Studies on Deformation Behaviour of A356/Al-20Cu-10Mg Particulate Composite Metallic Materials

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Cold upsetting experiments were carried out on as cast and homogenized A356/Al-20Cu-10Mg Particulate composite billets. The study was aimed to evaluate the deformation behavior. 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: Barreling, Upsetting, Al-20Cu-10Mg Particulates, Finite Element Analysis

1.0 Introduction

Metal matrix composites (MMCs) consist, a pure metal or alloy as matrix material, and the reinforcement as particulates, whiskers or continuous fiber. Metal matrix composites possess some attractive properties which include elevated temperature applications, high transverse strength, high electrical conductivity, and superior thermal conductivity and high wear resistance. Depending upon the application in service, a variety of composites with different combinations of matrix materials and reinforcements are being produced through different fabrication methods. These composites are fabricated by the addition of a reinforcement phase to the matrix using one of the following techniques namely powder metallurgy, spray atomization and co-deposition, plasma praying, stir casting (compo casting) and squeeze casting. MMCs with fiber reinforcements are the initial investigations through suitable processes. Expensive manufacturing cost, anisotropy and restricted secondary processing led to the use of particles/short fibers/whiskers as reinforcements in MMCs. Reinforcing with ceramic particulates extended its applications to a greater adaptability and wide range of properties. Metal matrix composites reinforced with ceramic particles are widely used due to their high specific modulus, strength and wear resistance.

Secondary processing is an integral part of manufacturing process of metal matrix composites. Such processing of the discontinuously reinforced composites leads to breakup of particle agglomerates, reduction or elimination of porosity and improved particle to particle bonding all of which tend to improve the mechanical properties of these materials. Forming processes are employed for the manufacture of a large range of engineering components, including those for use in aero-engines. Several workability tests are available to study the deformation behaviour under the combined stress and strain conditions usually found in bulk deformation process. The behaviour obtained from cold upsetting test to a 50% deformation is worth studying as most of the upset forging processes such as in cold heading, riveting, plate bending, stud welding, the deformations are limited to 50% in a single stroke in order to check the die filling. Though there are many applications with MMCs; fabrication, secondary processing, compatibility between the matrix and reinforcement and characterization are still the major hurdles in the manufacturing of these composites. Thought has been given to have the advantages of both MMCs and metal-metal combination systems by choosing the conventional alloy systems for the manufacture of composites with restricted solubility. In the present work an attempt has been made to fabricate A356 /Al-20Cu-10Mg particulate composites through stir casting technique.

2 EXPERIMENTAL PROCEDURE

Production of Reinforcements

Al-Cu Binary alloys and Al–Cu–Mg ternary alloys (Table.1) by weight is cast into Ø 180mm×18mm cylindrical fingers covering the region of standard for experimentation. Cast fingers are homogenized at 100^{o}C for 24 hours, among the investigated alloys, alloy 4 i.e. Al-20wt% Cu-10wt% Mg) ternary alloy powder/particles has been chosen as reinforcements due to its high hardness

Alloy	Copper	Magnesium	Aluminium
Alloy	10	-	Balance.
Alloy	10	10	Balance.
Alloy	20	-	Balance
Alloy	20	10	Balance.

Table-1

Fabrication of Composites

Composite metals are prepared by stir cast technique. Alloy (AA356) was melted in a clay graphite crucible in a pit type heating furnace (Figure 1) Melt was thoroughly purged with argon gas. A good vortex was created in the melt using a rotating impeller. Preheated (200^{o}C) Al–20%Cu-10%Mg particles were added to the melt through the sides of vortex at 720^{o}C. Throughout the process argon gas was maintained above the melt to prevent oxidation and hydrogen absorption. Composite metals AA356/ (5-15%)/Al–20Cu-10Mg are produced. Composite melt was poured in to preheated cast iron permanent mould of size Ø 60mm×90mm after stirring the melt for 30seconds. Subsequently billets were hot extruded into 14mm rods (extrusion ratio of 18:1) by maintaining extrusion container at 450^{o}C and preheating the billet at 450^{o}C for 30mins.

