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Evaluation of Mechanical Properties of Al/SiC-Graphite Hybrid Metal Matrix Composites

Yanamandala Raghuram Chowdary[1], C.Yuvaraj[2], K. Prahlada Rao[3], B. Durgaprasad[4]

[1]Research Scholar, JNTUCEA, Anantapuram, AP, India,
E-mail: raghuram.yanamandala@gmail.com
[2]Professor, Madanapalle Institute of Technology & Science, Madanapalle, AP, India
[3]Professor, JNTUCEA, Anantapuram, AP, India
[4]Assoc Professor, JNTUCEA, Anantapuram, AP, India

Abstract *:* The objective of the paper was to study the mechanical properties like Ultimate Tensile Strength and Young's modulus are found for the developed composites of different weight % of Graphite and SiC in Al alloy. The composites were prepared by pressure die casting technique and the specimens were subjected to artificial ageing for 172^0 for 2, 4 and 6 hours. The present work attempts to understand the influence effect of reinforcements on the matrix alloy and artificial ageing process on the Al alloy based hybrid composites compared to as-cast composites. This Paper describes effects of graphite on particles and SiC on the various mechanical properties of Al alloy composites, viz. ultimate tensile strength and Young's modulus. Results showed that ultimate tensile strength and Young's modulus of the hybrid composites increases with increase in the percentage reinforcements. But at higher percentages there is not much significant change in both the cases.

Key words: Aluminium, Graphite, SiC, MMCs, Ageing.

INTRODUCTION

Materials research over the past several decades has produced some advanced materials with properties superior to conventional materials, one of these being Hybrid Metal Matrix Composites (HMCs) which possess high specific strength, toughness, impact strength and low sensitivity to temperature changes. As a result, many of the current applications for HMCs are in aerospace and automobile components, where the service environments are demanding and dynamic loading is common [1]. HMCs typically are made of discontinuous fiber or particle phase that is stiffer and stronger than the continuous matrix phase. The desirable properties of these materials give them many potential applications in area's such as in the automotive, aerospace and sporting goods industries. The costs of manufacture of fiber reinforced MMCs are relatively high, making them uneconomical for the majority of applications. Electric Discharge Machining has proved as an effective machining process of the many non-contact metal removal processes in shaping such difficult-to-machine materials [2,3]. Because the application of EDM to HMCs is relatively new, the associated machine ability aspects have not been studied thoroughly[4].

The minimal presence of porosity at the matrix-reinforcement interfaces, as in the case of composite samples with reinforcement (graphite & SiC), may encourage accelerated aging kinetics through the generation of misfit strains. These strains are a result of a difference in the coefficient of thermal expansion between reinforcement and matrix, the punching of dislocations in matrix, and the subsequent heterogeneous nucleation of the strengthening phases in the matrix[5,6]. The presence of porosity at the reinforcement interface, which was relatively more prominent n the case of composites samples containing higher percentage reinforcements, reduces the misfit strains. This results from the graphite & SiC particulate being able to adjust in the metal-free space (porosity) during quenching, resulting in a lower dislocation density[7]. This reduces the amount of heterogeneous nucleation volume around the particulates and thus retards the rate of precipitation.

EXPERIMENTAL STUDIES

Materials Selection and Composite Preparation

In the present study, pressure die casting technique was adopted to prepare composites and Al-6061, which exhibits excellent casting properties and reasonable strength was selected as the base alloy. This alloy is suitable for mass production of lightweight castings.

Modified pressure die-casting is adopted for preparing Al6061 / SiC & Gr specimens. Liquid metallurgy technique was used to fabricate the hybrid composite materials in which the SiC and graphite particles were introduced into the molten metal pool through a vortex created in the melt by the use of an alumina-coated stainless steel stirrer. The SiC and graphite particles pre-heated to 500 °C were added into the vortex of the liquid melt which was degassed using pure nitrogen for about 3 to 4 min. The resulting mixture was tilt poured into preheated permanent moulds. SiC and graphite particles of diameter 30 µm and 50 µm and reinforcement content of 1 to 5%-SiC & upto 8%-graphite were used for specimen preparation. The specimens subjected to optical micrography were first rough polished with a series of silicon carbide papers of 100, 200, 400, 600, and 1000 grit. Then fine polishing was done using magnesium oxide paste followed by 3µm thick diamond paste on a velvet cloth.

