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Microstructure and Mechanical properties of Fly ash/Sic Particles Reinforced AA 7075 Hybrid Composites

N Tulasiram[1], k.manikanta[2]
[1]*(mechanical, smec/ jntuh, INDIA)*
[2]*(mechanical, klc Vijayawada/ klu, INDIA)*

Abstract: *This paper presents the deformation behavior of hybrid composites with aluminum matrix A7075 alloy, reinforced with silicon carbide (Sic) and Fly ash. Newly formed A7075/FA/Sic hybrid composites are the combination of the two different hybrid materials. Cold upsetting experiments were carried out on as cast and homogenized hybrid composite billets. Optical and scanning electron micrographic examination of the samples was also undertaken. Hardness measurements were carried out to observe changes, if any, before and after the forging. Specimens were deformed in compression between two flat platens to predict the metal flow at room temperature. The circumferential stress component σ_θ increasingly becomes tensile with continued deformation. On the other hand the axial stress, σ_z increased in the very initial stages of deformation but started becoming less compressive immediately as barreling develops. FEM simulation analysis of the forging of composite cylinders was then undertaken using Ansys software with a specified diameter-to-height ratio. Detailed comparisons of the experimental variables with the finite element method (FEM) results were carried out to ascertain the accuracy with which the deformation process can be modeled. Predictions from the simulation results were found to be in good agreement with the actual experimentation*
Keywords: *A7075 alloy, (SiC) and Flyash, Energy Dispersive x-ray Spectroscopy*

I. Introduction

Metal Matrix composites (MMCs) are becoming attractive materials for advanced aerospace and automobile structures because of their properties can be tailored through the addition of selected reinforcements [1, 2]. In particular particle reinforced MMCs have found special interest because of their high specific strength and specific stiffness at room or elevated temperature. Normally micron sized ceramic particles are used as reinforcement to improve the properties of the MMCs. Ceramic particles have low coefficient of thermal expansion (CTE) than metallic alloys, and therefore incorporation of the these ceramic particles may exist interfacial mismatch between matrix andreinforcement. This phenomenon may be higher for high ceramic particle concentration. Among various dispersoids used, fly ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste by-product during combustion of coal in thermal powerplants. Fly ash particles are classified into two types, precipitator and cenosphere

II. Experimental

II.1. *Fabrication of composites*

In the present investigation, aluminium based hybrid metal matrix composites containing 5, 10 and 15wt% SiC and Flyash particulates of 70μm were successfully synthesized by vortex method. The matrix materials used in this study was Al-Cu-Mg alloy (AA 7075) whose chemical composition was shown in table 1.

Table 1: Chemical composition of AA 7075 alloy, wt. %.

The synthesis of these composites was carried out by stir casting technique. The cylindrical fingers (18 mm Φ and 170 mm length) of AA 7075 alloy were taken into a graphite crucible and melted in an electric furnace. After maintaining the temperature at 770 °C, a vortex was created using mechanical stirrer made of graphite. While stirring was in progress, the preheated particulates SiC and Flyash at 300^0C for 2 hrs were introduced into the melt. Care has been taken to ensure continuous and smooth flow of the particles addition in the vortex. The molten metal was stirred at 400 rpm under argon gas cover. The stirring was continued for about 2 minutes after addition of particles for uniform distribution in the melt. Still, the melt with reinforcement was in stirring condition the same was bottom poured into preheated (200 ^{0}C) S.G. iron mould of 65 mm diameter and 90 mm height. Cast ingots of both alloy and composites were homogenized at 200 ^{0}C for 24hrs to get relieve the internal stresses and minimize the chemical inhomogenities which may be present in the cast condition.

II.1.1: Characterization of Composites

II.1.2: Metallographic and Hardness tests

Scanning electron microscopy ((Model: SEM – Hitachi S-3400N - Japan) with EDAX energy dispersive X-ray spectroscopy (EDS) was used in order to evaluate the morphological changes and the elemental analysis of the alloy and the composites. The hardness of the alloy and composite was evaluated by using Leco Vickers hardness tester (Model: LV 700- USA). An average of ten readings was taken for each hardness value.

II.1.3: Density and Porosity tests

The density of the alloy and composites was measured by the Archimedes drainage method by using the following equation:

$$\rho_{MMC} =(m) / ((m-m_1) X \rho_{H2O})$$

Where ρ_{MMC} is the density of the composite, 'm' is the mass of the composite sample in air, 'm_1' is the mass of the same composite sample in distilled water and 'ρ_{H2O}' is the density of distilled water (at 293K) is 998 kg/m^3.