Fig. 1 Production of composites by stir casting and Extrusion

Deformation test

Compression tests were carried out on cylindrical specimens of A356/Al-20Cu-10Mg particulate composites (5, 10 and 15%) of 12 mm Ø with H/D ratio of 1.0. These cylindrical specimens of standard dimensions were prepared using conventional machining operations of turning, facing and drilling. Specimen edges were chamfered to minimize folding. Concentric v- grooves of 0.5mm deep were made on the flat surfaces to have a low friction between die and work piece during compression. Standard samples were compressed by placing between the flat platens at a constant cross head speed of 0.5mm/min in dry condition, using a computer controlled servo hydraulic 100T universal testing machine (Model: FIE-UTE).

Fig 2 Deformed samples with H/D Ratio=1.0 &1.5

3 RESULTS AND DISCUSSIONS

3.1 Friction Factor

The decrease in internal diameter of the ring compression test was plotted against the deformation on calibration curves in increments of 10% deformation. When these ring compression values were fit into calibration curves for the given set of dies, it was found that the friction factor 'm' with high finish dies was nearly equal to 0.30, as shown in Figure 3 .The same set of dies was used for upset tests also.

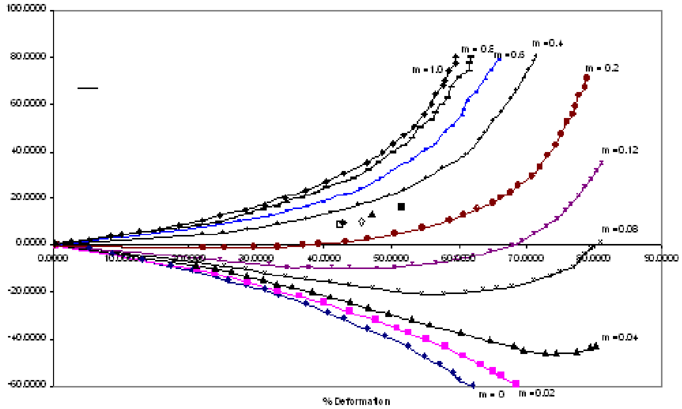


Fig 3 Friction Factor

3.2 Load Displacement Curves

The load requirement increased with increase in the axial displacement of the specimen, it was true for all the specimens. Further an increase in aspect ratio from 1.0 to 1.5; the load required gets reduced for the same amount of deformation. For a fixed diameter, a shorter specimen will require a greater axial force to produce the same percentage of reduction in height, because of the relatively larger undeformed region shown in figure 4, 5 and 6.

