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Deformation and Finite Element Flow Studies of Aluminium Based Copper Particulate Reinforced Metallic Composites

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Abstract: Work has been carried out to study the upshot of alloying constituent dispersal in the base metal by using composite manufacture method. Al–Cu composites (5–15 wt%) are prepared by vortex method by dispersing copper powder in molten A2024 alloy. Results are compared with the alloy having same concerto. Composites with 5, 10, 15% by weight were also compared. The hardness and compressive strength of the composites were determined as a function of the copper powder content. The best results were achieved with the aluminum composites with A2024 alloy. Deformation and flow studies were carried out and the results were compared with finite element methods in terms of compressive and hydrostatic stresses.

Key words: *Vortex* method **Aluminium** A2024 alloy

1. INTRODUCTION

Metal Matrix composites (MMCs) are becoming beckoning materials for advanced aerospace and automobile and naval 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 and reinforcement. This phenomenon may be higher for high ceramic particle concentration.

2.0 MATERIALS AND METHODS

2.1 Matrix Material

2.1.: Casting of A2024 alloy

Pure aluminum (99.5+ % EC grade) was procured from M/s NALCO as 20 kg ingots, bus-bars of conductivity grade copper (99.95% Cu) and the ingot of high purity magnesium (99.9+%) were purchased from local market. Cut ingots of pure aluminium were melted in a fixed pot type electric heating furnace in a graphite crucible at 670ºC. In order to prevent excess oxidation of the metal proprietary covering agent, supplied by M/s Fosceco (I) Ltd was used. Magnesium in the form of thin slices wrapped with aluminium foil was added to the Al-Cu alloy melt after the furnace temperature was reduced to 720ºC. Magnesium oxidation was minimized by plunging the Magnesium slices to the bottom of the melt and allowed to melt then itself. Melt was well mixed with a graphite covered tube for consistency in composition. Once the pouring temperature attained the metal was thoroughly degassed using Argon for one minute. The top layer was skimmed and metal was cast into a preheated (200^{O} C) Cast. Iron mould of 160 mm x 16 mm Φ cylindrical fingers. Homogenization treatment was carried out at 200 ^{0}C for 24hrs to alleviate the inside stresses and minimize the chemical inhomogenities which may be present in the cast alloys. The chemical composition of A2024 was shown in table 1; the same was carried out by using X-MET 3000 TX equipment.

Table 1: Chemical composition of AA 2024 alloy, wt. %.

Cu	Mg	Si	Fe	Mn	Ni	Pb	Sn	Ti	Zn	Al
4.42	1.769	0.052	0.663	0.131	0.072	0.029	0.012	0.013	0.11	balance

2.2: Fabrication of Composites

In the present research, aluminium based metallic composites containing 5, 10 and 15wt% copper particulates of 53µm were successfully synthesized by eddy method. The matrix materials used in this study was Al-Cu-Mg alloy (AA 2024) whose chemical composition was shown in table 1.

The fusion of these composites was carried out by stir casting technique. The cylindrical fingers (16 mm Φ and 160 mm length) of AA 2024 alloy were taken into a graphite crucible and melted in an electric furnace. After maintaining the temperature at 750 °C, a vortex was created using mechanical stirrer made of graphite. While rousing was in progress, the preheated particulates of copper at 300^{0}C 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.

2.3: Characterization of Composites
2.3.1: Metallography and Hardness tests

SEM with Energy dispersive X-ray spectroscopy (EDS) was used in order to evaluate the morphological changes and the rudimentary analysis of the alloy and the composites. The hardness of the alloy and composite was evaluated by using Vickers hardness tester. An average of 12 readings was taken for each hardness value.

3 RESULTS AND DISCUSSION

a. Microstructures and EDS of alloy and composites

Figure 1 (a-d) shows the SEM and optical micrographs of alloy and composites, it is clear from the microstructures that interdendritic regions (IDRs) were formed, and also the distribution of particulates was uniform throughout. Similarly, the reinforcement phase shows only the constituents, such that no contamination has occurred. Since, ideal protecting of nitrogen gas is maintained, traces of oxygen is not seen either with the matrix or the reinforcements and also

Figure (a)

