Fatigue behaviour of aluminium reinforced metal matrix hybrid composites (AA 6061 + Mg + TiO_2 + SiC)

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Abstract: This paper researched the metal matrix composites (MMCs) and this system used to produce good strength of the aluminium 6061 with fortified with SiC, TiO_2, and magnesium (Mg). That approach to describe the new composites utilising the scanning electron microscope (SEM) and malleable ductile weariness test have analysed. The hybrid composites have increased the strength for a contribution of reinforced particles. The fatigue behaviour of developed composites has analysed at the room temperature for the low cycle fatigue. The working conditions pursued by the low cycle weariness recurrence level 1 to 25 HZ. The diminishing existence of the metal framework in view of the LCF strain sufficiency for the room and hoisted temperature 3,000 C and R = (εmin/εmax) = 0. The experiments deliberate with continuous amplitude for a prearranged strain of amplitude. The disfigured assessment of weariness standard and thoroughly considered the mean pressure an incentive as far as weakness life acquired in the test results.

Keywords: fatigue life; metal matrix composites; MMCs; aluminium; reinforcement.

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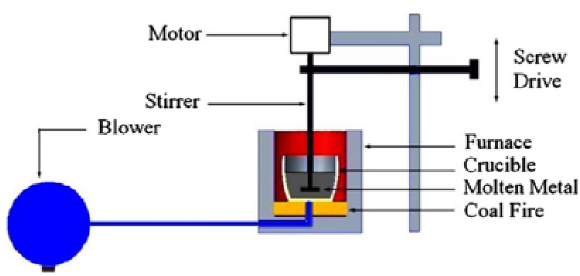
1 Introduction

Metal matrix composites (MMCs) mostly used in wide range of industrial applications. Following industries are used automobile, aerospace and shipbuilding by reason of aluminium having good wear resistance, low thermal expansion, high fatigue strength (Hall et al., 1994; Chawla and Allison, 2001; Chawla et al., 1998; Llorca, 2002), high stiffness (Ceschini et al., 2003, 2006) and good thermal stability. Late inquiries about upgraded better difficulties of enhancing mechanical properties and microstructure contrasted with the fatigue mechanism. Particularly ceramic reinforced metal matrix is a real challenge to the aerospace industry. The aluminium and TiO_2-based composite is a created the futuristic materials. Most of the powder metallurgy route was followed by creating new composite materials. It improved the great molecule circulation having less time of assembling and great exhaustion properties. Chawla et al. (2000) has reported mechanical and microstructure behaviour reinforced composite materials. The particle distribution is highly refined and predicts the good fatigue resistance. However decrease the particle shape and size to increase the fatigue strength by volume fraction method (Romanova et al., 2009; Zhang and Li, 2010). This article fortification of earthenware strengthened molecule dividing to expanded the break quality conduct. This process of interface particle to obtained the highest strength (Xue et al., 2002; Köhler et al., 2015). A combination of Al-SiC having good wear resistance for the character depending upon the percentage of matrix reinforcement (Hall et al., 1994). It can be develop the relation between the soft and hard particles. The matrix should contain the hard ceramic particles refined by the temperature and predict the good toughness and high yield strength (Nieh et al., 1995; Koh et al., 1999; Tjong, 2014).

Figure 1 Stir casting method of MMC (see online version for colours)