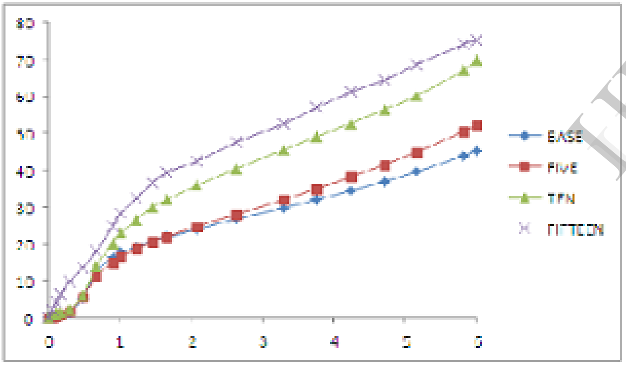


Fig 4 Load Displacement curve for H/D 1.0

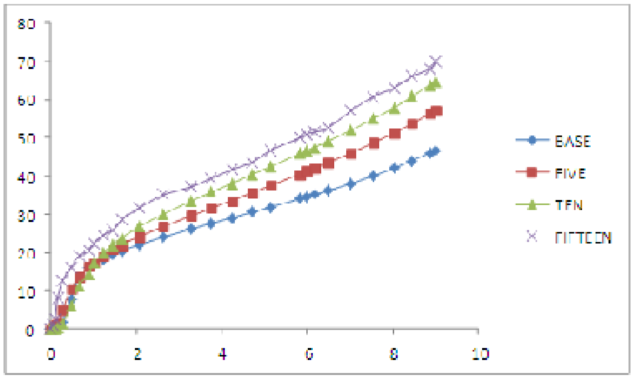


Fig 5 Load Displacement curve for H / D 1.5

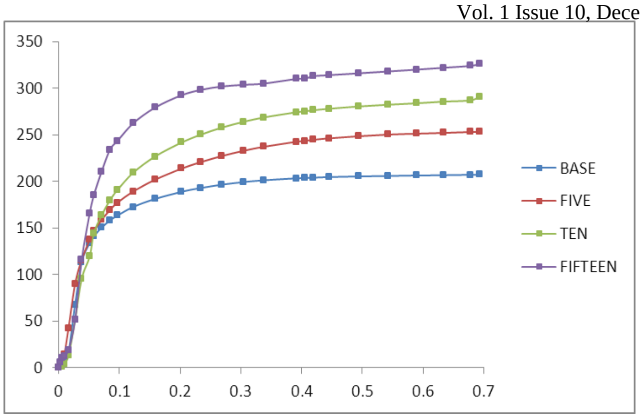


Fig 6 True Stress- Strain curve H/D 1.5

3.3 Finite Element Simulation

Finite element simulation (FEM) of the forged specimens by lagrangian finite element model of the cold upset forging process under unlubricated condition is developed using Ansys software. Rigid-flexible contact analysis was performed for the forming process. For such analysis, rigid tools need not be meshed. The billet geometry was meshed with 10-node tetrahedral elements (solid 92 in ANSYS Library). Material models were selected based on the properties of the tooling and billet materials. Due to high structural rigidity of the tooling, only the following elastic properties of tooling (H13 steel) were assigned assuming the material to be isotropic. Young's Modulus E = 210 GPa and Poisson's ratio $\gamma = 0.30$. For billet material model selected is isotropic Mises plasticity with E = 73 GPa, $\gamma = 0.375$ and plastic properties obtained from Hollomon power law equation

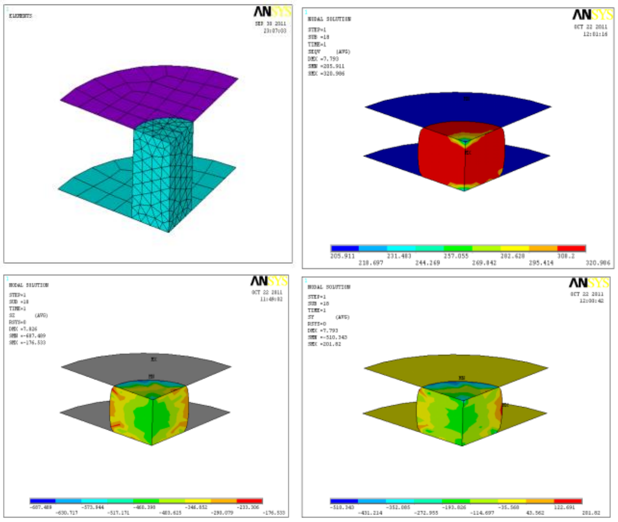


Fig 7 Deformation using FEM

Graphical comparisons between Experimental & Simulated results

Effective Strain	σ_z		σ_θ		σ_m	
	EXPT(N/m^2)	FEM	EXPT	FEM	EXPT	FEM
0	0.00	0.00	0.00	0.00	0.00	0.00
0.01	-21.5677	-25.12	4.984	7.47	-5.528	-3.61
0.04	-46.6982	-42.33	13.113	10.20	-11.195	-13.00
0.07	-66.2941	-72.73	22.163	25.64	-14.711	-15.61
0.10	-82.9545	-88.11	32.521	40.67	-16.811	-19.38
0.17	-110.372	-118.38	57.670	64.59	-17.567	-22.52
0.24	-131.723	-127.06	89.309	93.57	-14.138	-18.58
0.33	-147.817	-142.34	128.147	135.83	-6.556	-8.37
0.40	-156.561	-149.93	162.506	170.33	1.982	0.945
0.46	-160.787	-155.74	188.137	195.44	9.117	6.48
0.58	-161.23	-152.55	246.631	239.42	27.134	19.17

Table 2 15 % Reinforcement (50%Deformation)

