Deformation Studies on A2024/Flyash/Sic Hybrid Composites

M.Gopi Krishna[1], K. Praveen Kumar [2] J.Babu Rao [3], NRMR Bhargava [3], K.Vijaya Bhaskar [4]

[1] Acharya Nagarjuna University, Guntur 522 510, India.
[2] R.V.R. & J.C. College of Engineering, Guntur 522 019, India
[3] Andhra University College of Engineering, Visakhapatnam 530 003, India.
[4]M.B.T.S Polytechnic College, Guntur, India

ABSTRACT

This paper presents the deformation behavior of hybrid composites with aluminium matrix A2024 alloy, reinforced with silicon carbide (Sic) and Flyash. Newly formed A2024/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: A2024, Fly Ash, Silicon Carbide, Hybrid Metal Matrix Composites

INTRODUCTION

Composites are most promising materials of recent interest. Metal matrix composites (MMCs) have been studied for some years and their potential advantages over conventional monolithic alloys are increasingly being appreciated. A vast range of MMC materials has been conceived and studied. By far, the largest commercial volumes are for Aluminum matrix composites (AMCs), which accounts for 69% of the annual MMC production by mass [1]. To produce these composites, both solid and liquid phase processing methods have been used; the later has the advantages that the fluidity of the metal allows for the use of a wide range of reinforcements and the capability of producing near net shaped casting. The major problem in fabricating metal matrix composites by liquid phase is the poor readability which leads to the non-uniform distribution of the particles. Vortex (liquid phase processing) technique involves incorporating of ceramic particulates into molten alloy using the rotating impeller [2, 3]. Normally, micro-ceramic particles are used to improve the hardness and ultimate strength of the metal. However, the ductility of the MMCs deteriorates with high ceramic particle concentration [4]. It is of interest to use micro-sized ceramic particles to strengthen the metal matrix, while maintaining good ductility, high temperature creep resistance and better fatigue [4]. A 2024 alloy is the most widely used aluminum-copper alloys in forging as well as rivets for aircraft industry. This alloy has a higher tensile and yield strength with lower elongation. Typical uses of this alloy are aircraft structures, rivets, hardware, truck wheels and screw machine products.

EXPERIMENTAL

Composite metals are prepared by stir cast technique. A2024 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 (300^{o}C) Flyash and silicon carbide 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. To increase the wettability, 1.5% of pure Mg was added with all composites. The melt temperature was maintained 700°C during addition of Mg, SiC, fly ash, SiC-fly ash mixture particles. The dispersion of fly ash and other particles were achieved by the vortex method. The melt with reinforced particulates were poured into the preheated permanent metallic mold. The pouring temperature was maintained at 680ºC. The melt was then allowed to solidify in the permanent grey cast iron mould (**Fig. 2**). The metal matrix hybrid composites that were obtained are shown in the **Fig. 3**.

Figure 1 Furnace

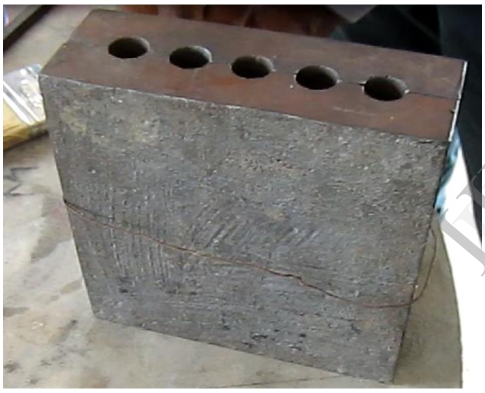

Figure 2 permanent die

Figure 3 Hybrid composite fingers

COMPRESSION TESTS

Compression tests were carried out on cylindrical specimens of A2024 and A2024/ (5%SiC), 2024/ (10%SiC), 2024/ (15%SiC), A2024/ (5%flyash), 2024/ (10% flyash), 2024/ 15% flyash), Al 2024/(5%SiC+5%FA), 2024/(10%SiC+10%FA),2024/(15%SiC+15% FA) of 16 mm Ø with H0/D0 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). Cold work die steel dies (flat flattens) were machined to produce smooth finish to yield low friction. Online plotting of load versus displacement was done continuously through a data acquisition system

Figure 4 Deformed sample between dies

Figure 5 compression testing equipment

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 γ = 0.30. For billet material model selected is isotropic Mises plasticity with E = 73 GPa, γ = 0.375 and plastic properties obtained from Hollomon power law equation.