Aluminium is a lightweight metal, even though reinforcement of composite particles could affect the fractured toughness. However the material will behave cyclic deformation of first crack initiated by the plastic flow character. These are the important factors for low cycle and high cycle fatigue test. Hall, et al has reported the various process of stress controlling fatigue behaviour of Al reinforced SiC particles, volume fraction, particle size and effect of matrix reinforcements. However, improved the strength and fatigue life as decreasing particle size by the powder metallurgy route. The fracture crack propagation initiated by various frequencies based on the effect of particle shape and volume fraction, stress intensity. Aluminium reinforced composites of volume fraction 25% Sic to improve the fatigue behaviour in room temperature at 300ºC (Alaneme and Bodunrin, 2013). Koh et al. (1999) investigated low cycle behaviour reinforced Al with Sic particle to meet the more strain hardening by the various conditions (Oghenevweta et al., 2014; Lu and Hirohashi, 2001). This article has compared with strain hardening of unreinforced material to reinforced composites consist of more strain hardening. Some of the research paper consisted reinforcement of 5%, 10% and 15% of SiC to AA6061 found low strain amplitude during cyclic loading conditions (Fresques et al., 2015; Park et al., 2008). Similarly for used high strain amplitude in the unreinforced composite materials (Dobrzanski et al., 2007). Llorca (2002) has reported low cycle fatigue behaviour to enhanced amount of reinforcement material 0%, 3%, 6% and 9% SiC to aluminium, where the volume fraction of monolithic deformation relatively affected by the cyclic deformation (Kulu et al., 2007; Dinesh et al., 2016).

Although previous aluminium reinforced particles studies are discussed about the physical and mechanical properties of MMCs. In this examination to make new half breed composite materials of a system as mixing powder metallurgy course has considered (Kumar and Menghani, 2016). For this compose producing a composites to discover the porosity and other surface components, contrasted and the past scientist aluminium strengthened composites. And furthermore elastic and weakness conduct clarified the above blends of MMCs. Previous researches of particle size 5 µm were examined the particle distribution and microstructure properties. This study various percentage ratio of reinforced SiC, Mg for the effect of particle distribution and fatigue behaviour was discussed.

2 Materials and experimental procedure

Aluminium 6061 reinforced metal matrix composites (AMMCs) made of powder metallurgy technique. In this method aluminium heated in the furnace at 700ºC for a liquid form (Butt et al., 2015). Further improved the wettability and strength by adding two more matrixes such as SiC, Mg and TiO_2. It will be the normal molecule estimate 20 µm–150 µm and volume content strengthened with 10%, 15% and 20%. Tensile test were conducted by the universal testing machine (UTM). The tensile specimen has prepared along with the ASTME466 standards. It consists of various properties such as a lowest and highest yield point, greatest strength, and elongation. The tensile results have used for fatigue experiments. The cross sectional area has the gauge length 32 mm and thickness 6 mm used. The tensile strength analysed the before and after the fractured specimen. Three specimens tested for each combination of the metal composites Materials. Totally 20 specimens prepared for the fatigue test from the casting metal plates. The specimens have polished using silicon carbide paper. Specimen over a load of 50 KN to 100 KN has tested by the servo-hydraulic testing machine. This fatigue test consists of frequency and constant amplitude can apply to the machine. There is different stress levels applied for each combination of three specimens. The stress value has 100, 150, 200 MPa, tested up to the 108 cycles. Low cycle weariness test have the pressure proportion as 0.1 connected on the examples. The trial natural will kept up at room temperature for the pivotal malleable tractable hub stacking conditions. Using varies sinusoidal form the different amplitude for fractured surface has monitored. A UTM is used to measure the tensile and compressive strength of the material. It absorbs the energy and fractured without rupturing. In repeated cyclic loading conditions exceed the limits load cell will be introduced for achieving a high value of life. Load cell reduce the output signal put to 50%.

Figure 2 Tensile specimen

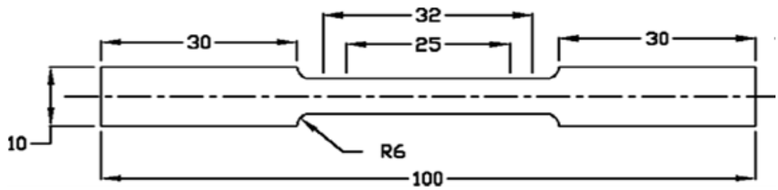


Table 1 Chemical composition of composite materials

Element	*Mg*	*Mn*	*Zn*	*Fe*	*Cu*	*Si*	*Cr*	*Al*
AA6061-T6	0.84	0.01	0.06	0.40	0.24	0.54	0.18	bal
Mg	bal	0.13	0.22	0.005	0.35	0.50	0.003	5.5–6.5

