 in aluminum matrix increased the hardness, impact strength and normalized displacement [6].

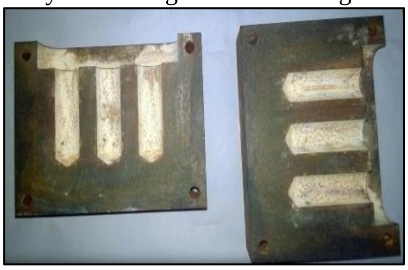
In this paper, we investigate the synthesis and characterization of Al-Si-1%Al2O3 hyper-eutectic alloys with different pouring temperature through stir casting method.

II. MATERIALS & EXPERIMENTAL METHODS

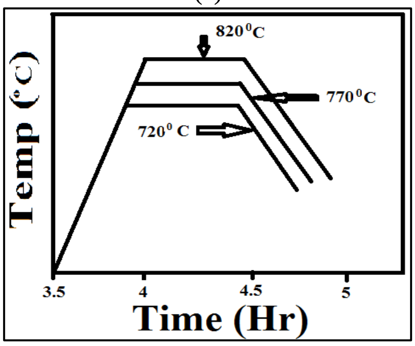
The materials used for Al-16Si-1%Al_2O_3 composite samples are 99.97% purity aluminium ingot, 99.9% purity alumina (gamma-Al_2O_3) and Al-50%Si master alloy. Al-16Si-1Al_2O_3 has been manufactured at different pouring temperatures by stir casting methods and the samples were inspected for their physical and mechanical properties.

A. *Synthesis of Al- 16Si- 1%Al_2O_3 composite*

The melting of commercially pure Aluminium and Al-50 wt% Si master alloy with 1% Al_2O_3 was carried out in a graphite crucible in a pit type melting furnace, poured at three different pouring temperatures (i.e. 720 °C, 770 °C and 820 °C) manufactured by conventional stir casting method. The melted was poured in a specific die having holding time at pouring temperature (after addition of Al_2O_3) and pouring time were half an hour and 10 seconds respectively which was followed by air cooling as shown in Figure1.



(a)



(b)

Fig.1: (a) Die for Casting and (b) Time Temperature Graph of AMC Al-16Si-1%Al_2O_3 by stir Casting Method

B. Sample preparation for characterization

The samples for of size 10mm x 10 mm x 2mm were prepared and taken for XRD analysis which was carried out with Cu-Kα target. The XRD patterns were recognized the different phases present in the sample by matching of obtained peaks with JCPDS data files.

The preparation of hardness and density samples were taken care to make both the horizontal faces parallel to each other by polishing of the test sample. The hardness of the specimens were measured in Microvicker's hardness tester using square based diamond pyramid indenter having angle between opposite faces is 136° using 1kgf applied load for 15 seconds. The Vickers Hardness values (VHN) of the samples were get from load divided by surface area of the indentation. The average value of the measured diagonals of the indention made at five locations of a sample was taken for calculation. The density tester (METTLER TOLEDO) measured the density of the samples turn by turn.

The samples having height 30mm with 8 or 10mm diameter were tested in a pin on disc wear testing machine to investigate the dry sliding wear behaviour of the composite. The load was varied from 40, 50 & 60N and rotation speed of 300, 400 and 500rpm (Disc track radius having 40mm) tested for 5 minutes at room temperature without using lubricant. The microprocessor controlled wear testing machine provides simultaneous data for height loss (in micron). The mass loss was due to wear was determined after every test of each specimen. The role of applied load and alumina content on wear behaviour of the prepared composites was studied.

III. RESULTS & DISCUSSIONS

A. XRD Analysis of Composite

The XRD test describe major peaks certified the presence of mainly of Aluminium and silicon, whereas the minor peaks denote the existence SiO_2 and Al_2O_3 as shown in Figure 2, Figure 3 and Figure 4 for three different pouring temperatures. It was seen that the Al-rich intermetallic compound ($Al_{3.21}Si_{0.47}$) with SiO_2 peaks were found at all three pouring temperatures. The existence of phase Al_2O_3 was detected only at higher pouring temperatures (770°C and 820°C)