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Etching was done on the samples using Keller's reagent as etchant.

Tensile Test

The ultimate tensile strength and young's modulus were measured using a 10 ton capacity. All tests were conducted in accordance with ASTM standards. Tensile tests were conducted at room temperature using UTM in accordance with ASTM E8-82. The tensile specimens of diameter 6.25 mm and gauge length 76 mm were machined from the cast composites with the gauge length of the specimen parallel to the longitudinal axis of the castings. Five specimens were tested and the average values of the ultimate tensile strength were measured.

RESULTS AND DISCUSSION

ULTIMATE TENSILE STRENGTH

The tensile specimens prepared in accordance with ASTM E8-82 were subjected to homogeneous and uniaxial tensile stresses in an universal testing machine.

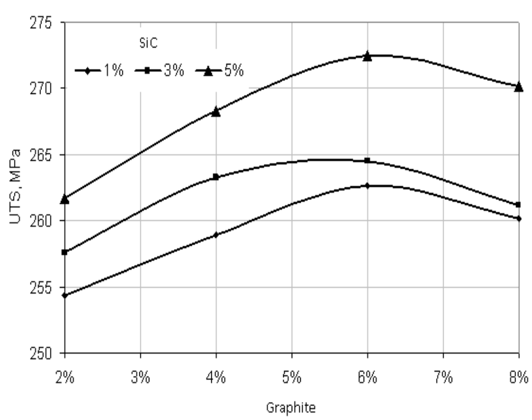

Fig. 1 The effect of graphite and SiC on the UTS of the hybrid composites at Ascast condition

Fig.1 shows the ultimate tensile strength of the composite specimens and of the base alloy, along with standard deviations, plotted against the graphite content and SiC. It follows from the graphs that the specimens show an increase in UTS by about 28% as the content of graphite 8 wt.% and SiC 5 wt.% in the composite is increased in ascast conditions. The 6% of graphite yields best results then it reduced its properties.

Effect of Graphite and SiC on UTS

The factors influencing the UTS are complex and inter-related. Several variables, such as distribution of the particles / in the matrix, the mechanical properties of the matrix and the reinforcing particles, and the bonding between the matrix and the reinforcement, are reported to influence the strength of discontinuously reinforced composites strongly. Also, various strengthening mechanisms have been proposed to explain the improvement in strength in the case of discontinuously reinforced MMCs. They include the classical composite strengthening through the load transfer between the ductile alloy matrix and the hard and brittle ceramic particle reinforcement [8-10].

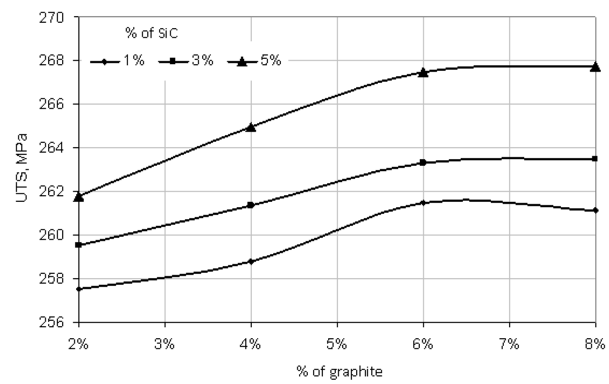

Fig. 2 The effect of graphite and SiC on the UTS of the hybrid composites at 2 hr aged

The graph showing the effect of particulate addition on UTS of the composites is presented in Fig 2, Fig3 and Fig4. It can be seen that the UTS of the composites monotonically increases as the particulate content is increased up to 6 % and decrease at higher percentage. The increase in strength can attributed to the addition of SiC which impart strength to the matrix alloy, there by enhanced resistance to tensile stresses. There is a reduction in the inter–spatial distance between particulates, which cause an increase in the dislocation pile–up as the particulate content is increased. This leads to restriction to plastic flow due to the random distribution of the particulate in the matrix, there by providing enhanced strength to the composites. At higher percentages of reinforcements the decrease in the strength may be due to poor bonding of Graphite particles. Vogelsang et al [96] believe that the improvement in UTS may be due to the matrix strengthening following a reduction in composite grain size and generation of a high dislocation density in the matrix, as a result of the difference in the thermal expansion between the metal matrix and the particulate reinforcement. and Mc Coy et al[97] produced TiB_2 particulate reinforced Al- alloy composite TiB_2 particulate content ranging from by volume and found the same effect..