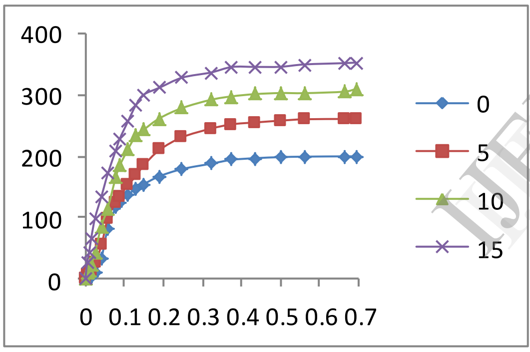

Figure 6 True Stress- Strain curve H/D 1.0
(X-axis–Strain, Y-axis-Stress)

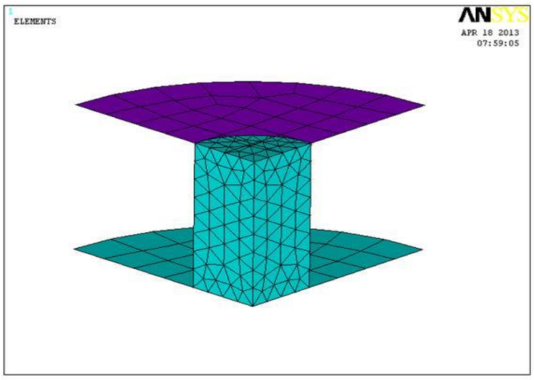

Figure 7 Undeformed sample h/d 1.0

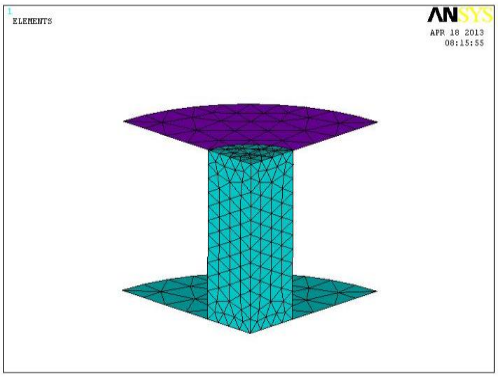

Figure 8 Undeformed sample h/d 1.5

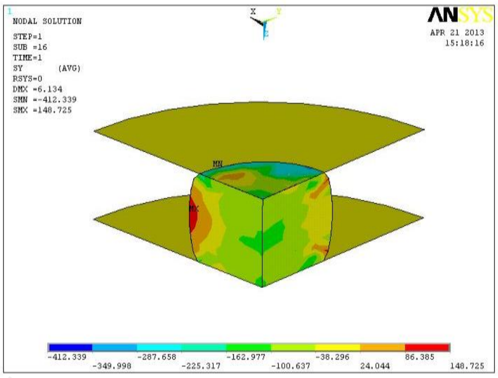

Figure9 Radial Stress at 50% deformation

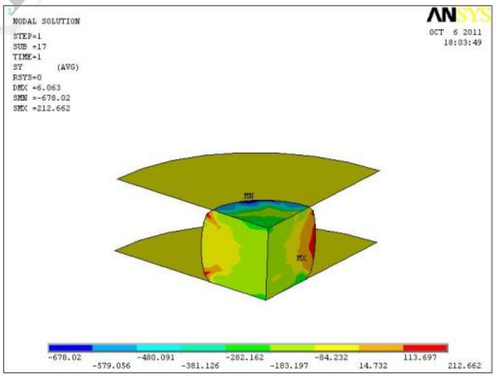

Figure10 circumferential Stress

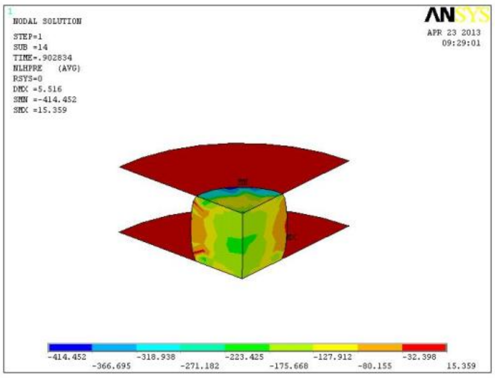

Figure11 Hydrostatic Stress

RESULTS AND DISCUSSION

Al-SiC, Al-fly ash, Al-SiC-fly ash (various concentrations) composites were successfully fabricated by two-step stir casting process. Wetting of reinforcements with the aluminium matrix was further improved by the addition of magnesium. By increasing the content of the reinforcement the density of the composites decreased, Hence, it was found that, instead of Al-SiC and Al-fly ash composites, Al-SiC-fly ash composites show better performance So these composites can be used in applications where to a great extent weight reductions are desirable Tensile strength, yield strength and hardness were determined for the test materials. Increase in area fraction of reinforcement in matrix result in improved tensile strength, yield strength and hardness With the addition of SiC and fly ash with higher percentage the rate of elongation of the hybrid MMCs is decreased significantly Optical micrographs revealed that both the SiC and flay ash particles are well distributed in aluminium matrix.

CONCLUSIONS

1. The hybrid particles are well dispersed in the matrix.
2. The circumferential stress component σ_θ increasingly becomes tensile with continued deformation
3. Further an increase in aspect ratio from 1.0 to 1.5; the load required gets reduced for the same amount of deformation.
4. For a fixed diameter, a shorter specimen will require a greater axial force to produce the same percentage of reduction in height
5. Friction factor 'm' was determined experimentally for given set of dies.
6. FEA modeling and analysis was successfully performed from the experimentally obtained friction factor values.
7. Results obtained by finite element analysis closely matched with the experimental Values

