Investigation of Aluminium Alloy - 20% Fused Silica Metal Matrix Composite

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Abstract— Combining high specific strength with good corrosion resistance, metal matrix composites (MMCs) are materials that are attractive for a large range of engineering applications. Given the factors of reinforcement type, form, and quantity, which can be varied, in addition to matrix characteristics, the composites have a huge potential for being tailored for particular applications. Incorporation of hard second phase particles in the alloy matrices to produce MMCs has also been reported to be more beneficial and economical due to its high specific strength and corrosion resistance properties. This work focuses on the fabrication of aluminum alloy (LM13) matrix composite reinforced with 20% fused silica particulates using stir casting route. The microstructure and hardness of the fabricated composite were analyzed and reported.

Key words: Aluminum Alloy, Fused Silica particles, Metal Matrix Composite, Stir casting

I. Introduction

The trend is towards safe usage of the MMC parts in the automobile engine, which works particularly at high temperature and pressure environments. Particle reinforced MMCs have been the most popular over the last two decades. The modern trend for potential applications is to optimize the mechanical properties and heat treatment of MMCs. Industrial technology is growing at a very rapid rate and consequently there is an increasing demand and need for new materials. Particulate reinforced composites constitute a large portion of these new advanced materials. 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 if cryogenically treated B4Cp/Al-12% Si composite was studied by Joel Hemanth[1].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%.

Garnet particles reinforced composites exhibited reduced wear rate than the unreinforced alloy specimens [2]. 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[3].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.

S.C Tjong and K.C Lau,[4] investigated the Properties and abrasive wear of TiB_2/Al-4%Cu composites produced by hot isostatic pressing. They found that tensile and hardness measurements show that the tensile strength and hardness of MMCs increase with increasing TiB_2 content. Furthermore, SEM fractographs reveal that particle cracking is the main failure mode of the MMCs during the tensile tests. SEM observation reveals that TiB_2 Particles are redistributed near the subsurface region of the MMC specimen during the abrasive wear tests. Most of these particles remain intact with the matrix of MMC, thereby effectively resisting the abrasive wear attack of SiC particulates.

Microstructure and mechanical properties of in situ synthesized (TiB_2 + Al_2O_3)/Al–Cu composites have been investigated by D.G. Zhao et.al.,[5] and concluded that, In situ(TiB_2+Al_2O_3)/Al-Cu composites have been fabricated by the direct melt reaction technology. TiB_2 particles distribute along the grain boundaries and interweave with $CuAl_2$ phases. The size of TiB_2 is about 1μm and Al_2O_3 particles are about 3μm in size. The mechanical properties of (2%TiB_2+2%Al_2O_3)/Al-Cu are superior to those of the composite reinforced with 4%TiB_2 or 4% Al_2O_3 particles.

Processing variables such as holding temperature, stirring speed, size of the impeller, and the position of the impeller in the melt are among the important factors to be considered in the production of cast metal matrix composites as these have an impact on mechanical properties [6]. These are determined by the reinforcement content, its distribution, the level of the intimate contact of the wetting with the matrix materials, and also the porosity content. Therefore, by controlling the processing conditions as well as the relative amount of the reinforcement material, it is possible to obtain a composite with a board range of mechanical properties. The method is potentially very cost effective, but wide spread adoption is dependent on a satisfactory resolution of the technical difficulties presented.

Processing and characterization of particulate reinforced aluminium silicon matrix composite was studied by A.M.S. Hamouda et.al.,[7].They found that the split tensile strength and young's modulus values decreased gradually as the silicon dioxide content in the composite increased from 5% to 30% by volume fraction. The reason for this mechanical behavior is due to the dominating nature of the compressive strength of the quartz particulate reinforced in the LM6 alloy matrix. The hardness value of the silicon dioxide reinforced LM6 alloy matrix composites is increased with the increased addition of quartz particulate in the matrix and it is well supported. The mechanical behavior of the processed composite had a strong dependence on the volume fraction addition of the second phase reinforcement particulate on the alloy matrix. Decreasing the Silicon Dioxide particulate content less than 30% along with the particle size constraint as 230 mesh-65 microns would increase the tensile strength but cracking on the surface might not be too dominant.