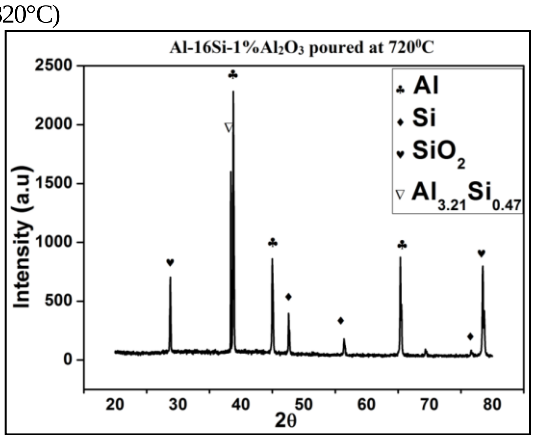


Fig. 2: X-Ray Diffraction Patterns of Al-16Si-1%Al_2O_3 Melted at 720°C

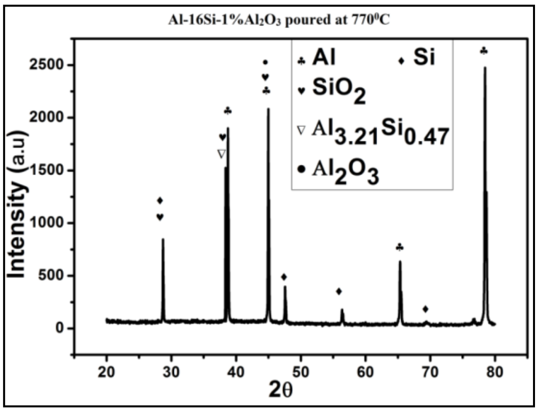


Fig. 3: X-Ray Diffraction Patterns of Al-16Si-1%Al_2O_3 Melted at 770°C

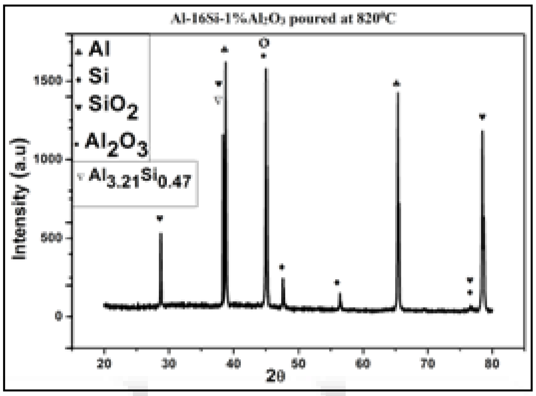


Fig. 4: X-Ray Diffraction Patterns of Al-16Si-2%Al_2O_3 Melted at 820°C

B. Hardness & Density

Table 1 depicts the density of the sample was 2.6388 g/cm^3 which includes combine effect of Si (Density 2.328g/cm^3) and Al_2O_3 (about 3.95 g/cm^3). On the other hand the critical factors affecting the wettability are temperature, atmosphere, substrate surface roughness, crystallographic orientation, and the influence from the experimental technique. The results show that the aluminium surface oxidation and the thickness of the oxide film of composite Al-16Si-1%Al_2O_3 have a pronounced effect on the wettability, especially at low temperatures. To eliminate this effect, the experimental temperature must be over a critical value [7]. From the hardness test it was detected that the hardness value initially increases with increasing temperature (720°C to 770°C) but it was again decreases with further increase in temperature (770°C to 820°C). It may be because of the wettability and distribution of alumina particles were more in case of higher temperature i.e. 770°C and 820°C. The hardness at 820^{0}C was again decrease as compared to 770°C because of the dominant factor of grain growths.

Sample	Pouring Temperature (°C)	Density(g/cm^3)	Hardness(VHN)
Al-16Si-1%Al_2O_3	720	2.6388	54.29
	770		57.29
	820		53.526

Table 1: The Density & Hardness of the Different Compositional Samples

C. Wear Test

The wear rate initially decreases with increasing pouring temperature from 720°C to 770°C as shown in Figure 5 or Figure 6 or Figure 7, because of wettability and uniform distribution of the alumina was more at 770°C which causes for increasing the nucleation sites over the melt. It was also detected that the wear rate again increases with further increase in pouring temperature i.e. 770°C to 820°C and this may be because of grain growths factors was more dominant factors at higher and higher pouring temperatures. In Figure 5, Figure 6 and Figure 7, it shows the same wear rate pattern were observed in three tested loads, i.e. 40N, 50N & 60N and at different rotation speeds.

