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Impact of TiB_2 Content and Sliding Velocity on Wear Performance of Aluminium Matrix Composites

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Particulates dispersed aluminium matrix composites are the major substitute for variety of application at present scenario due to its massive strength, ductile nature and great thermal conductivity. In this work, TiB_2 micro-sized particulates dispersed aluminium matrix composites prepared with different weight percentages of TiB_2 particles by using liquid state stir casting process. Present investigation influence the impact of TiB_2 particles content (0, 3, 6 and 9 wt.%) and variation of sliding velocity (0.5, 1, 1.5 and 2 m/s) for a constant load 20N and sliding distance 1000 m on the wear performance of composite rubbing against EN31 steel disc. Wear analysis revealed that TiB_2 content enhanced wear rate and reverse trend noticed in case of coefficient of friction. Similarly, wear rate deteriorated and enhanced COF as increasing sliding speed of counter plate rotation.

Keywords: Liquid state stir casting, Micro-sized, Sliding velocity, Wear rate

Introduction

Aluminium metal matrix composites (AMMC) significantly developed its research application phenomenally in last decades recorded by earlier researchers and scientists because of its higher thermal conductivity and great specific strength compared to previous conventional materials.[1,2] MMC prepared by metals plays as matrix and fibers, whiskers or particles plays as dispersive agents. Mixing of matrix material and dispersive agents and instructing proper fabrication process make some better combination of properties in composite such as higher strength, temperature resisting capacity and wear resisting strength etc.[3] In MMC, density deviation in between matrix and reinforcement impact vitally to make a functionally graded material.[4] According to earlier research survey, it is observed that to make better quality aluminium matrix composites, it is required to mix some potential ceramic reinforcement agents like SiC, TiB_2, Al_2O_3, TiC, ZrB_2 and so on.[5,6] Titanium diboride (TiB_2) dispersed aluminium matrix composites acquired some unique properties like stiffness capacity, elasticity, low wear rate and higher thermal conductivity acted as an embryonic materials that utilized in aircraft and automotive industries.[7,8] Pazhouhanfar and Eghbali[9] investigated the impact on microscopic and mechanical characterization of Al6061-TiB_2 composites with several content of TiB_2 powder dispersed processed by stir casting fabrication method. Result concluded that micro hardness and UTS enhanced significantly with raising amount of TiB_2 agents. Akbari *et al.*[10] reported the fracture analysis of nano and micro grain sized TiB_2 dispersed A356/TiB_2 composites. Result revealed that over 1.5 vol.% of reinforcement reduced strength and agglomeration formed. Fractography explored that nano-sized TiB_2 reinforcement composite obtained better ductility than micro-sized particle reinforced composite. Poria *et al.*[11] investigated wear behaviour of TiB_2 dispersed aluminum matrix composite. It is fortified that wear frequency enhanced significantly with continuously addition of TiB_2 powder. Singh *et al.*[12] reported the wear characteristics of TiB_2 reinforced AA6082/TiB_2 aluminium matrix composite. It is noticed that TiB_2 dispersed homogeneously throughout the matrix, instead of that a notable amount of cluster identified due to incorporation TiB_2 particulates.

The present study investigates wear behaviour of TiB_2 particles dispersed Al7075-TiB_2 composites fabricated by stir casting process. Dry sliding pin-on-disc tribotester is employed to analyse wear resistance of composite with variation of TiB_2 content and sliding velocity of rotating disc.

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Materials and Experimentation