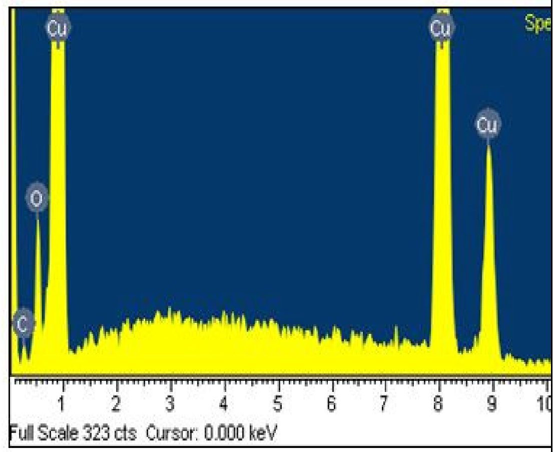


Figure (b)

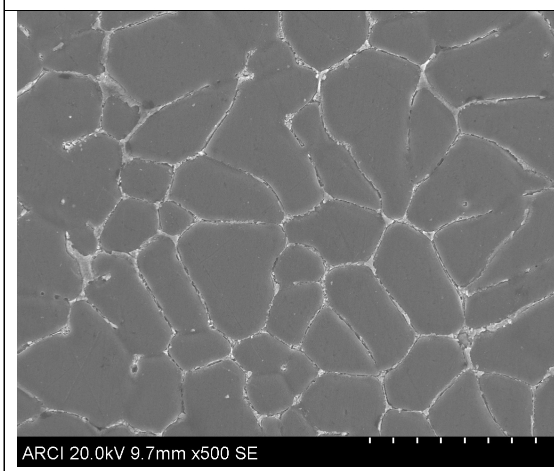


Figure (c)

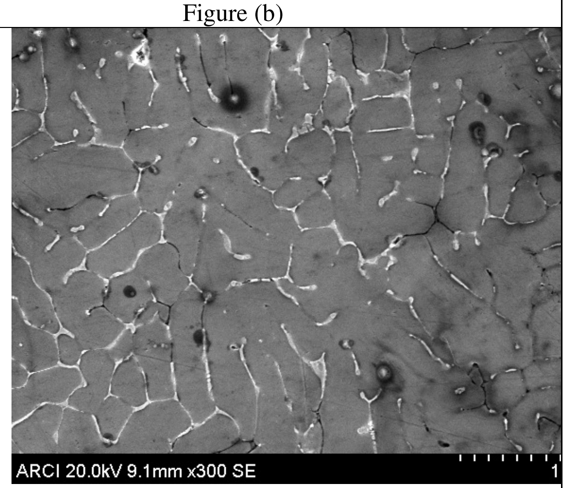


Figure (d)

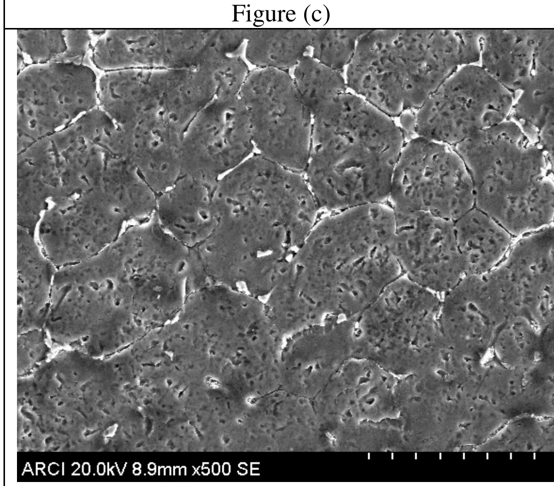


Figure (e)

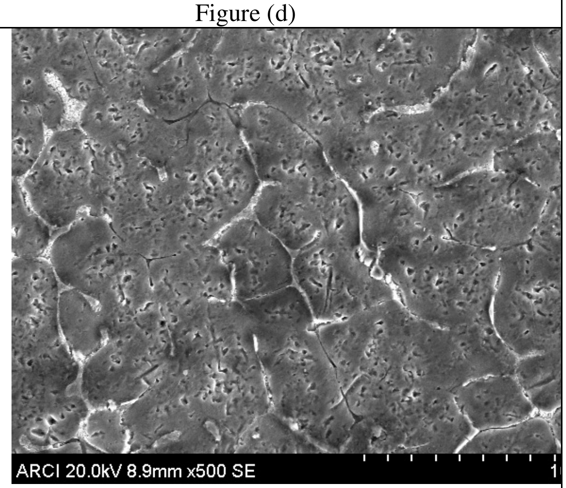
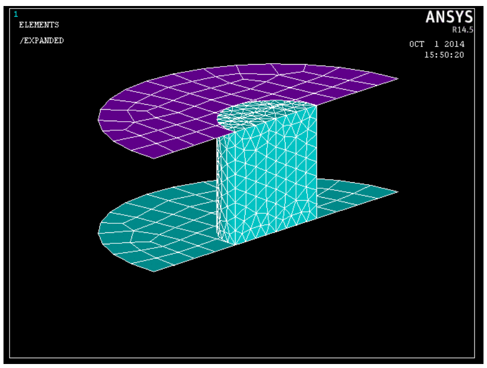