Table 2 Mechanical properties of aluminium alloys

Element	*Yield strength* (*MPa*)	*Tensile strength* (*MPa*)	*Elongation* (*%*)
AA6061-T6	276	310	17
Mg	130	220	6

Table 3 Percentage of material reinforcement

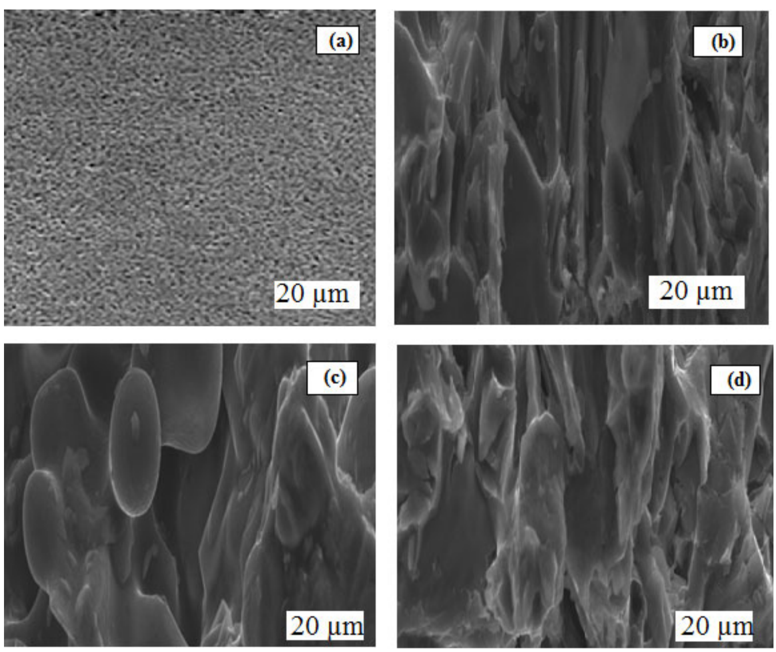
Pure Al 6061.
• Al6061 + 3% Mg + 3% TiO_2 + 4% SiC
• Al6061 + 3% Mg + 3% TiO_2 + 9% SiC
• Al6061 + 3% Mg + 3% TiO_2 + 14% SiC

3 Result and discussion

The investigation of SiC, TiO_2 and Mg strengthened with aluminium metal grid composites has watched the reactions from the tensile and fatigue tests. The microstructural studies have explained the behaviour of hybrid composites materials. The Mg reinforced with the aluminium MMCs. The surface analysis of SEM images as shown in Figure 3. SiC and Mg particles having good brittle nature (Hvizdoš et al., 2015). Using chemical etchant of polished surfaces to shows a particle size for containing composite materials. From the SEM examination extraordinarily watched the scattered alloying network, surface porosity and shrinkage of the new composite materials. For little amount of defects has observed due to the poor solidification process. And decreased a particle sizes in reinforcement the metal matrix to offer a good bonding strength. During the stirring process value is an important for material deposition in MMCs. This investigation of particle distribution and wettability both are improve the solidification process. The precipitated and dispersed matrix has studied with high magnification factor in Figure 3.

From Figure 4 shows the tensile and breaking load of the all combinations of MMCs. The experimental results show, tensile and fatigue behaviour of Sic, particulate reinforcement on aluminium MMCs. The tensile and greatest strength have observed from the experimental testing's carried out by the UTM. The specimens have ready according to the ASTME466 standards. The SEM observation of 4%, 9% and 14% of SiC particle reinforced aluminium MMCs. However the volume fraction has increased and not changed in clustered particles due increasing SiC content. Slightly by adding Mg it will vary with the clustering particles. This relationship of the clustering particles to create a good bonding agreement. These stages of formation of particle enhanced with the Al_4C_3, Al_4SiC_4, and $CuAl_2O_4$ and intermediate faces (Nandi and Datta, 2011). The magnesium is supplementary to encourage the wetting among Al matrix and reinforced SiC.

