Mechanical Behaviour of A380 Alloy Reinforced with SiC/Flyash Hybrid Composites using Stir Casting

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Abstract - *The present study investigated the mechanical behavior of silicon carbide (SiC) reinforced A380 matrix aluminum alloys and flyash hybrid metal matrix composites. The stir casting molding technique was used to prepare the samples. Microstructure analysis was performed by scanning electron microscopy. Chemical characterization of the matrix and compounds was performed by energy dispersion X-ray spectroscopy. Density, hardness and tensile tests were performed on both the alloy and composite materials. Improved hardness and mechanical properties were observed for all compounds. An interesting improvement in tensile properties was observed for all composites compared to alloys. The dispersion of particles (SiC) and fly ash in the aluminum matrix improves the hardness of the matrix material and the mechanical behavior of the composite material.*

Keywords: A380 alloy, (SiC) and Flyash, Energy Dispersive x-ray Spectroscopy.

1. INTRODUCTION

Aluminum-metal matrix composites (AMMCs) are becoming excellent materials for advanced aerospace and automotive structures because their properties can be customized by adding selected reinforcements [1, 2]. In particular, particle-reinforced MMCs have found particular interest due to their high specific strength and specific stiffness at ambient or elevated temperatures. Typically, micron-sized ceramic particles are used as a reinforcement to enhance the properties of MMC. Ceramic particles have a low coefficient of thermal expansion (CTE) compared to metal alloys, so the incorporation of these ceramic particles can cause a misalignment of the interface between the matrix and the reinforcement. This phenomenon can be greater with a high concentration of ceramic particles. Of the various dispersions used, fly ash is one of the cheapest low-density reinforcements available in large quantities as a byproduct of solid waste from coal burning in power plants. Fly ash particles are divided into two types: separators and cenosphere.

2. EXPERIMENTAL

2.1 Fabrication of composites

In the present study, aluminum-based hybrid metal matrix compounds containing 5 and 10% by weight of SiC and 53 µm of fly ash particles were successfully synthesized by the vortex method. The matrix materials used in this study were Al-Si-Cu (A380) alloys, the chemical composition of which is shown in Table 1.

Table 1: chemical composition of alloy A380, weight. %

Cu	Mg	Si	Cr	Mn	Fe	Ni	Zn	Al
4.0	0.3	9.5	0.18	0.5	1.0	0.5	2.9	balance

The preparation of these compounds was carried out using the stir casting technique. Cylindrical samples (18 mm Φ and 170 mm long) of the A380 alloy were placed in a graphite crucible and melted in an electric furnace. After maintaining the temperature at 770 °C, a vortex was created using a mechanical stirrer. With stirring, preheated SiC and fly ash particles were introduced into the melt at 300^0C for 2 hours. Care was taken to ensure a continuous and regular flow of particles added to the vortex. The molten metal was stirred at 400 rpm under the protection of inert gas (argon). Stirring was constant for about 2 minutes after the particles were added for even distribution in the melt. However, the casting with reinforcement was performed under stirred conditions, it was performed in a S.G. preheated (200 ° C). The ingots of both the alloy and the composites were homogenized for 24 hours at 110 ° C to relieve internal stresses and minimize the chemical inhomogeneities that may be present in the casting state.

2.2 Characterization of Composites

Metallographic and Hardness tests

Scanning electron microscopy ((Model: SEM - Hitachi S-3400N - Japan) with EDAX Energy Dispersive X-ray Spectroscopy (EDS) was used to evaluate morphological changes and elemental analysis of the alloy and compounds. of the alloy and the composite were evaluated using the Leco Vickers durometer (Model: LV 700 - USA) an average of ten values was measured for each hardness value.

Density and Porosity tests.

