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Characterization of mechanical properties of aluminium/tungsten carbide composites

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ABSTRACT

This study deals with the investigation on mechanical properties of aluminium alloy (AA 6082) composites reinforced with tungsten carbide particles. Stir casting process was employed to fabricate the aluminium composite specimen by varying tungsten carbide in 2, 4, 6, 8 and 10% by weight. The composites were exposed to density, hardness, tensile and impact studies. Scanning electron microscope was used to investigate the mechanism of the fractured tensile and impact test specimen. The density, impact strength and elongation of the composites decreased with increase in addition of tungsten carbide, while the hardness of composites increased with increase in tungsten carbide. The tensile strength of the composites increased initially and then tends to decrease. Fracture of the composites is characterized by dimples, voids, cracks, ridges, pits and particle fracture. Brittle fracture of composites in the form of cracks and particle fracture are due to the strong interfacial bonding between the tungsten carbide and aluminium matrix at high strain rate. High impact strength of composites are due to ductile failure in the form of dimples, while low impact strength are due to brittle and plastic deformation characterized by micro and macro cracks, particle fracture.

1. Introduction

Metallic Matrix Composites (MMCs) reinforced with ceramic particles very encouraging materials for marine, defense, aerospace and automotive applications that require stronger, light weight and less expensive materials. Aluminium matrix composites owning excellent properties like high stiffness, high strength, high fatigue resistance, low density and superior wear resistance at elevated temperature is a challenging replacement for conventional alloys. Selection of appropriate reinforcement particles and fabrication process with a control over processing conditions improves the mechanical properties of composites. Doel et al. [1] revealed that the tensile and fracture toughness of aluminium/SiC composites fabricated by co-spray deposition process differs with the ageing conditions and inter particle spacing. Composites reinforced with fine particulates showed better yield strength, fracture stress and ductility compared to those of composites reinforced with coarse particulate. Velasco et al. [2] fabricated aluminium/Fe_3Al particles by powder metallurgy technique and reported that the composites exhibited better tensile strength than the conventionally forged components. Peng et al. [3] fabricated aluminium matrix composites by squeeze casting and observed that the composites reinforced with alumina in the form of perform exhibited higher tensile strength compared to that of the alumina fiber reinforced composites. Kok [4] employed vortex method and subsequently applied pressure to fabricate composites and revealed that coarser Al_2O_3 particles dispersed uniformly in aluminium matrix, while agglomeration and porosity were observed in composites with finer Al_2O_3 particles. In situ mechanical properties of Al–Lithium alloy reinforced with SiC particles studied by Rodriguez et al. [5] exposed that hardness of the composites was higher than that of the base alloy and decreases with increase in distance from the reinforcement particle. Hamouda et al. [6] worked on processing aluminium/quartz/silicon dioxide composites by sand mould technique and suggested that decrease in tensile strength and young's modulus of composites are due to increase in silicon dioxide content and the quartz particulate having high compressive strength. Yadav et al. [7] embedded nickel particles into Al matrix by friction stir processing and reported that the composite exhibited significant improvement in tensile strength with an appreciable retention in ductility.

Anilkumar et al. [8] processed aluminium/fly ash composites by stir casting process and reported that increase in reinforcement particle size decreased the strength, hardness and ductility of

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composites. Wichianrat et al. [9] developed aluminium/SiC composites and observed that the impact strength and micro hardness of composites increased due to the modification in microstructure at the residing node and struts of the ceramic particles. Rajmohan et al. [10] reported that the density of aluminium composites reinforced with mica was higher than those of the composites reinforced with SiC fabricated by stir casting process. Aruria et al. [11] fabricated aluminium, SiC and Al_2O_3 particles by friction stir processing and reported that increase in micro hardness of composites is due to the pining effect of SiC and Al_2O_3 particles. Kumar et al. [12] reported that the tensile surface of aluminium was branded by uneven distribution of dimples leading to ductile failure, while aluminium fly ash composites fabricated by stir cast route is characterized by brittle failure due to the plastic flow of the matrix. Sivaprasad et al. [13] worked on stir cast rice husk ash and SiC particles reinforced composites and reported that the density, coefficient of thermal expansion of hybrid composites decreased, while the yield strength, ultimate tensile strength, porosity and hardness increased in composites. Vijaya Ramnath et al. [14] observed that the impact strength and hardness of unreinforced aluminium was less than that of the alumina/boron carbide reinforced composite. Das et al. [15] reported that the impact strength of aluminium matrix composites increased due to ageing and the mechanical failures are due to the initiation and growth of micro cracks, particle pull-out and particle fracture. According to Amirkhanlou et al. [16] the tensile strength of composites increased with increase in number of continual annealing and press-bonding process cycles. Bodunrin et al. [17] reported that boron carbide, alumina, silicon carbide, graphite and carbon nano tubes can be used as reinforcement particles in aluminium composites. Ghasali et al. [18] fabricated Al/boron carbide composites using a microwave furnace for sintering and reported that the hardness and strength of composites increased with increase in addition of boron carbide. Sharma et al. [19] found that addition of 12% of graphite decreased the hardness of the aluminium alloy by 11.1% and revealed a non-uniform distribution of graphite particles. Rana et al. [20] recorded that aluminium composites reinforced with SiC, Al_2O_3, fabricated by ultrasonic assisted stir casting decreased the porosity of composites leading to higher tensile strength, compression strength, hardness and elastic modulus of the composites was Alaneme and Sanusi [21] worked on alumina, rice husk ash and graphite based aluminium matrix hybrid composites and observed that the % elongation of composites decreased in the range of 10–13%. Kursun et al. [22] reinforced glass bubbles with aluminium–alumina matrix composites and reported that the addition of glass bubbles decreased the density, plastic deformation, impact strength and compression strength of the composites.