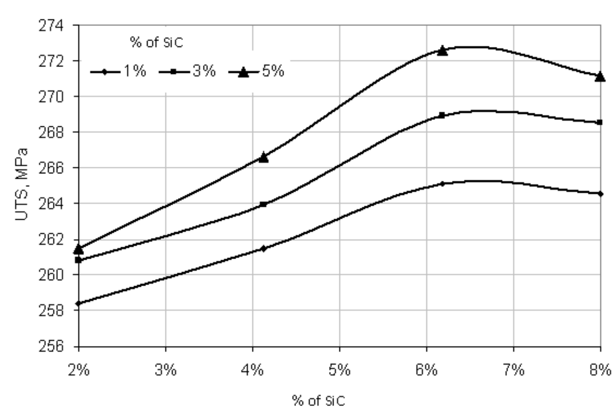

Fig. 3 The effect of graphite and SiC on the UTS of the hybrid composites at 4 hrs aged

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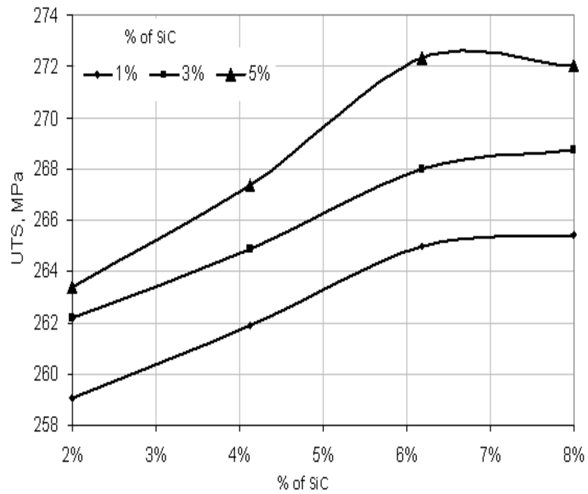

Fig. 4 The effect of graphite and SiC on the UTS of the hybrid composites at 6 hrs aged

YOUNG'S MODULUS

Effect of graphite and SiC on Young's modulus

Fig 5, Fig 6. Fig 7 and Fig 8 presents the Young's modulus of hybrid composites with varying compositions of graphite & SiC s of as cast and heat treated conditions. It may be inferred from the table that as the percentage of graphite particulate increases from 2 to 8 % y weight there is increase of Young's modulus from 75.54 GPa to 79.53 GPa for as-cast condition and up to 80.57 GPa at heat treated condition. It is also observed that the increase in the percentage of SiC s also increased the Young's modulus significantly.

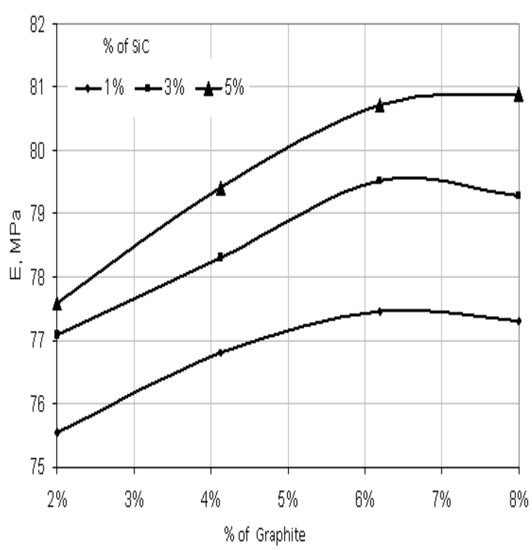

Fig. 5 The effect of graphite and SiC on the Young's modulus (10^3) of the hybrid composites at ascast condition

As the modulus of SiC is high, the presence of SiC would definitely contribute to increasing the Young's modulus. From the Fig. 5.7 it is observed that the Young's modulus of the composite increases with increase in the percentage reinforcements. But at higher percentages there is not much significant change in the modulus of elasticity. The young's modulus of the composite increases monotonically and significantly as the reinforcement content is increased. The increase in young's modulus is broadly inline with rule of mixtures prediction. Mc Danels[98], obtained similar results in particulate reinforced Al- composites and observed an increase in young's modulus with addition of particulate regardless of the type of reinforcement used

