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Microstructure and Hardness of Aluminium Alloy- Fused Silica Particulate Composite

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Abstract: ***Aluminum matrix composites (AMCs) refer to the class of light weight high performance aluminum centric material systems. The reinforcement in AMCs could be in the form of continuous/discontinuous fibers, whiskers or particulates, in volume fractions. Properties of AMCs can be tailored to the demands of different industrial applications by suitable combinations of matrix, reinforcement and processing route. This work focuses on the fabrication of aluminum alloy (LM13) matrix composites reinforced with 9%, 12% &15% fused silica particulates using stir casting route. The microstructure and hardness of the fabricated composite were analyzed and reported.***

Keywords: Aluminum Alloy, Fused Silica particles, Metal Matrix Composite, Stir casting.

I. INTRODUCTION

The need for new materials able to match increasingly stringent engineering requirements has led to the development of metal matrix composite for automotive applications. Properties such as friction and wear resistance in lubricated or un-lubricated conditions are of particular importance for the development of engine parts. In this regards MMCs have many advantages such as high strength, high hardness, high wear resistance, high stiffness, corrosion resistance and high strength to weight ratio with its good performance at elevated temperature. Berghezan[1] differentiate a composite material from an alloy by saying that a composite material is one in which the individual components retain their characteristics but are incorporated into the composite so as to exhibit only their advantages and not their shortcomings ,in order to obtain an improved material. In the past various investigations have been carried out on metal matrix composites. SiC, Al_2O_3,TiC, B_4C are the commonly used particulates to reinforce in the metal matrix, while the study of Fused silica reinforcement in aluminum alloy is rare. In this investigation the microstructure and hardness of Fused silica reinforced LM 13 aluminum alloy are reported.

II. LITERATURE REVIEW

Tribological behavior of Al-Li and Al-Li+15% SiC composite was studied by J.Rodriguez et al.,[2] and concluded that the temperature dependency transition from mild to severe wear has been observed for both materials, leading to changes of two orders of magnitude in wear rate. The temperature transition exhibits a clear dependency on nominal pressure. The reinforcement benefit is limited to shift the transition temperature to higher values. Within the mild wear regime, composite wear rates are even higher than those of the reinforced alloy. The formation of a mechanically mixed layer seems to be a key factor controlling the mild wear of these materials.

Mandal et al.,[3] investigated the Sliding wear behaviour of T6 treated A356–TiB_2 *in-situ* composites.They found that the wear rate of the composite improves significantly with the TiB_2 content.The study also shows that wear rate is a strong function of TiB_2 content rather than the overall hardness of the composite.The coefficient of friction of the composite does not shows any particular trend. However it may be deduced that addition of 2.5 wt.% TiB_2 lowers COF, followed by an increase in COF for higher TiB_2 content.

Tribological behavior if crogenu\ically treated B4Cp/Al-12% Si composite was studied by Joel Hemant[4].He reported that the microstructures of chilled composites are finer than that of the un-chilled matrix alloy with uniform distribution of B_4C particles. Strong interfacial bond was observed with no agglomeration between the matrix and the dispersoid. Strength,hardness and wear resistance of chilled MMCs are superior to those of the matrix alloy.It was found that these particles increases with an increase in dispersoid content up to 9%.

The investigation of Wear resistance of aluminium alloy and its composites reinforced by Al_2O_3 particles by a vortex method was conducted by M.kok and K.Ozdin[5].They observed that the reinforcement of the 2024 Al matrix alloy with Al_2O_3 particles significantly improved the abrasion wear resistance of all composite tested against all the abrasive used, and the wear resistance of the composites was much higher than that of the unreinforced 2024 aluminium alloy.The excellent wear resistance of the composites was mainly dependent on the effective resistance of Al_2O_3 particle to penetration,cutting and grinding by the SiC abrasive papers.

Garnet particles reinforced composites exhibited reduced wear rate than the unreinforced alloy specimens [6]. The wear rate decreased with increasing garnet content. The wear rate of the composites as well as the matrix alloy increased with increase in load applied.

Quartz (SiO_2p) reinforced chilled metal matrix composite (CMMC) for automotive applications was developed by Joel Hemanth[7].He observed that the microstructure of chilled composites are finer than that of the matrix alloy and the interfacial bonding between the matrix and the dispersoid is stronger in chilled composites. Mechanical properties of the chilled composites are superior to those of the matrix alloy. Strength and hardness increases with increase in dispersoid content and this may be possible because of the occurrence of a more uniform distribution of SiO_2 particle within the matrix.

Al–7Si/TiB2 in-situ composites with significant improvement in hardness, yield strength, tensile strength, Young's modulus and wear resistance have been successfully synthesized by salt reaction route[8]. The mechanical properties of the present Al–7Si/TiB2 composites are better than those reported earlier with SiC reinforcement. TiB2 appears to not only act as a grain refiner for primary α-Al but also act as modifier of Si in the eutectic mixture.

III.EXPERIMENTAL WORK

The metal matrix composite produced in this investigation is based on LM 13 alloy used for automotive applications. The chemical composition of this alloy is given in Table 1.