Figure (f)

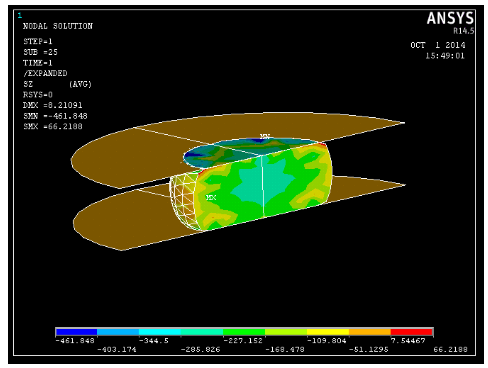
Figure 1: (a) Cu particles (b) X-ray diffractogram of Cu (c) **AA2024 base** at 100X (d) **AA2024 –5%** COMPOSITE at 100X (e) **AA2024** –10**%** COMPOSITE at 100X (f) **AA2024** –15**%** COMPOSITE at 100X

4.0 FINITE ELEMENT FLOW BEHAVIOR

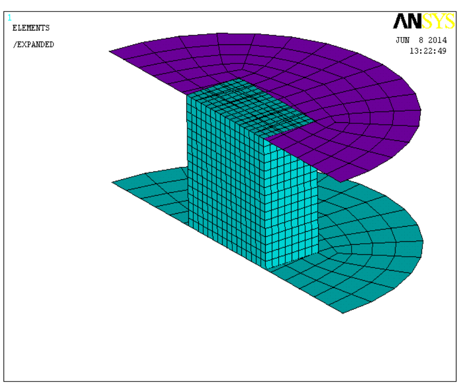
The finite element simulation helps in analyzing the progression and predicting the defects that may occur at the design stage itself. Consequently, modifications can be made easily, before tool manufacturing and part production, reducing the trial and error stage and its coupled costs.



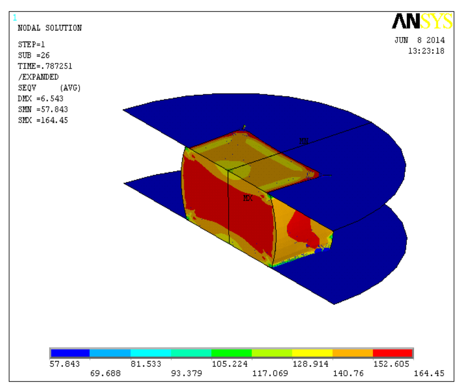
Half geometry after meshing,
Cylindrical shape (platens made rigid)



Half geometry after 50 % deformation
(Circumferential stress)



Half geometry after meshing,
Square shape (platens made rigid)



Von-Mises stress

Meticulous 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 modelled. Prediction from the simulation results were found to be in good agreement with the actual experimentation.

4. CONCLUSIONS

1. AA2024/Cu particulate composites were produced by stir casting route successfully.
2. There was a homogeneous distribution of particles in the matrix phase.
3. From the SEM figures, it evidently shows that there were no voids and discontinuities in the composites; there was a good interfacial bonding between the Cu particles and matrix phase.
4. 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 nitrogen gas was maintained during the mechanical stirring while reinforcement addition.
5. The hardness of the composites increased with increasing the amount of Cu to the base alloy.
6. Finite element analysis of deformation behaviour of cold upsetting process was carried out for all the metallic composites and base alloy (A2024) with aspect ratios of 1.0 and 1.5 in dry condition.
7. Due to axisymmetric nature of the geometry only quarter portion was modeled with symmetric boundary conditions.

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