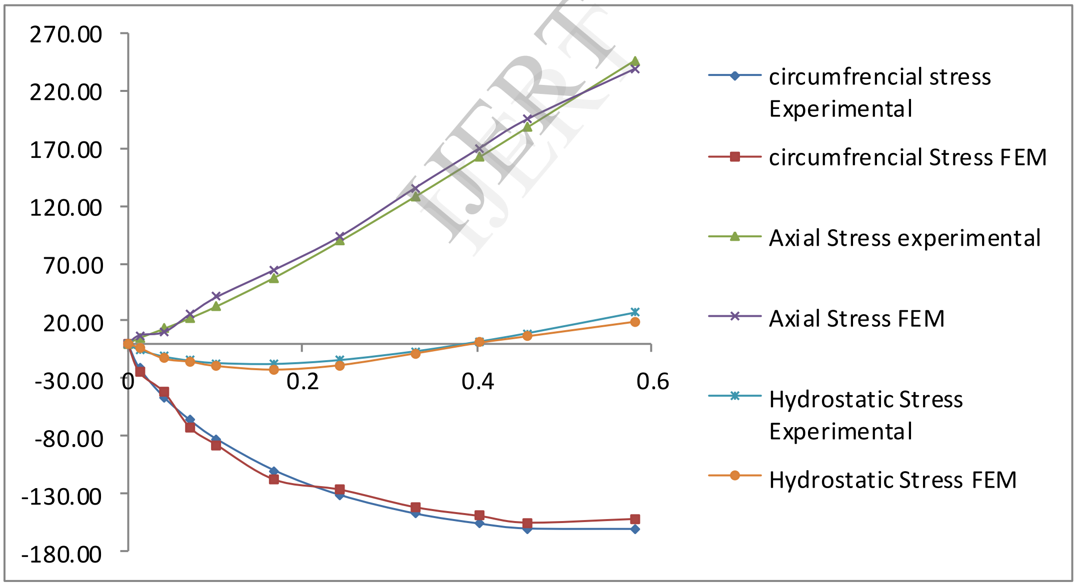
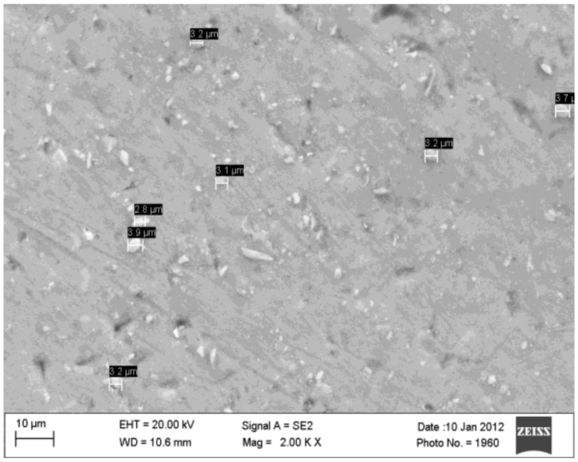
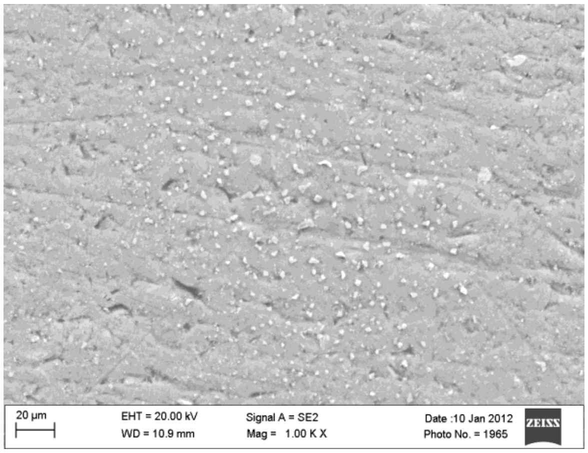