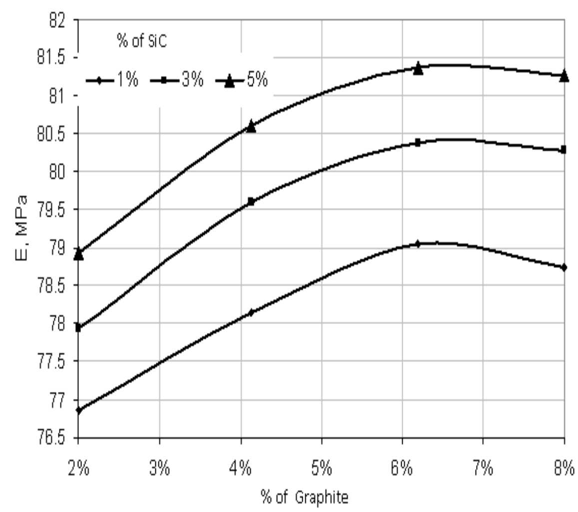

Fig.6 The effect of graphite and the Young's modulus (10^3) of the hybrid composites at 2hrs aged condition

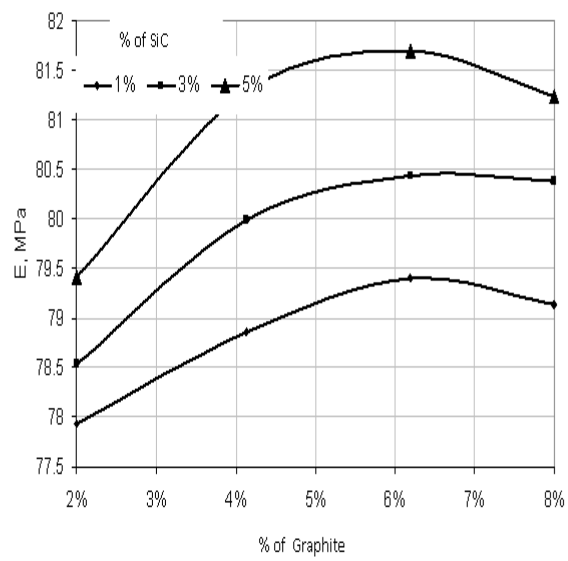

Fig.7 The effect of graphite and SiC on the Young's modulus (10^3) of the hybrid composites at 4hrs aged condition

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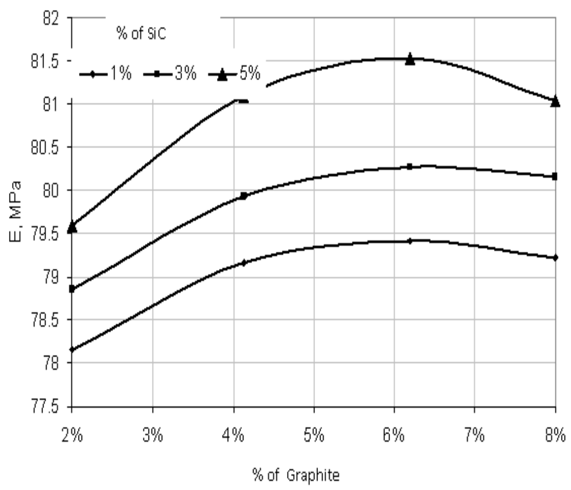

Fig.8 The effect of graphite and SiC on the Young's modulus (10^3) of the hybrid composites at 6hrs aged condition

CONCLUSIONS

From the study it can be concluded that an increase in the percentage of graphite & SiC reinforcements in aluminium alloy increases the ultimate tensile strength and youngs modulus. Further, at higher percentages of graphite & SiC reinforcement content there is not much significant change in both the cases. The presence of graphite & SiC reinforcement content particles in the matrix decelerates the ageing of the matrix in the composites as compared to that of un-reinforced matrix subjected to identical heat treatment procedures. When the composites were under-aged, the aluminium alloy matrix contained coherent and semi-coherent precipitates which had little resistance to plastic deformation and therefore provided the aluminum alloy matrix with relatively high strength. The enhancement in mechanical properties namely ultimate tensile strength and youngs modulus of the composites can be well attributed to the high dislocation density.

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