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.

$$\rho_c = V_r \rho_r + (1-V_r) \rho_m$$

Where ρ_c is the density of the composite, Vr is the weight ratio of reinforcement, ρ_r is the density of reinforcement and ρ_m is the density of the unreinforced AA7075 alloy. The porosity of the test materials were also calculated from the following equation.

Porosity (%) = (1- (measured density / calculated density)) X 100

Table-1

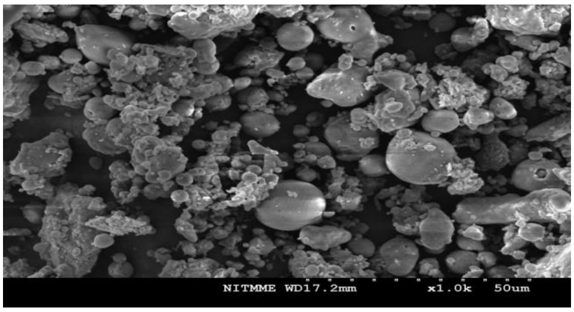
C2.2:

Cu	Mg	Si	Fe	Mn	Ni	Pb	Sn	Ti	Zn	Al
0.42	1.26	0.52	0.663	0.131	0.072	0.029	0.012	0.013	0.11	balance

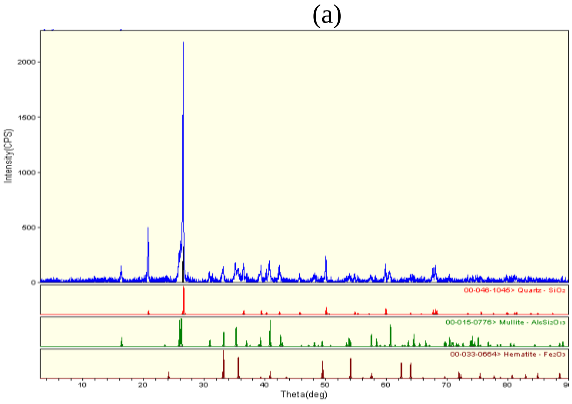
III. Results And Discussion

a. Microstructures and EDS of alloy and composites

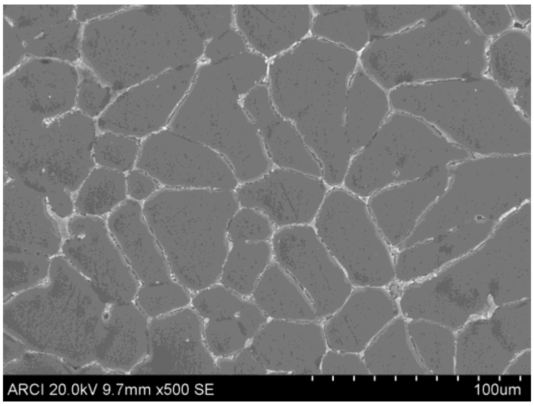
Figure (a-f) shows the SEM and optical micrographs of flyash particles, X-ray diffractograph and hybrid composites varying with wt. percentages of 5 to 15%. We can observe that, addition of fly ash and SiC in the alloy, i.e. by increasing the fly ash and SiC by weight percent the increased percentage content can be seen clearly by using the Olympus- 5060- G x 4, Japan, fig (c) shows the the microstructure of the alloy and whereas the figures d, e, f shows the addition of the fly ash and SiC to the alloy, difference in the microstructures was noticed clearly.



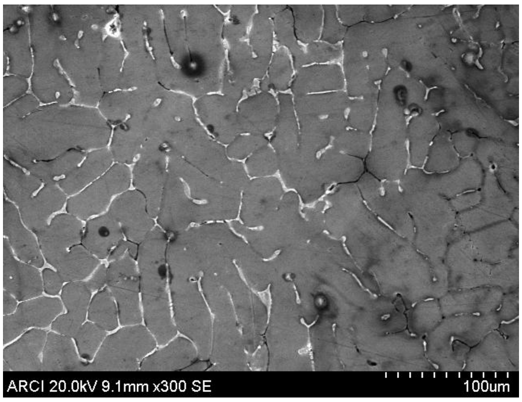
(a)



(b)



(c)