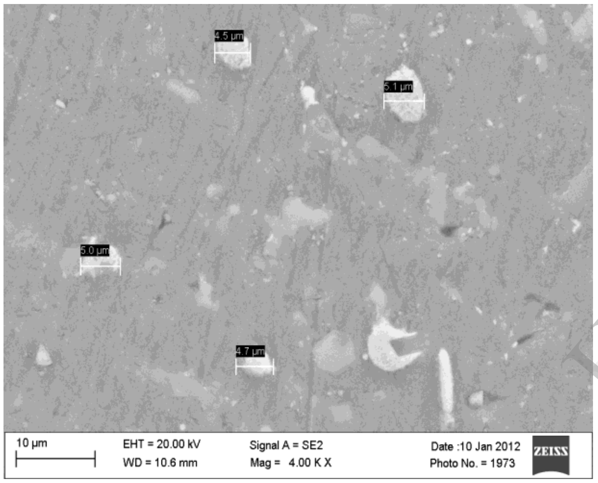
Fig 8 Comparison Graph at (50%Deformation)

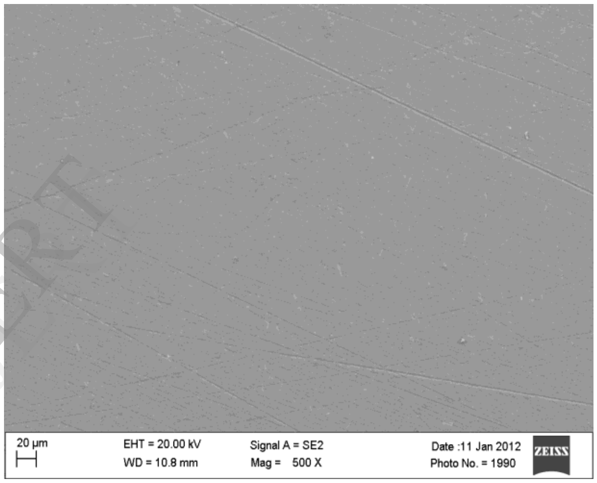


SEM Image for 5 % Reinforcement



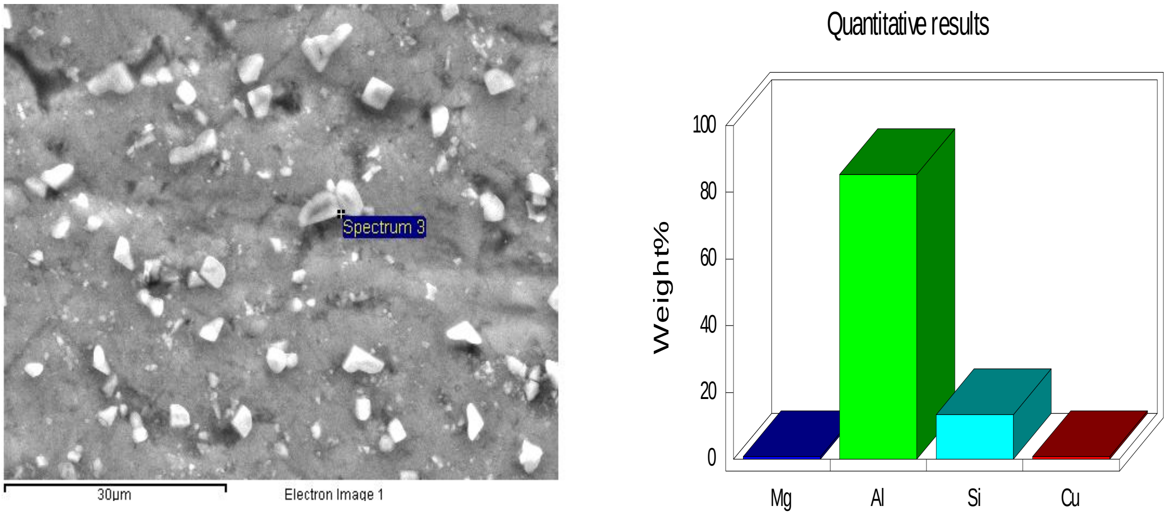
SEM Image for 10 % Reinforcement





SEM Image for 15 % Reinforcement

SEM Image for A356 BASE



EDAX of the Reinforcements

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Conclusions

1. The circumferential stress component σ_θ increasingly becomes tensile with continued deformation.

2. Friction factor 'm' was determined experimentally for given set of dies.

3. FEA modeling and analysis was successfully performed from the experimentally obtained friction factor values.

4. Results obtained by finite element analysis closely matched with the experimental values and hence the model is validated**.**

5. Scanning electron micrographic examination of the samples was taken and it was observed that the particles are distributed uniformly.

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