Table 1. Chemical composition of LM 13(wt%)

Si	Cu	Mg	Mn	Fe	Ni	Zn	Pb	Ti	Al
11.76	0.92	0.27	0.02	0.17	0.03	0.05	0.04	0.007	Rest

The aluminum alloy was reinforced with 9,12 and 15% of fused silica particles(supplied by Dupré Minerals Ltd, United Kingdom).The properties of the reinforcement are as follows: Crystalline Structure: Amorphous, Young's modulus: 71.7 GPa, Softening point:1665 °C and Hardness: 5.3-6.5 (Mohs Scale).

The manufacturing of the metal matrix composite used in the present work was carried out by stir casting route. Al alloy was procured in the form of ingots. The metal ingots were melted to the desired temperature in graphite crucible. Cover flux was added in to the molten metal in order to minimize the oxidation. Fused Silica particulates preheated to around 400°C were then added to the molten metal and stirred. The dispersion of the fused silica preheated particulates was achieved with the stir casting route. This stir casting route makes the dispersoid to disperse uniformly with random orientation. The melt was next poured into the sand moulds, which were prepared using silica sand with 5 bentonite as binder and 5 moisture and were dried in an air furnace. The melt was allowed to solidify in the moulds. All the MMC castings were heated to around 450^{o}C in a furnace and hammered before testing.

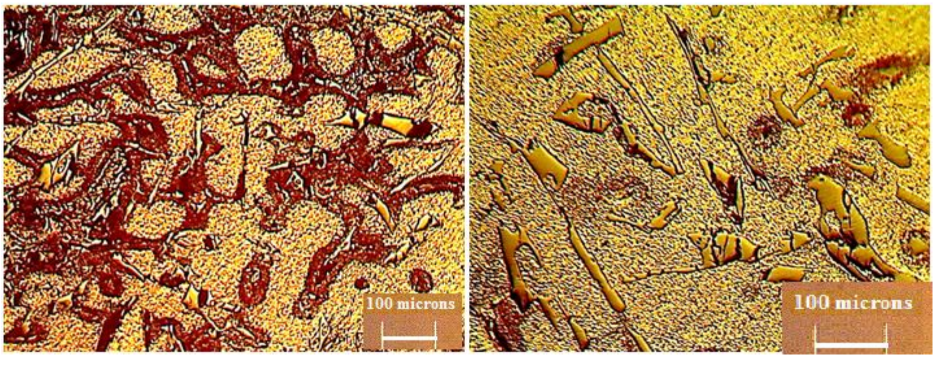
Microstructural analysis was carried out using a light optical microscope. The specimens for metallographic examination were sectioned to the required sizes from the metal matrix composites. Usual metallographic procedures were followed to prepare the specimens and then etched with 0.5% hydrofluoric acid solution. Vicker's microhardness testing machine (Wilson Wolpert, Germany) was employed for measuring the hardness of base metal and MMCs. Photograph of the Vicker's microhardness testing machine is displayed in Fig.1.

Fig.1 Photograph of Vicker's microhardness testing machine

IV.RESULTS

A.Microstructure

Fig. 2 shows the optical micrographs of base metal.The matrix is interdentitic and shows fine dispersion of Al-Si eutectic particles in Al solid solution. Presence of un-dissolved copper also noticed at locations. The higher magnification has resolved the Al-Si eutectics showing longer in length. High resolution image also shows the precipitation of alloy carbides (dark).



Magnification: 100X Magnification: 250X

Fig.2 Optical Micrographs of Base Metal

The microstructure of 9% MMC is shown in Fig. 3. The increase in the content of Fused silica particles in the metal matrix is clearly established by the presence of higher quantum of particle in the metal matrix. The higher quantity of Fused silica particles lead to the agglomeration of the particle at certain fields, however individual particles are also observed. The particles have occupied the grain boundary pores of the primary silicon particles.

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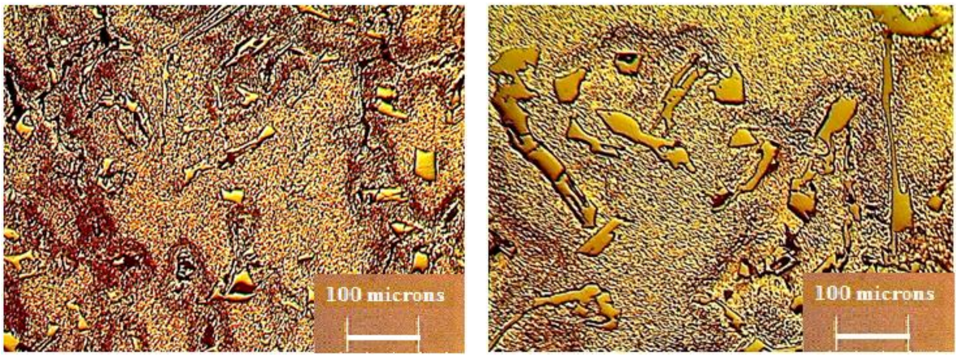

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Fig.3 Optical Micrographs of 9% MMC

Fig. 4 displays the microstructure of 12% MMC at lower and higher magnification. Higher quantum of particles is observed but they are less compared to the 9% Fused silica particles composition. The matrix also shows the presence of primary silicon surrounded by Fused silica particles. As the density of Fused silica particles is higher compared to pure primary silicon they occupy the boundaries. Some agglomerated particles of Fused silica also observed. Magnified image of the 12% Fused silica particles composition shows the clear presence of primary silicon in Al solid solution surrounded by Fused silica particles.