Alloy and composite densities were measured by the Archimedean dewatering method using the following equation:

$$\rho_{MMC} = (m) / ((m\text{-}m1) \text{ X } \rho_{H2O})$$

Where ρ_{MMC} is the density of the compound, "m" is the mass of the composite sample in air, "m1" is the mass of the same composite sample in distilled water and "ρ_{H2O}" is the density of distilled water (at 293) K) is 998 kg / m3.
Theoretical density calculations, according to the rule of mixture were also used to determine the densities of the composites. This was obtained from the below equation.

$$\rho_c = Vr\ \rho r + (1\text{-}Vr)\ \rho m$$

Where ρ_r is the density of the composite, Vr is the weight ratio of the reinforcement, ρ_r is the density of the reinforcement and ρ_m is the density of the unreinforced A380 alloy. The porosity of the test materials was also calculated from the following equation.
Porosity (%) = (1- (measured density / calculated density)) X 100

3. RESULTS AND DISCUSSIONS

3.1 Microstructures and EDS of alloy and composites

Fig.1 (a-d) shows SEM images of fly ash, SiC particles and hybrid compounds that vary with weight. Percentages. We can see that the addition of fly ash and SiC to the alloy, i.e. by increasing the fly ash and SiC by weight percentage, the percentage content increase can be clearly seen, Figure (c) shows the microstructure of the alloy and while the figure (ie) shows the addition of fly ash and SiC to the alloy, the difference in microstructures was clearly noted. In figure (e) it can be seen that the SiC particle is embedded in the matrix.

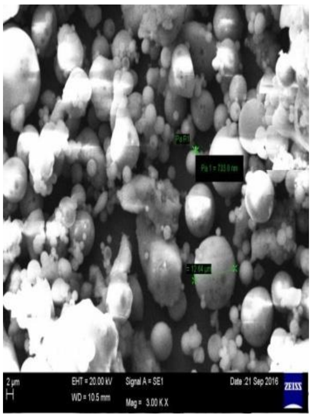

Fig -1: (a)

Fig -1: (b)

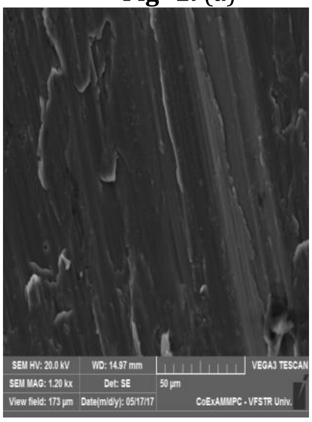

Fig -1: (c)

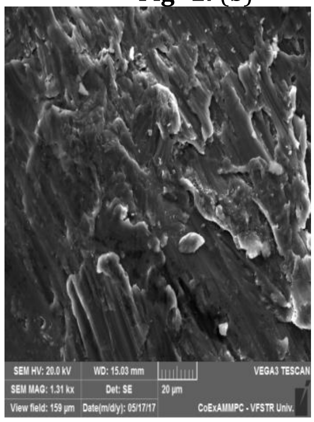

Fig -1: (d)

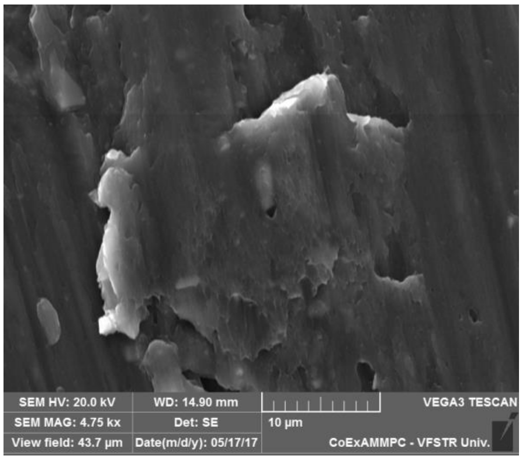

Fig -1: (e)

Fig -1: (a) SEM Micrograph of Flyash particles (b) SEM Micrograph of SiC particles (c) A380 Base d) A380 –5% FA/SiC composite e) A380 –10% FA/SiC composite.

EDS analysis

The EDS spectrum of the composite material shows the presence of Al, Si and Mg in the matrix phase, as shown in Figure 2, and silicon and carbon components in the reinforcement, 3, which were present in the fly ash. The matrix shows no increase in Cu and Mg concentration, indicating that the gain resolution is limited to its neighborhood. Also, the amplification stage shows only the components so that no contamination has occurred. Since perfect shielding of the argon gas is maintained, no traces of oxygen can be seen in either the matrix or the reinforcements. An average of six measurements on the particle-free matrix was performed.