Wear behaviour of high tensile strength aluminium alloys under dry and lubricated conditions was studied by Yoshiro Iwai et.al.,[8] and concluded that the wear behaviour seems to be affected by the material characteristics which are responsible for the differences in fatigue behaviour rather than tensile strength or hardness.

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.

Si	Cu	M	M	Fe	Ni	Zn	Pb	Ti	Al
11.7	0.9	0.2	0.0	0.1	0.0	0.0	0.0	0.00	Re

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

The aluminum alloy was reinforced with 20% 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.

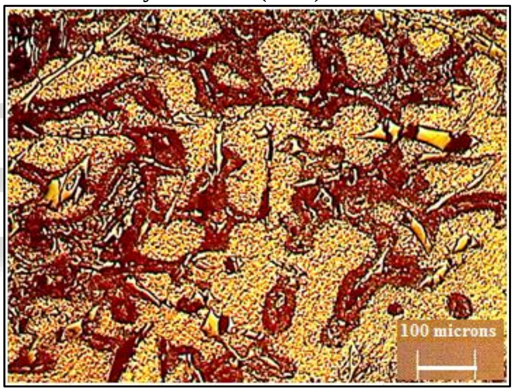
Microstructural analysis was carried out using a light optical microscope. Photograph of the microscope is displayed in Figure 1. The specimens for metallographic examination were sectioned to the required sizes from the metal matrix composites. Usual metallographic procedures were followed to prepare 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.

Fig. 1: Photograph of Optical Trinocular Metallurgical Microscope

IV. RESULTS

A. *Microstructure*

Figure 2 show 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

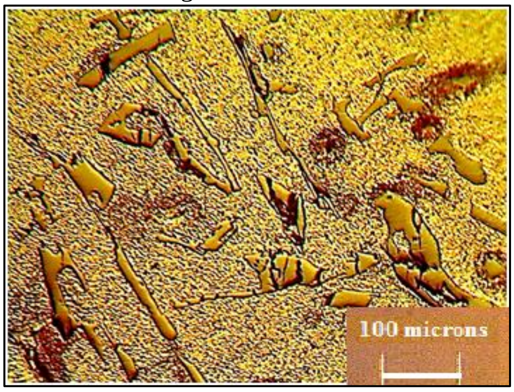


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Fig. 2: Optical Micrographs of Base Metal

The microstructure of 20% MMC is shown in Figure 3 at two locations. More particles of primary silicon in aluminium solid solution observed. The dark particles are fused silica particles. The fused silica particles are finer and not agglomerated. The matrix shows the distribution of the fused silica particles in aluminium metal matrix. The

Aluminium matrix consists of fine needle shaped particles of Al-Si with some primary large particles of silicon.

Magnification: 100X

Magnification: 100X

Fig. 3: Optical Micrographs of 20% MMC

B. Hardness

The hardness values (Vickers hardness) of the matrix alloy and the MMCs are shown in Table 2 and also in Figure 4. It is clear that the hardness value of the composite increased with the addition of fused silica particulates.

S.No	Material	Hardness(HV)
1	Matrix Material	86.2
2	20% MMCs	101.4

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

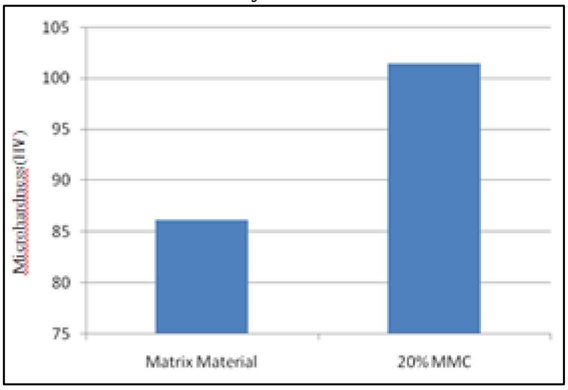

Fig. 4: Microhardness of Matrix Material and 20% MMC

V. Conclusions

Aluminum-Fused Silica particulate composite was manufactured by the stir casting method. Microstructural observation shows the Fused silica particulates distribution in the LM13 matrix.

The hardness value of the Fused silica reinforced LM 13 alloy matrix composite is higher compared to the base metal.

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