Figure 3 (a) Pure aluminium (b) AA 6061 + 10% SiC (c) AA 6061 + 15% SiC (d) AA 6061 + 20% SiC



The tensile graph clearly shows the effect of reinforcement with SiC, Mg, and TiO_2 particle distributions. The stress, strain and last breaking load 30%, 50% and 80% will be greater than that of pure aluminium alloy. Tensile strength increased nearly 56% than pure aluminium 6061 MMCs. The largest breaking load 6.87 and Al 6061 consist of 2.485 KN comparatively 6% percentage efficiency for the composite materials. From the experimental results clearly observing hybrid composites and it will increase the fatigue life of the MMCs.

Figure 4 Reinforcement vs. stress

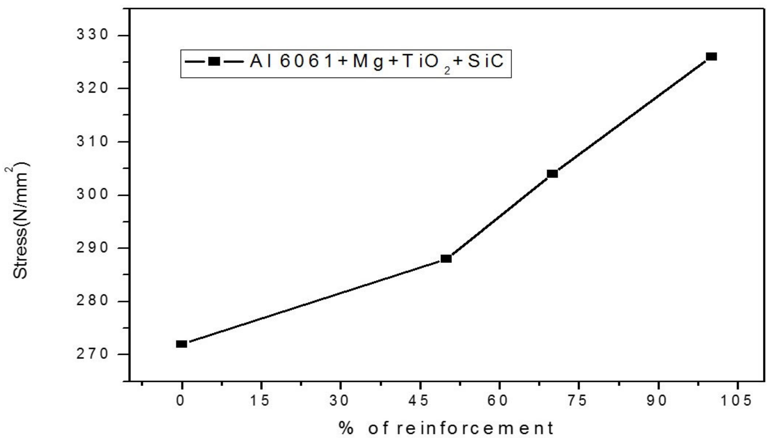


Figure 5 Reinforcement vs. strain

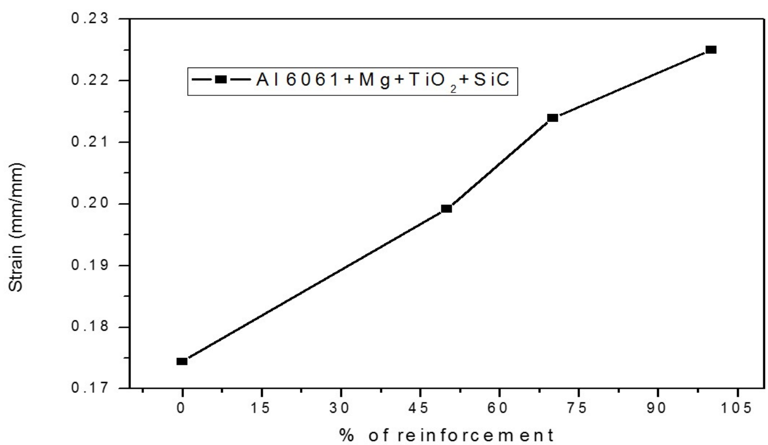


Figure 6 Strain vs. stress (see online version for colours)