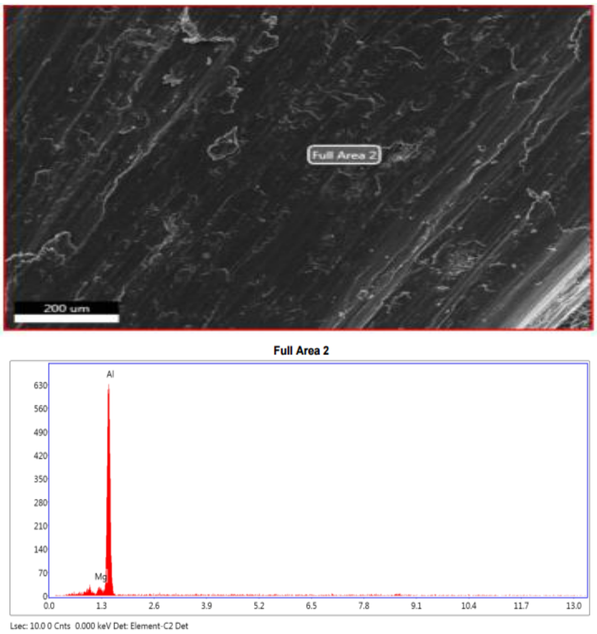

Fig -2: EDS spectrum of base alloy

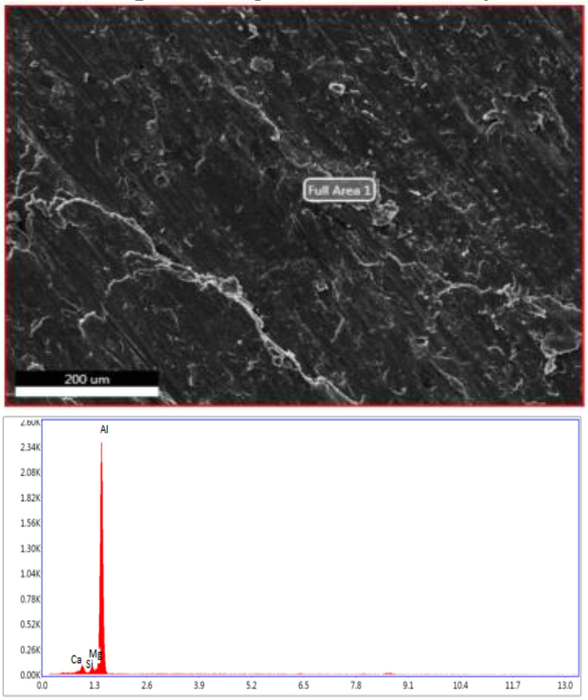

Fig -3: EDS spectrum of composite

XRD analysis

The XRD analysis shows the presence of alumina (Al_2O_3), mullite ($3Al_2O_3 \cdot 2SiO_2$) and silica (SiO_2) shown in figure 4.

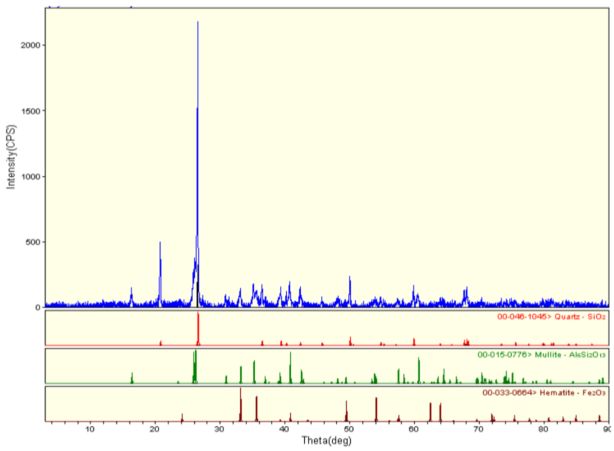

Fig -4: XRD

3.2 Density and Hardness studies

The theoretical and measured average density values of alloy A380 and its respective compounds are shown in Table 2. It was observed that the addition of fly ash and SiC particles into the matrix of alloy A380 significantly reduces the density of the resulting compounds. respect. to the base alloy.