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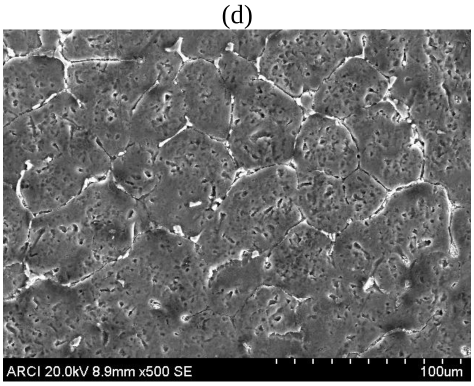
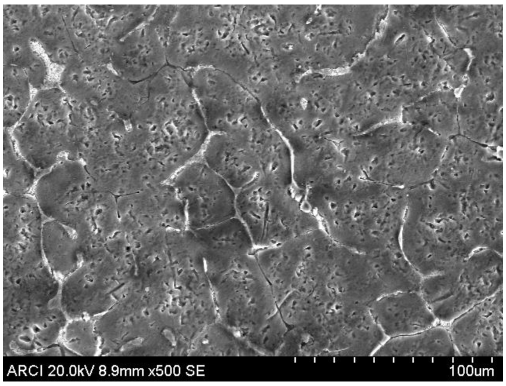


(e)

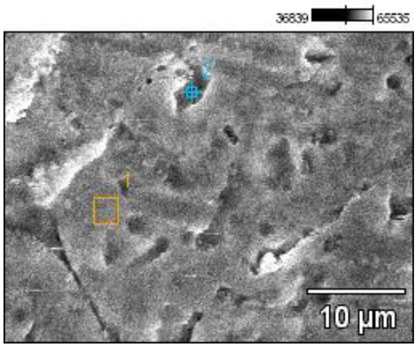


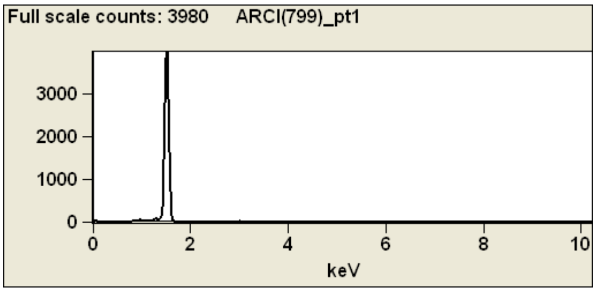
(f)

Figure : (a) SEM Micrograph of Flyash particles (b) X-ray diffractogram of fly ash particles (c) **AA7075 base** at 100X (d) **AA7075** –**5%** FA/SiC COMPOSITE at 100X (e) **AA7075** –10**%** FA/SiC COMPOSITE at 100X (f) **AA7075** –1**5%** FA/SiC COMPOSITE at 100X.

The EDS spectrum of the alloy shows the presence of Al, Cu and Mg in the matrix phase, figure 2.2, and silicon and carbon constituents on the reinforcement, figure 4.3.Also figure 4.4 shows alumina (Al_2O_3), mullite ($3Al_2O_3{\cdot}2SiO_2$) and silica (SiO_2); which were present in the fly ash. The matrix does not show any increment in Cu and Mg concentration reveals that the dissolution of the reinforcement is restricted to its vicinity. Similarly, the reinforcement phase shows only the constituents, such that no contamination has occurred. Since, perfect shielding of argon gas is maintained, traces of oxygen is not seen either with the matrix or the reinforcements. An average of six readings was taken on the matrix, free from particulates.

ARCI(799)





Weight %

	C-K	O-K	Na-K	Mg-K	Al-K	Si-K	K-K	Ca-K	Ti-K	Mn-K	Fe-K	Cu-K	Zn-K	As-K	Ta-L
ARCI(799)_pt1	5.00	0.40	0.00	0.93	88.34	0.00	0.04	0.02	0.18	0.00	0.00	2.11	0.00	0.00	2.97
ARCI(799)_pt2	10.36	1.53	0.00	1.39	80.49	0.36	0.00	0.09	0.00	0.00	0.35	5.15	0.30		

Weight % Error

	C-K	O-K	Na-K	Mg-K	Al-K	Si-K	K-K	Ca-K	Ti-K	Mn-K	Fe-K	Cu-K	Zn-K	As-K	Ta-L
ARCI(799)_pt1	+/- 1.54	+/- 0.36	+/- 0.00	+/- 0.12	+/- 0.55	+/- 0.00	+/- 0.08	+/- 0.08	+/- 0.10	+/- 0.00	+/- 0.00	+/- 0.44	+/- 0.00	+/- 0.00	+/- 1.07
ARCI(799)_pt2	+/- 1.50	+/- 0.45	+/- 0.00	+/- 0.16	+/- 0.51	+/- 0.14	+/- 0.00	+/- 0.08	+/- 0.00	+/- 0.00	+/- 0.20	+/- 0.79	+/- 0.35		

ARCI(803)

