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Evaluation of mechanical and wear properties of hybrid aluminium matrix composites

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Abstract: Hybrid metal matrix composites are important class of engineering materials used in automotive, aerospace and other applications because of their lower density, higher specific strength, and better physical and mechanical properties compared to pure aluminium. The mechanical and wear properties of hybrid aluminium metal matrix composites were investigated. Mica and SiC ceramic particles were incorporated into Al 356 alloy by stir-casting route. Microstructures of the samples were studied using scanning electron microscope (SEM). The chemical composition was investigated through energy dispersive X-ray (EDX) detector. The results indicate that the better strength and hardness are achieved with Al/10SiC−3mica composites. The increase in mass fraction of mica improves the wear loss of the composites.

Key words: hybrid metal matrix composites; SiC; mica; Al 356; stir casting; wear loss

1 Introduction

The increased demand of light weight materials with high specific strength in the aerospace and automotive industries has led to the development and use of Al alloy-based composites (mainly Al alloy/SiC composites). The metal matrix composites (MMCs) are slowly replacing the general light metal alloys such as aluminium alloy in different industrial applications where strength, low mass and energy savings are the most important criteria. The combination of various properties like electrical, mechanical, and even chemical can be achieved by the use of different types of reinforcements, i.e., continuous, discontinuous, short, whiskers, etc., with the MMCs [1]. The MMCs are attractive materials for use in structural applications because they combine favourable mechanical properties, good wear resistance, and low thermal expansion [2]. Particle-reinforced metal matrix composites (PMMCs) are very promising heterogeneous materials for structural applications due to their isotropic material properties, low cost, and ability to be formed using conventional metal forming processes such as rolling, forging, and extrusion to produce the finished products. However, the indentation characteristics of heterogeneous material systems in various forms of composites, precipitation-hardened alloys, and dispersion-strengthened alloys are not known well. Their macroscopic indentation responses are affected by the mechanical properties of the matrix material and reinforcement as well as the type, shape, dimension, geometric arrangement, and volume fraction of the reinforcement [3]. Particulate-reinforced metal matrix composites have paved a new path to produce high strength and high wear-resistant materials by introducing hard ceramic particles and solid lubricant in the metal matrix [4]. Addition of ceramic reinforcements such as SiC, Al_2O_3, TiC, B_4C, and ZrO_2 to metal matrix improves hardness and thermal shock resistance [5].

Hybrid metal matrix composites (HMMCs) are second-generation composites where more than one type, shape, and sizes of reinforcements are used to obtain better properties [6]. Hybrid composites possess better properties compared with single reinforced composites as they combine the advantages of their constituent

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reinforcements [7]. PRASAD and ASTHANA [8] reported that reinforcement of aluminium alloys with graphite solid lubricants and hard ceramic particles were used in automotive applications. DEONATH and ROHATGI [9] revealed that cast aluminium−mica particulate composites and copper-coated ground mica particles have enough strength and they are used as bearings in several applications.

JHA et al [10] reported that the addition of talc particles in the composite improves the wear resistance in the range of 22%−30% compared with the matrix alloy. RAJMOHAN and PALANIKUMAR [11,12] found that hybrid aluminium/ceramic–mica composites showed better machinability in terms of reduced thrust force, tool wear and burr height compared with aluminium/ceramic composites. 10% (volume fraction) SiC_p/Al−Mg composites with different Mg contents were successfully fabricated by semi-solid mechanical stirring technique under optimum processing conditions. The effects of Mg content on microstructure and mechanical properties were studied by scanning electron microscopy (SEM), X-ray diffractometry (XRD) and transmission electron microscopy [13]. It was found that the wear rate of 11% SiC MMC is higher on SiC abrasives compared with the 50% SiC MMC due to wear of the aluminium matrix. This trend is reversed on diamond abrasives due to pulling-out of the irregular shaped composite particles [14]. The yield strength and tensile strength increase, but the elongation decreases with the increase in the volume fraction of the SiC particles [15]. The addition of SiC particles in the form of composite powders by casting in semi-solid state decreases the SiC_p particle size, enhances the wettability between the molten matrix alloy and the reinforcements and improves the distribution of the reinforcement particles in the solidified matrix. It also increases the hardness and the impact energy of the composites and decreases their porosity [16]. The squeeze cast Al/SiC composite materials find enormous applications in industry. Al_2O_3 fiber (Al_2O_{3f}) and SiC particle (SiC_p) hybrid metal matrix composites (MMCs) are fabricated by squeeze casting method [17]. The homogeneity of reinforcement and tensile properties increase with decreasing the stirring temperature and increasing the stirring time [18]. The hybrid SiC foam−SiC particles/Al double interpenetrating composites used as the brake materials of high-speed train were fabricated by squeeze casting technique [19].

The review of literature left the scope for the researcher to study the mechanical properties and wear loss of ceramic–mica reinforced hybrid composites. Moreover, adequate investigations have not been carried out to find the mechanical properties of hybrid Al/SiC−mica composites. In this study, SiC reinforcement is added to the Al356/mica composite to form stronger hybrid Al/SiC−mica composites. The mechanical and wear properties of Al356/SiC−mica composites are studied and presented in detail.

2 Experimental

2.1 Materials

Aluminium alloy, Al 356, was used as a matrix material and its chemical composition is presented in Table 1. The mechanical properties of Al 356 alloy is presented in Table 2. The silicon carbide particles with size of 25 μm and mica with average size of 45 μm were used as the reinforcement materials. The chemical composition of mica is presented in Table 3. The composites were fabricated with the mica particles of 0−6% in mass fraction in step of 3% and a fixed quantity of 10% of SiC.

The composites were fabricated by stir casting method to ensure uniform distribution of the reinforcements. The Al 356 alloy, which was in the form of ingot, was cut into small pieces to accommodate in the silica crucible. The mica for the study was procured from

Table 1 Composition of Al 356 alloy (mass fraction, %)

Cu	Si	Mg	Mn	Fe	Ti	Zn	Al
<0.0005	7.27	0.45	<0.002	0.12	0.08	0.005	Bal.

Table 2 Mechanical properties of Al 356 alloy

Density/ ($g\cdot cm^{-3}$)	Ultimate tensile strength/MPa	Yield tensile strength/MPa	Elongation/ %	Modulus of elasticity/GPa	Poisson ratio
2.67	234	165	3.5	72.4	0.33

Table 3 Chemical composition of mica (mass fraction, %)

SiO_2	Al_2O_3	K_2O	Fe_2O_3	Na_2O	TiO_2	CaO	MgO
45.57	33.10	9.87	2.48	0.62	Traces	0.21	0.38