Table.2 : Theoretical and measured densities of A380 alloy and A380-FA/SiC composites

S.No	Specimen	Density (g/cm3)	
		Theoretical	Measured
01	A380 alloy	2.79	2.78
02	Composite-1	2.65	2.61
03	Composite-2	2.51	2.43

The density of the compounds decreases as the proportion of fly ash and SiC particles increases, as shown in Table 2. With 10% fly ash and SiC, the compound density relative to density was reduced to 2.50 g/cm^3 of the composite. Alloy 2.79 g/cm^3. However, the measured densities were lower than those obtained from the theoretical calculations. The magnitude of the deviation increases with increasing fly ash and SiC content. This can be attributed to higher porosity with fly ash and SiC content, as shown in Table 2.

The hardness of a material is a physical parameter that indicates its ability to resist local plastic deformation. Hardness has been increased from 99 VHN for A380 alloy to 121 and 127 VHN for composite 1 and composite 2. This may be due to the presence of fly ash

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particles, which by nature are mainly hard alumina and silica, and also in the presence of hard SiC particles.

3.3 Tensile studies

Table 3 shows the tensile behavior of alloys and composites with reinforcements between 5% and 10%. Compared to the base matrix, the connections show superior strength properties. By increasing the reinforcement content, the strength properties are further improved. It was found that the tensile properties of the composites increased with the reinforcement content of the composites.

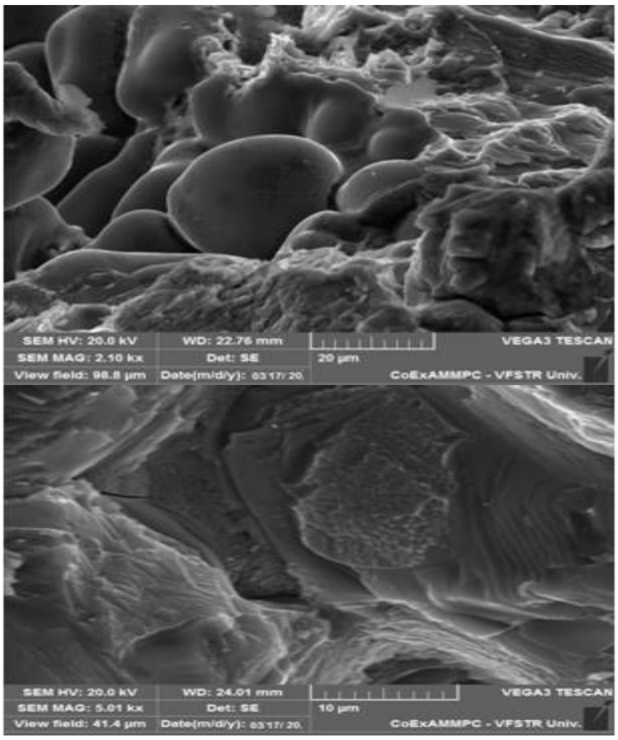
Table -3: Summary of yield strength, UTS, and modulus of composites.

Specimen	Ultimate Tensile Strength(UTS) MPa	Young's Modulus(GPa)
A380	191.76	19.49
Composite-1	204.53	21.34
Composite-2	231.11	24.23

Rohatgi et al. [5] reported an increase in the tensile modulus of elasticity with an increase in the volume percentage (3–10) ashes. Lloyd [6] examined the tensile stress and fracture behavior of a 6061 SiC-reinforced aluminum alloy and reported on the modulus of elasticity of discontinuously reinforced composite materials, which should be a function of the volume fraction of the reinforcement and of the transfer capacitance the load at anchor via the interface Al-Dheylan et al. [7] reported that UTS, elastic limit and modulus of elasticity of composites increased as the volume fraction of the reinforcement increased, while ductility decreased. Due to the limitations imposed on deformation caused by the presence of hard and brittle Al2O3 particles in the soft and ductile Al 6061 alloy matrix, higher applied stress is required to compensate for plastic deformation in the matrix.