REFERENCES

1. Singaresu S Rao., "The Finite Element method in Engineering", Elsevier Butterworth-Heinemann 2005 edition.
2. Kopp, R., Cao, M.L., de Souza, M.M., "Multi-level Simulation of Metal Forming Process", Proc. 2nd ITCP, Stuttgart, p.1128-1234, August, 1987.
3. ANSYS 10.0 Help manual documentation.
4. Wu, W.T., Jinn, J.T., and Fischer, C.E. "Modeling Techniques in Forming Processes" Scientific Forming Technologies
5. http://www.matweb.com
6. Lee C.H. and Kobayashi S., "New Solutions to Rigid-Plastic Deformation Problems Using a Matrix Method", J. Eng. Ind. (Trans. ASME), vol. 95, 1973, p 865
7. Oh, S. I., and Kobayashi S., "Workability of aluminium alloy 7075 T-6 in upsetting and rolling", Trans. ASME, J. Eng. Ind vol. 95, 1976, p 800-806.
8. Kobayashi, S., Oh, S.I., and Altan T., "Metal Forming and the Finite Element Method", Oxford University Press, New York, 1989
9. Zeinkiewiez O.C., "Flow Formulation for Numerical Solution of Forming Processes", in. PITTMAN J.F.T et al. (Eds), "Numerical Analysis of Forming Processes", Wiley. New York, 1984, pp 1-44.
10. Appa Rao, J. Babu Rao, Syed Kamaluddin and NRMR Bhargava, "Studies on cold workability limits of brass using machine vision system and its finite element analysis" Journal of Minerals & Materials Characterization & Engineering, Vol. 10, No.9, 2011, pp.777-803,

11. Syed Kamaluddin, J Babu Rao, MMM Sarcar and NRMR Bhargava, "Studies on Flow Behavior of Aluminum Using Vision System during Cold Upsetting". Met and Mater. Trans. B, 38 B, 2007: pp.681-68

12. J Appa Rao, J Babu Rao, Syed Kamaluddin, MMM Sarcar and NRMR Bhargava "Studies on Cold Workability Limits of Pure Copper using Machine Vision System and its Finite Element Analysis" International Journal of Materials and Design - Vol. 30, 2009, pp. 2143–2151.

13. J Babu Rao, Syed Kamaluddin, J Appa Rao, MMM Sarcar and NRMR Bhargava "Finite Element Analysis of deformation behavior of Al-Cu alloys" – International Journal of Materials and Design" – Vol. 30, 2009, pp. 1298–1309.

14. J Babu Rao, Syed Kamaluddin, J Appa Rao, MMM Sarcar and NRMR Bhargava "Deformation behavior of Al-4Cu-2Mg alloy during cold upset forging" –International Journal of Alloys and Compounds— Vol. 471, 2009, pp. 128-136.