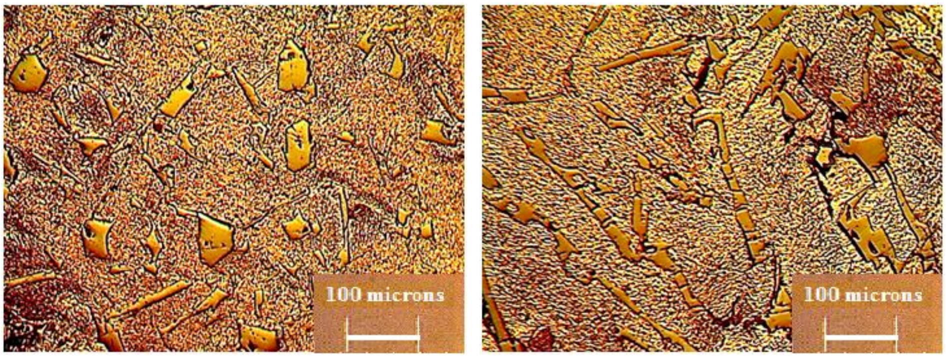

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Fig.4 Optical Micrographs of 12% MMC

The microstructure of 15% MMC is shown in Fig. 5. Scanning the photomicrograph (100X and 250X) does not show substantial amount of Fused silica particles with respect to the percentage of Fused silica particles as additive in the metal matrix composite. Probably uneven distribution might have caused agglomeration and isolation of the particle in the metal matrix.

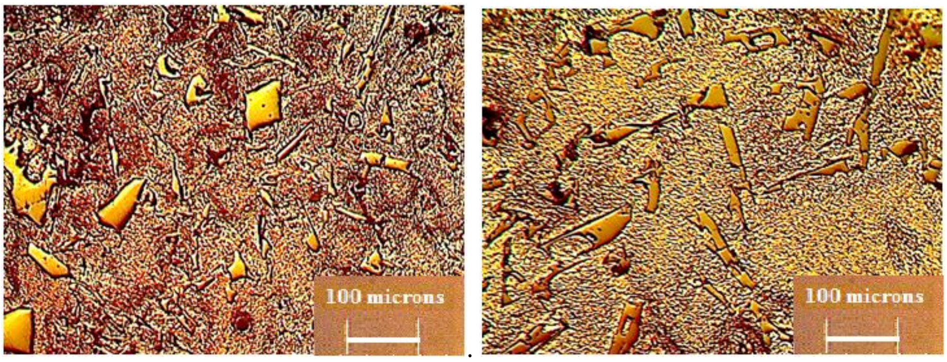

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Fig.5 Optical Micrographs of 15% MMC

B.Hardness

The hardness values (Vickers hardness) of the matrix alloy and the MMCs are shown in Table.2 It is clear that the hardness value of the processed composites increases with the increase in addition of fused silica particulates.

Table.2 The hardness values (Vickers hardness) of the matrix alloy and the MMCs

S.No	Material	Hardness(HV)
1	Matrix Material	86.2
2	9% MMC	93.6
3	12% MMC	94.5
4	15% MMC	97.7

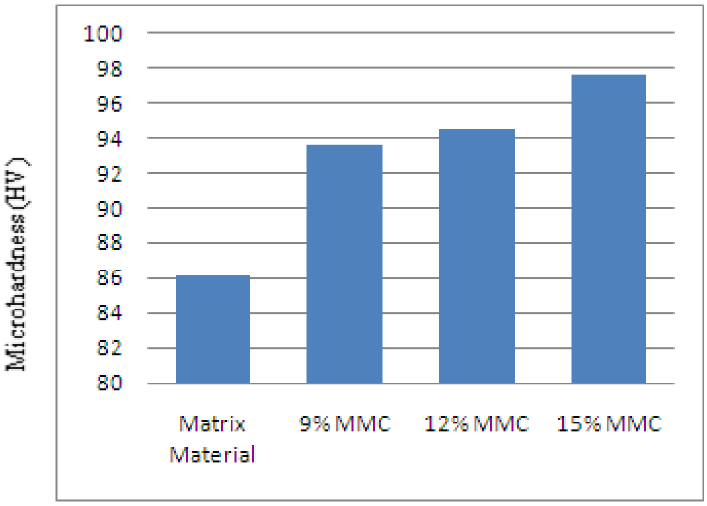

Fig.6 Microhardness of Matrix Material and MMCs

V.Conclusions

Aluminum-Fused Silica particulate composites were manufactured by the stir casting method. Microstructural observation shows the Fused silica particulates distribution in the Aluminum alloy (LM13) matrix.

The hardness value of the Fused silica reinforced LM 13 alloy matrix composites increased with the increased addition of Fused silica particulates in the matrix.

VI.References

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