To prepare composite, aluminium alloy 7075 and TiB_2 reinforcement were utilized in this investigation as matrix and reinforcement respectively to conquer the drawbacks of conventional aluminium 7075 alloy. Titanium diboride (TiB_2) particle reinforced aluminium 7075 matrix composites ensuring a wide range of uses in corrosive and extreme temperature region because of its combination of superb thermal conductivity and low wear rate. Chemical composition of aluminium alloy 7075 is Chromium-0.21%, Iron-0.22%, Silicon-0.04%, Magnesium-2.58%, Manganese-0.03%, Copper-1.65%, Zinc-5.75%, Titanium-0.03% and Aluminium-Balance. Physical properties of TiB_2 particles are: Density-4.52 g/cm^3, Melting point-3230°C, Purity-99%, Formation-powder, Size-13-14 micron. Several weight percentages of TiB_2 particulates (0%, 3%, 6% and 9%) dispersed with molten matrix alloy. Initially, 900 gm aluminium block placed during a graphite crucible and began heating with the assistance of induction furnace. After melting aluminium matrix material and reached 750°C temperature, a certain amount of TiB_2 particles mixed with molten matrix and started stirring at fixed stirring speed 300 rpm for 10 minutes stirring time with the assistance of mechanical stirrer. Reinforcement particles are preheated before mixing during a muffle furnace at 450°C constant temperature to avoid wetness and minimising porosity in composite. 2% magnesium was used during mixing which enhancing wettability. Composite slurry discharged in a warmed permanent mould and composites were shaped in a rectangular form of 140 mm length, 80 mm breath and 15 mm height. For microstructural analysis, samples were cut at a specific size and started polishing by different grade emery paper and 0.1 µm diamond paste for acquiring mirror finish. For wear test, casted samples make 6 millimetre diameter and 40 mm length cylindrical pins to revolve on counter plate EN31 steel disc having hardness 62 HRC.

Results and Discussion

Energy Dispersion X-ray Spectroscopy

Energy Dispersion X-ray spectroscopy (EDX) validate the existence of matrix and reinforced grains in composite with proper atomic and weight percentage of each and every element identified by formation of peaks. EDX spectra curves of Al7075 matrix detect the presence of elements of Al, Si, Ti, Cr, Fe, C, Mg, Mn, Cu, Zn and O depicts in Fig. 1(a). EDX spectra curves of TiB_2 particles reinforced