Figure 4 shows the microstructures of broken alloy samples and their compounds. It can be seen that the incorporation of SiC and fly ash particles into the matrix alloy leads to higher tensile strength. This was due to the fact that the large particles used in this study have a slightly acute angle shape; these shaped particles act as a notch effect and reduce UTS. The other reasons could be that the large particles had smaller surface area in the matrix and even the large particles could have some defects than the small ones and could easily crash under load. During the tensile and compression tests it was assumed that the initiation of the fractures depended mainly on the breaking of the particles or the detachment of the particle matrix. Both are complex phenomena that are influenced by a number of factors, such as the limited stress field, the presence of interfacial inhomogeneities, structural changes in the matrix near the interfaces or surrounding notch effects and brittle reinforcing particles. Since the particle distribution is quite homogeneous in all three compounds, it is also suggested that it is possible to increase the particle-matrix bond by changing the type of reinforcement from hard ceramic to cemented carbide compounds with controlled dissolution at the matrix interface.

Lorca and González [8] predicted that in the initial stages of plastic deformation, the increase in load borne by the particles is mainly due to the gradual hardening of the surrounding matrix, which is relatively ductile. Several authors [9-12] have reported that the deformation hardening ability of the matrix is due to the relaxation of the flooded stresses of the broken particles, which causes the transfer of stresses to the neighboring particles and causes a larger breakage of the particles. They also concluded that the ultimate rupture of the joints is through a ductile mechanism that involves the nucleation and growth of voids in the matrix, which contributes to the ultimate amalgamation of larger voids that arise around the broken particles.



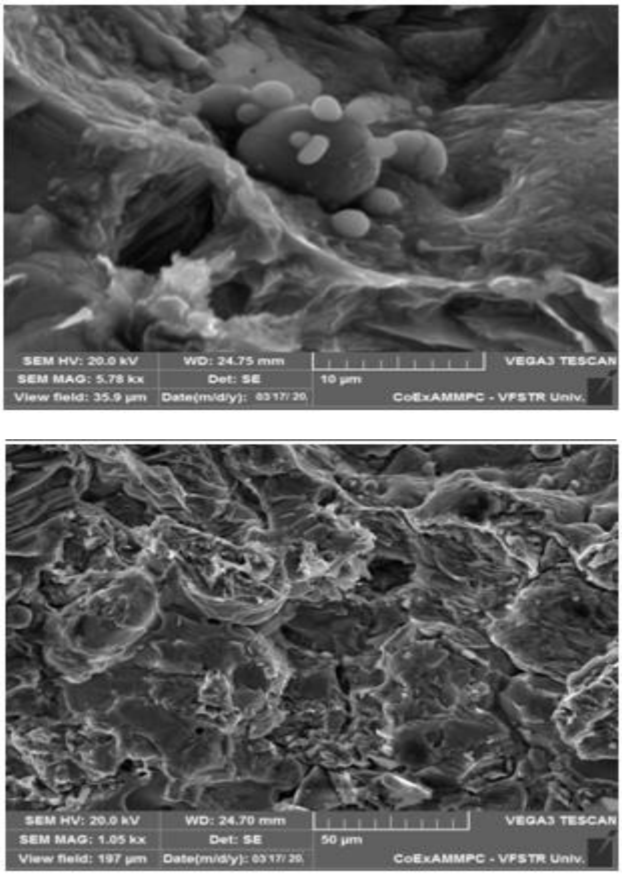


Fig -5: (a, b) SEM Micrograph of A380 fractured specimens (c) A380 –5% FA/SiC composite (d) A380 - 10% FA/SiC composite

4. CONCLUSIONS

The bulk density of the fly ash particles was 2.42 g/cm^3. The hybrid compounds A380/FA/SiC were successfully produced by stirring. There was a uniform distribution of the FA/SiC particles in the matrix phase. It is clear from the SEM numbers that the compounds showed no voids or discontinuities. There was a good interfacial bond between the FA/SiC particles and the matrix phase.

The density of composite materials decreases with an increasing proportion of FA / SiC particles compared to the density of the alloy 2.79 g/cm^3. The measured densities were lower than those obtained from theoretical calculations. The extent of drift increases with increasing FA/SiC content. EDX analysis of the composites shows that no oxygen peak was observed in the mold area, confirming that the composite material produced did not contain any additional atmospheric contamination. This could be because argon gas protection was maintained during mechanical stirring while adding the booster.

The hardness of the composites increases as the amount of FA / SiC increases as the base alloy increases.

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