Rashad et al. [23] attributed that increase in strength of aluminium/graphene nano platelets composites is due to the change in load transfer mechanism, crystallographic texture and dislocation densities between the aluminium alloy and the platelets. Singh and Chauhan [24] observed that fly ash, SiC aluminium alloy were not uniformly distributed in aluminium composites due to the gravity regulated segregation of particles in the melt. Tamilarasan et al. [25] investigated the mechanical properties of carbon fiber reinforced aluminium sandwich laminates and observed pit formation, fuzziness, debonding and fiber fracture on the surface. Radhika and Raghu [26] recorded that the functionally graded aluminium composites reinforced with SiC, Al_2O_3 and Al/TiB_2 exhibited higher hardness and tensile strength at the particle-rich outer region of the specimen.

Harichandran and Selvakumar [27] added micro and nano B_4C carbide particles to aluminium matrix by stir and ultrasonic cavitation assisted casting processes and reported that the nano composites exhibited better tensile stress, ductility and impact energy compared to that of micro B_4C particle-reinforced composites. Jiang et al. [28] fabricated aluminium/iron bimetallic composites by hot-dip galvanizing and aluminizing method and observed uniform and compact intermetallic layer between the aluminium and the iron.

From the literature review, it is implicit that works were carried to study the mechanical properties of various metal matrix composites fabricated by different liquid and solid state techniques. Aluminium alloy (AA 6082), a medium strength alloy having outstanding corrosion resistance and good machinability replaces other similar kind of alloys in engineering applications. Presence of large amount of manganese in AA6082 alloys control the grain structure making it a very strong competent even at elevated temperatures. Studies revealed that adequate investigations were not carried out using Tungsten Carbide (WC) as a potential reinforcement in aluminium matrix composites. Tungsten carbide owing to its high hardness, low density, high strength, high rigidity, good chemical stability and better resistance at high temperature is one of the most promising ceramic materials. An attempt has been made in this study to explore the mechanical properties like hardness, density, tensile strength, impact strength, elongation and the related mechanisms of aluminium (AA6082)/tungsten carbide composites. Stir casting is one of the low cost processes employed in the present study for manufacturing the composites.

2. Materials preparation

In this work, aluminium alloy (AA6082), shown in Table 1 in the form of rod of 100 mm diameter and 300 mm length is used as base material, while tungsten carbide with particle size in the range of (53–75) μm is used as reinforcement. The properties of AA6082aluminium alloy is shown in Table 2. The density of the tungsten carbide and AA6082 aluminium alloy is 2.05 g/cm^3 and 2.69 g/cm^3 respectively. Composite samples were prepared by varying tungsten carbide in 2, 4, 6, 8 and 10% by weight. Stir casting process is one among the highly productive, low cost manufacturing techniques used to fabricate aluminium matrix composites for a wide range of processing conditions [24]. Aluminium metal matrix is melted in a graphite crucible at 850 °C by stir casting process as shown in Fig. 1. Simultaneously the tungsten carbide parti-

Table 2
Properties of AA6082 aluminium alloy.

Sl. no.	Properties	
1	Density	2.71 g/cm^3 (Max)
2	Young's modulus	71 GPa (Max)
3	Ultimate tensile strength	140–330 MPa
4	Yield strength	90–280 MPa
5	Thermal expansion	23.1 μm/m K (Max)
6	Proof stress	85 MPa (Max)
7	Tensile strength	150 MPa (Max)

Table 1
Composition of aluminium 6082 alloy.

Weight %	Al	Si	Fe	Cu	Mn	Cr	Mg	Zn	Ti	Others
6082	Bal	1.12	0.19	0.02	0.87	0.15	0.92	0.17	0.086	0.075