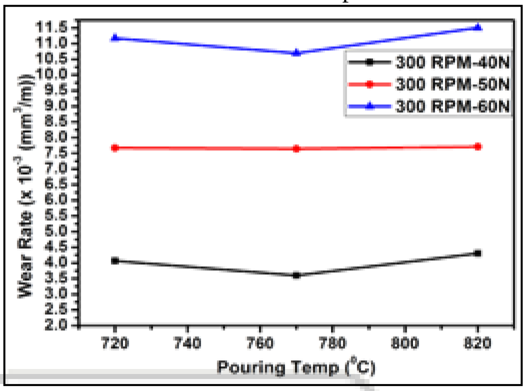


Fig. 5: Wear Rate vs pouring Temperature Graphs of Al-16Si-1%Al_2O_3 Composite in 300 RPM at Different Load

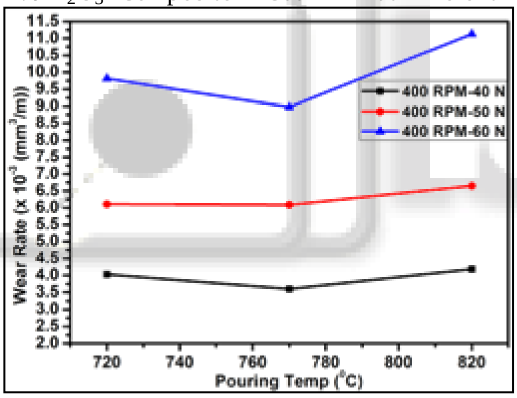


Fig. 6: Wear Rate vs pouring Temperature Graphs of Al-16Si-1%Al_2O_3 Composite in 400 RPM at Different Load

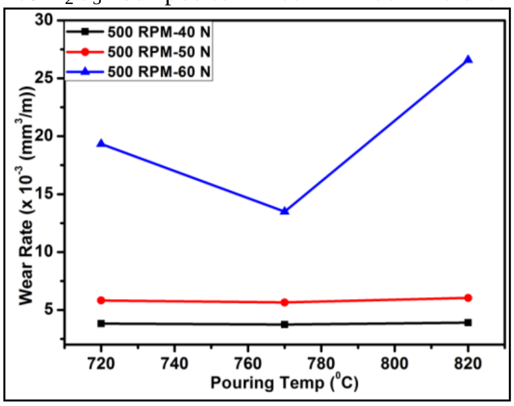


Fig.7: Wear rate vs pouring temperature graphs of Al-16Si-1%Al_2O_3 composite in 500 RPM at different load

The wear rate decreases with increasing RPM because of more residence time for friction at low rotation speed. Similarly the effect on wear rate was depending on the load applied and it was observed that the wear rate is directly depending on load.

From Figure 5, Figure 6 and Figure 7, it was detected that the slope of the wear rate was more at 60N load with increasing the speed of 300RPM to 500RPM. The wear rate of the sample was decreased with increasing pouring temperature from 720°C to 770°C. This may be because of combine effect of RPM, well distribution of Al_2O_3 particles and formation of intermetallic compound ($Al_{3.21}Si_{0.47}$). But in case of increase in pouring temperature i.e. 770°C to 820°C, it was seen that the wear rate is again increases and this may be based on following effects. 1) Grain growth of the nuclei were occurs at higher temperature which soften the materials. 2) These soft phases were again softened due to temperature rises caused by higher friction at high load (60N). So more and more materials was removed in this conditions.

IV. CONCLUSIONS

1) The major peaks of Aluminium and silicon with minor peaks denoted the existence SiO_2 and $Al_{3.21}Si_{0.47}$ phases were detected at all three pouring temperatures, whereas Al_2O_3 phases was seen only at higher pouring temperature i.e. 770°C and 820°C.
2) The hardness value of the sample initially increases with increasing temperature (720°C to 770°C) but it was again decreases with further increase in temperature (770°C to 820°C).
3) The wear rate of the materials were decreases in the pouring temperature of 720°C to 770°C but it was again increase at increasing pouring temperature from 770°C to 820°C.
4) The slope of the wear rate of sample Al-16Si-1%Al_2O_3 at 60N load was increases from 300RPM to 500RPM.

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