

Fatigue Behavior of Heat Treated Aluminium Matrix Composites

Ali Afzal¹, Mohammed Naveed²

^{1,2}Department of Mechanical Engineering, Ghousia College of Engineering, Ramnagaram

Abstract: Present work aims at investigating the result of heat treatment and age hardenability on fatigue behavior of aluminum hybrid composite. Aluminum 6061 alloy, aluminium-5wt%silicon carbide composites and aluminium-5wt%silicon carbide-xwt%graphite hybrid composite specimens with graphite varied from 1wt% and 3wt% were fabricated by stir casting method. Microstructure and Fatigue strength studies of aluminium alloy and its composites have been carried out. The fabrication of aluminium silicon carbide graphite & aluminium 6061 alloy was done through vortex stir casting methodology. In this alloy of aluminium it was found through Microstructure studies that the particles of graphite and silicon carbide were present. Microhardness of aluminium-silicon carbide composite was higher than the hybrid composites and base alloy. Heat treatment enhances microhardness of base alloy and its composites with ice quenching resulting in maximum value. Fatigue strength of aluminium-silicon carbide-graphite hybrid composite was higher than aluminium-silicon carbide composites and base alloy. Heat treatment enhances fatigue strength of base alloy and its composites with ice quenching resulting in maximum value.

Keywords: Stir casting, Fractography, Heat treatment, Fatigue behavior

1. Introduction

Alloys and monolithic metals have restrictions in obtaining high-quality combination of high temperature performance, wear resistance, strength, corrosion resistance and toughness. As a result material analysts have redirected their concentration towards composite materials. To obtain an advanced material with sound mechanical and other properties different materials are blend together which are known as constituents to form a material called as composite. These constituents which form the composite are called as reinforcements & matrix [1-3]. The matrix is a smooth phase which has excellent thermal conductivity, ductility and formability and in which the rigid reinforcements are bordered. The reinforcements may be steady or irregular, slanting or mixed-up. Aluminum matrix composites (AMCs) have been preferred for advanced applications in automobiles and also in aerospace. The various properties possessed by this composite to be used in advanced applications are high rigidity modulus, high fatigue resistance, high particulate strength, great wear resistance at high temperatures and great corrosion resistance [4-5]. These composites have the ability to replace the long-established engineering alloys. Al6061 composites give an incredible combination of break tolerance and strength at soaring and cryogenic temperatures. For applications like basic components related to structures and high-quality weldments Al6061 is utilized in light of its age hardenable nature which is suited for high temperature and high quality [6]. This alloy dissipates heat to a great extent. This is because of its high heat conducting property. The Aluminium 6061 mechanical properties greatly depend upon the heat treatment carried on the material. AMC's mixed with graphite and SiC particles are a distinctive group of superior engineered materials that have been produced to make use in tribological applications. From the literature review it has been found that tremendous research has been carried out on study of mechanical properties and properties related to tribology of Al6061-SiC-Gr hybrid composites [7-9]. But less work is carried out on fatigue behavior of these composites

subjected to heat treatment [10].

In light of this fact, the present work describes the fabrication of Al6061 based hybrid matrix composites by stir casting technique. Since the presence of only hard particulate reinforcement in composite leads to poor surface finish and higher tool wear. Therefore composites were prepared with both hard reinforcement (SiC) and soft reinforcement (Gr). Microstructure, Fatigue test with respect to heat treatment along with have been carried out in the present research work.

2. Methodology

Aluminium 6061 alloy is chosen as the base matrix as it is most widely used alloy. Its chemical composition is shown in table 1 and 2. It is more qualified for heat treatment with medium to high quality abilities. Normal properties incorporate medium to high strength, great durability, and great surface complete, superb erosion imperviousness to air conditions, great consumption, great weld capacity great workability and it is additionally generally accessible [26].