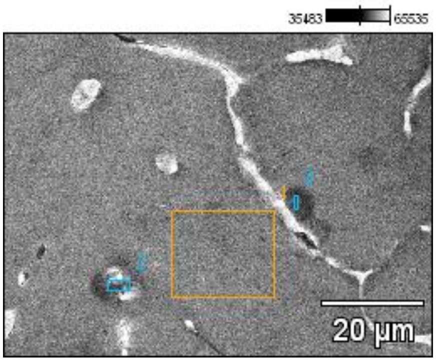
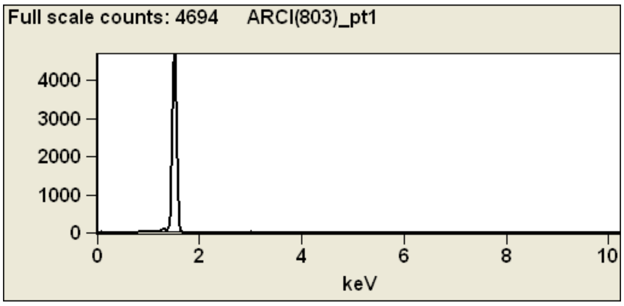


Figure EDS spectrum on the SiC particulate



	C-K	O-K	Na-K	Mg-K	Al-K	Si-K	K-K	Ca-K	Ti-K	Mn-K	Fe-K	Cu-K	Zn-K
ARCI(793)_pt1	3.29	0.00	0.00	0.79	93.62	0.00	0.00	0.11	0.00	0.00	0.15	2.05	0.00
ARCI(793)_pt1	+/-1.30	+/-0.00	+/-0.00	+/-0.08	+/-0.49	+/-0.00	+/-0.00	+/-0.07	+/-0.00	+/-0.00	+/-0.15	+/-0.35	+/-0.00

Figure EDS spectrum on the Flyash particulate

b. Density and hardness studies

The average theoretical and measured density values of the AA 7075 alloy and its respective composites were given in table 2. It was observed that the addition of fly ash and SiC particles into the AA 7075 alloy matrix significantly decreases the density of the resultant composites in compare to the base alloy.

Table.2 Theoretical and measured densities of A7075 alloy and A7075-FA/SiC composites

S. No	S p e	Density (g/cm^3)	
		Theoretical	Measured
1	AA 7075 alloy	2.81	2.81
2	AA 7075 alloy - 5% FA/SiC composite	2.78	2.76
3	AA 7075 alloy - 10% FA/SiC composite	2.69	2.66
4	AA 7075 alloy - 15% FA/SiC composite	2.64	2.63

The density of the composites decreases with increasing the percentages of fly ash and SiC particulates, as shown in table 2. With 15% fly ash and SiC, the density of composite decreased to 2.64 g/cm^3 compared to the density of the alloy 2.81 g/cm^3. The measured densities, however, were lower than that obtained from theoretical calculations. The extent of deviation increases with increasing flyash and SiC content. This can be attributed to the increase in porosity with fly ash content as shown in table2.

The hardness of a material is a physical parameter indicating the ability of resisting local plastic deformation the hardness values of the AA 7075 alloy and flyash/SiC particles reinforced composites. The hardness was increased from 88 VHN for AA 7075 alloy to 94 and 104 VHN for composite 1 and composite 2 and 130 VHN for composite 3 with 15 % reinforcement respectively. This could be due to the presence of fly ash particulates which consists of majority of the alumina and silica which are hard in nature and also due to presence of hard SiC particles. This is also confirming the result reported by Hassan, S. F *et al.* and Ma, NG *et al.*

IV. Conclusion

I. The bulk density of the fly ash particles was found to be 2.42 g/cm3.
II. A7075/FA/SiC Hybrid composites were produced by stir casting route successfully.
III. There was a uniform distribution of FA/SiC particles in the matrix phase.
IV. From the SEM figures, it clearly shows that there were no voids and discontinuities in the composites; there was a good interfacial bonding between the FA/SiC particles and matrix phase.
V. The density of the composites decreases with increasing the percentages of FA/SiC particulates compared to the density of the alloy 2.81 g/cm3.
VI. The measured densities were lower than that obtained from theoretical calculations. The extent of deviation increases with increasing FA/SiC content.
VII. From the EDX analysis of composites shows that no oxygen peaks were observed in the matrix area, confirming that the fabricated composite did not contain any additional contamination from the

atmosphere. This might be due to a shield of argon gas was maintained during the mechanical stirring while reinforcement addition.

VIII. The hardness of the composites increased with increasing the amount of FA/SiC than the base alloy.

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