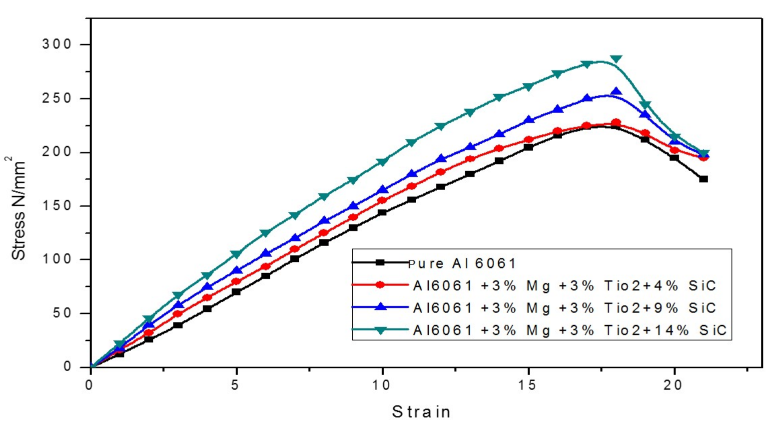
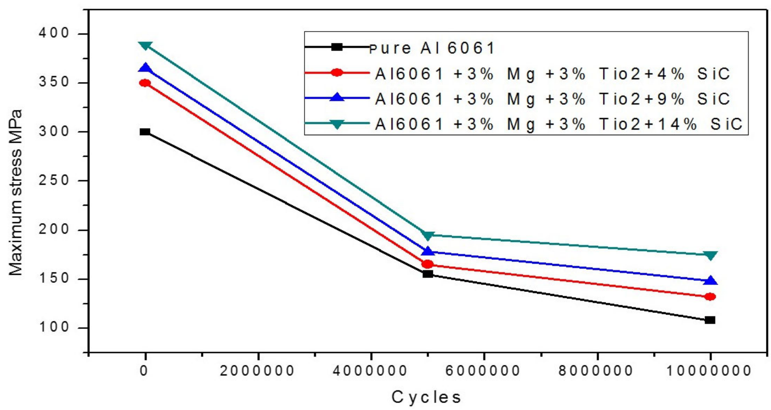


Figure 6 shows the effect of reinforcement hybrid composites in the stress-strain (Srivatsan and Mattingly, 1993) curve. The fourth blend Al6061 +3% Mg + 3% TiO_2 + 14% SiC has acquired the most astounding mechanical quality as 380 MPa thought about without fortified material.

The load applied gradually on the tensile specimen, it will elongated over the gauge length after fracture measured. The large particle strengthening method is used. These strategies demonstrate the collaboration between the phase and matrix. Since of particulate phase is stiffer than matrix phase. It will restrain the movement of matrix phase locality to the all particle. The matrix conveys to the hard phase several applied stress formed. The matrix conveys to the hard phase several applied stress formed. The hard phase and matrix achieved the strong bonded strength for the quantity of reinforcement. The intermixing bonds improve the mechanical strength of the MMCs.

Figure 7 Fatigue life (see online version for colours)



From the experimental observation the SiC and Mg content of high volume fractional MMCs fatigue life can increased. The fatigue behaviour of S-N curve shows in Figure 7. Anyway the exhaustion quality and weariness life expanded for support of SiC, Mg and TiO_2 contrasted and unreinforced metal framework composites. Stress level could be determined by the literature surveys and tensile test done by the UTM. According to the test result helps to plot the S-N curve of the MMCs. The low cycle fatigue behaviour carried out in room temperature with various stress controlled factors. The controlled factors transferring load as stifferred to the material. The fatigue strength over a cycle decreased the stain value for the little amount of volume fractions. Pure aluminium alloy fatigue strength obtained value 96 MPa at 5×10^6 cycles.

4 Conclusions

The tensile and fatigue behaviour of aluminium MMCs have been investigated with the reinforcement material SiC, Mg, TiO_2. This examination anticipated the elastic and weakness quality of the strengthened aluminium MMCs of different cyclic stacking condition. Predictable material appropriation utilising powder metallurgy course has examined and it can stay away from the surface porosity, non-uniform dissemination, and furrowing absconds. Wherever minimising process characteristic, easily solidified and settling time decreased. The microstructure analysis inspected uniform conveyance of particles. Therefore SiC and Mg content increased density and mechanical strength of the MMCs. Added Mg to creating good interparticle bonding strength and increased wettability for the MMC'S. Shape the ductile examination, impact of different fortification substance the weak nature will happened and bring down strain in 130% of SiC contrasted and the unadulterated aluminium combination. The malleable outcomes have 326 MPa demonstrated the stretching straightly and the new composites got quality more than the pure aluminium compounds. During the test fatigue fracture has observed for the pure aluminium alloy and by adding SiC particle to increase the fatigue strength of 380 MPa. Low cycle fatigue behaviour maintained at 300ºC room temperature and the deformation consequent of total plastic strain involved in the tension that proficient in its place of the plastic strain.

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