Table 1: Base matrix chemical composition

Elements	Fe	Mn	Cr	Si	Cu	Mg	Al
%(Max)	0.7	0.8	0.35	0.8	0.4	1.2	Balance

Table 2: Physical Properties of Al6061

Elongation at Break	12 %
Tensile Strength	276 MPa
UTS	310 MPa
Vickers Hardness Number	107

2.1 Micro Hardness Test

The microhardness (VHN) for Al6061, Al6061+SiC and Al6061+SiC+Gr composites was carried by using Shimadzo microhardness tester. Machine is shown in Figure 1.



Figure 2: Shimadzu micro hardness tester

2.2 Fatigue Test

Fatigue test was conducted on all the composites prepared using fatigue machine. Machine is shown in Figure 2.



Figure 2: Fatigue testing machine

The bending stress of the specimen is calculated as per the formulae listed below.

a. Load on Specimen.

$$F = (2p + 2.5) * 9.81;$$

Where p = load on pan in kg, Tare load on specimen for p =

$$0 \text{ kg, Tare load} = (2 * 0 + 2.5) * 9.81 = 24.52 \text{ N}$$

$$\text{For } p = 1 \text{ kg, } F = (2 * 1 + 2.5) * 9.81 = 44.14 \text{ N}$$

b. Sectional moment of inertia about the bending stress.

$$I_{XX} = I_{YY} = \pi * d^4 / 64.$$

d = Gauge diameter = 6mm

$$I_{XX} = I_{YY} = \pi * 6^4 / 64$$

$$I_{XX} = I_{YY} = 63.61 \text{ mm}^4$$

c. Sectional Modulus

$$Z_{XX} = Z_{YY} = I_{XX} / r = I_{YY} / r \quad \text{mm}^3$$

r = Gauge radius = 3mm

$$Z_{XX} = Z_{YY} = 63.61 / 3 = 21.2 \text{ mm}^3$$

d. Bending Moment

$$M = F * L \quad \text{Nmm}$$

L = 75mm

$$M = 44014 * 75 = 3310.5 \text{ Nmm}$$

e. Bending Stress

$$= M / Z \quad \text{N/mm}^2 \dots \dots$$

$$= 3310.5 / 21.2 = 156.15 \text{ N/mm}^2$$

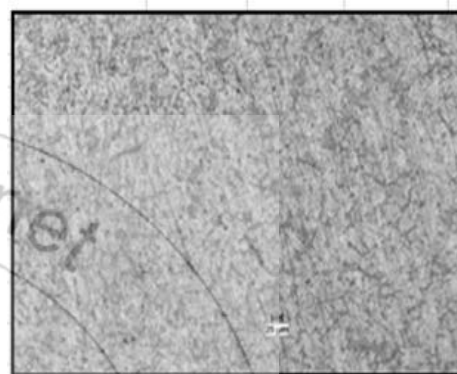
2.3 Heat Treatment

Heat treatment was carried out in an electric resistance furnace. The specimen were heat treated at a temperature of 5500C for a duration of one hour followed by quenching media such as air, water and ice. They were further heat treated at a temperature of 1750C for a duration of 6 hrs followed by air cooling under normal room temperature.

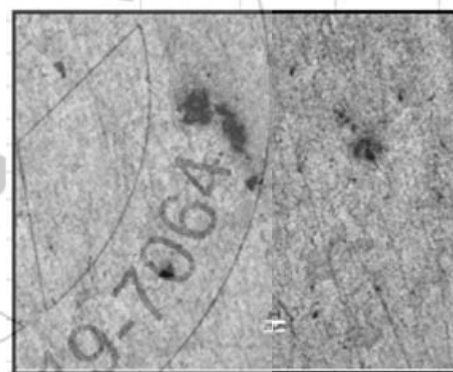
3. Results and Conclusion

3.1 Heat Treatment

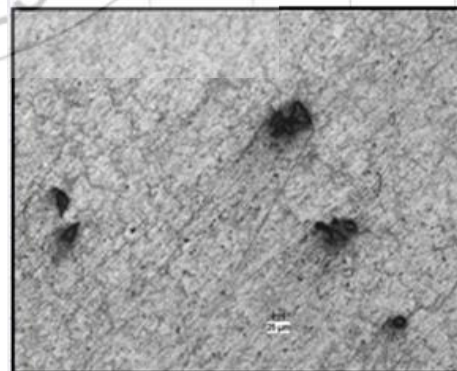
The microstructure of Al6061 and its composites before heat treatment in etched condition is shown in figure 3.



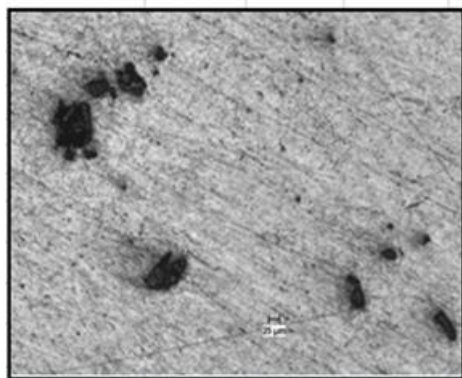
(a)



(b)



(c)



(d)

Figure 3: (a) Al6061 (b) Al6061+5%wt SiC (c) Al6061+5%wtSiC+1%wtGr (d) Al6061 5%wt SiC+3%wtGr

From the figure 3 it is observed that both SiC and Gr are uniformly distributed in the matrix alloy. The level of porosity is also less. There is an excellent bonding of reinforcement with matrix alloy.

3.2 Fatigue Strength

The number of cycles for fatigue failure for this hybrid composite before heat treatment is shown in figure 4.

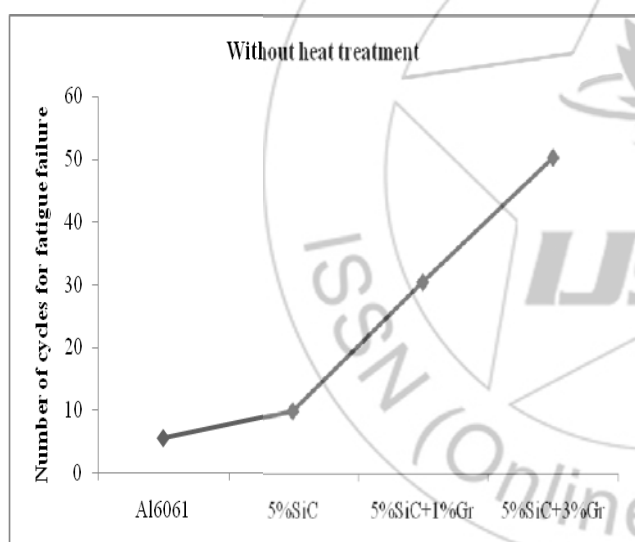


Figure 4: No. of cycles for fatigue failure of Al alloy and its composites before heat treatment

From the figure 4 it is observed that the number of cycles for fatigue failure increases with addition of SiC and Gr. The fatigue behavior of aluminum SiC graphite hybrid composite is superior to its base alloy Al 6061. This may happen due to the adding up of SiC & Gr. It results in better grain structure and higher stiffness of the composites.

The number of cycles for fatigue failure of Al alloy and its composites after heat treatment with air, water and ice quenching is shown in figure 5.

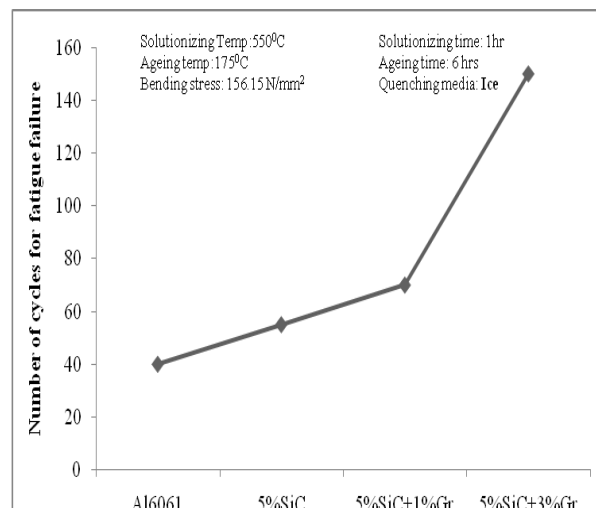


Figure 5: No. of cycles for fatigue failure of Al alloy and its composites after heat treatment

From the figure 5. It is observed that with heat treatment the number of cycles for fatigue failure increases with addition of SiC and Gr in Al alloy. Ageing heat treatment performed at 1750C for 6 hours followed by air, water and ice quenching has a significant influence on improving the fracture toughness of Al-SiC-Gr composites. The precipitation of fine particles results in improving the fatigue behavior of this composite. Considerable changes in microstructure and precipitation of second phase particles attributes to superior fatigue resistance of age heat treated hybrid composite. Fatigue behavior of age heat treated hybrid composite is found to be superior to as-cast hybrid composite. Among all the quenching media ice quenched composites showed better results. Figure 5 shows comparison of number of cycles for fatigue failure of Al alloy & its related composites both before & after heat treatment.

4. Conclusions

- By vortex stir casting method aluminium 6061 alloy, aluminium6061-silicon carbide and aluminium6061-silicon carbide-graphite composites were successfully fabricated.
- Micro structure and XRD studies indicated uniform distribution and occurrence of graphite and silicon carbide particles in the alloy used.
- Aluminium-silicon carbide composite microhardness was higher than the hybrid composites and base alloy.
- Heat treatment enhances microhardness of base alloy and its composites with ice quenching resulting in maximum value.
- Fatigue strength of aluminium-silicon carbide-graphite hybrid composite was higher than aluminium-silicon carbide composites and base alloy.
- Heat treatment enhances fatigue strength of base alloy and its composites with ice quenching resulting in maximum value.

References

- [1] William F Smith, Materials Science and Engineering, Tata McGraw Hill, 4 Edition, 2008.

- [2] Chawla K.K, Composite Materials, Springer-Verlag,, ASTM International Tata McGraw Hill, 4 Edition, 1987
- [3] J.Y Fakrudinali, Noor Ahmed R, K.S Badarinarayan and Abrar Ahamed, A survey on aluminium matrix composites, Indian Journal of Science Research and Technology, Vol 3, Apr 2015, pp 34-42
- [4] Yogesh Sharma, Rajender Singh and Vikas Sharma, Examine of mechanical properties of Al6061/SiC metal matrix composites, International Journal for Research Publication and Seminar, Vol 05, March -July 2014.
- [5] Karl M. Prewo and John J. Brennan, High-strength silicon carbide fibre-reinforced glass-matrix composites, Journal of Materials Science, Vol 15, Feb 1980, pp 463-468.
- [6] M. K. Surappa, Aluminium matrix composites: challenges and opportunities, Sadhana, Vol 28, Feb 2003, pp 319-334
- [7] S C Jirapure and A B Borade, Heat treating of non ferrous alloys, International Journal of Engineering Research and General Science, Vol 2, August – September 2014, pp 84-88
- [8] Ramakrishna Hegde , B S Ajaykumar, L J Kirthan and V A Girish, Influence of heat treatment on fatigue behavior of aluminum silicon carbide graphite hybrid composite,
- [9] International Journal of Applied Engineering Research, Vol 11, 2016, pp 4179-4183
- [10] Gowri Shankar M.C, Jayashree P.K, Raviraj Shetty, Achutha Kini and Sharma S.S, Individual and combined effect of reinforcements on stir cast aluminium metal matrix composites-a review, International Journal of Current Engineering and Technology, Vol 3, Aug 2013, pp 922-934.
- [11] T V Christy, N Murugan and S Kumar, A comparative study on the microstructures and mechanical properties of al 6061 alloy and the mmc Al 6061 / TiB₂ / 12 p, Journal of Minerals & Materials Characterization & Engineering, Vol 9. 2015, pp 57-65

Author Profile



Ali Afzal, a post graduate student at Ghousia College of Engineering.