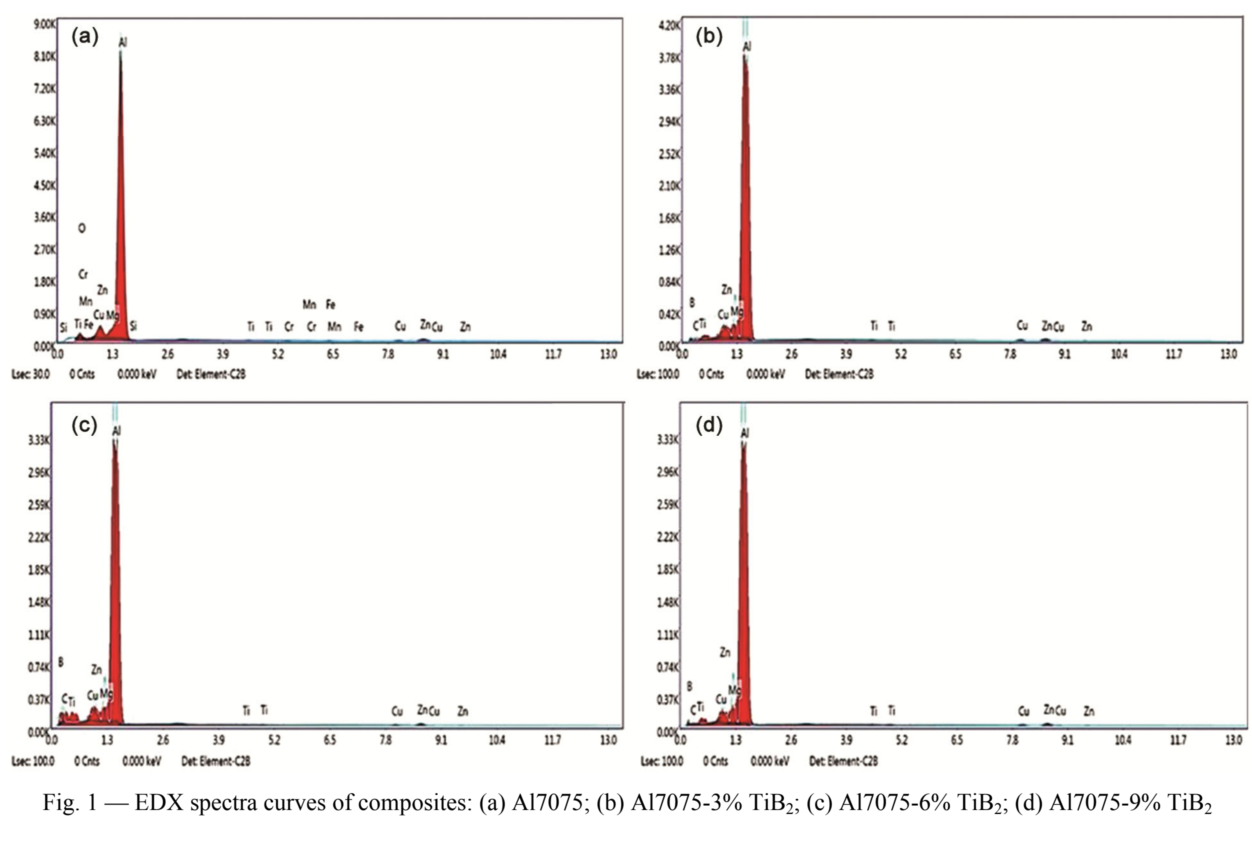

Fig. 1 — EDX spectra curves of composites: (a) Al7075; (b) Al7075-3% TiB_2; (c) Al7075-6% TiB_2; (d) Al7075-9% TiB_2

composites of 0, 3, 6 and 9 wt.% shown in Fig. 1(b), (c) and (d) respectively. EDX curves of TiB_2 reinforced composites identified the peaks of Ti and B that revealed the existence of reinforcement particles in matrix. EDX elemental mapping authenticate microstructural evaluation.

Impact Test

Impact strength calculates the capability of a metal to protect against dynamic load. Impact tests were done by charpy impact testing setup as per ASTM E23 standard. Four specimens for each composite were performed and measured the average result of impact strength. Graphical representation of various weight percentages of TiB_2 powder reinforced Al7075/TiB_2 composite depicts in Fig. 2. It is clearly understood that impact strength enhanced simultaneously with increasing weight percentages of TiB_2 reinforcement. Unreinforced aluminium matrix 7075 contains low impact strength instead of TiB_2 reinforced aluminium matrix composites.

Microstructure Evaluation

Microstructural analysis of Al7075-TiB_2 aluminium matrix composites reinforced with 0, 3, 6 and 9 wt.% TiB_2 were fabricated by stir casting method conducted by Scanning Electron Microscope (Model - Sigma 300, Carl Zeiss) depicts in Fig. 3. These all microscopic figure revealed the existence of TiB_2 particulates throughout the composite. The uniform dispersion of reinforced grains in entire matrix portion also depicts Fig. 3. Unreinforced Al7075 without addition particle reinforcement is shown in Fig. 3(a). General casting defects such as metallic shrinkage during composite slurry solidification and slag integration period aren't shown in scanning electron micrograph that impact on behaviour of casting.[13] During solidify melt, the actual content of ceramic particulates are enforced by aluminum dendrites into ultimate freezing eutectic liquid.[10] Density differentiation among matrix and reinforcements discloses suitable reason for non-homogeneous

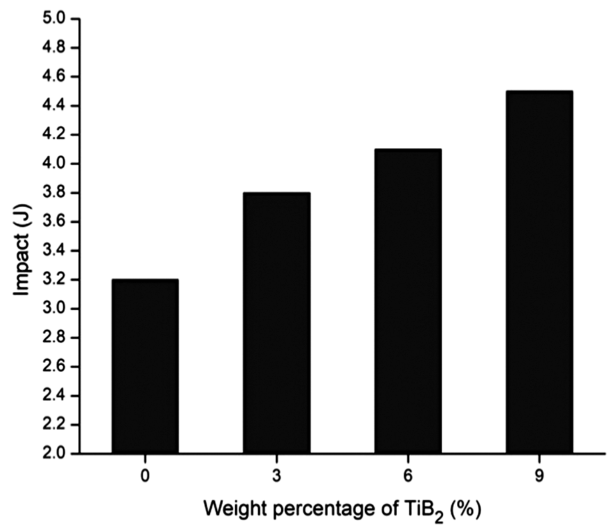

Fig. 2 — Variation of impact strength of TiB_2 reinforced composite

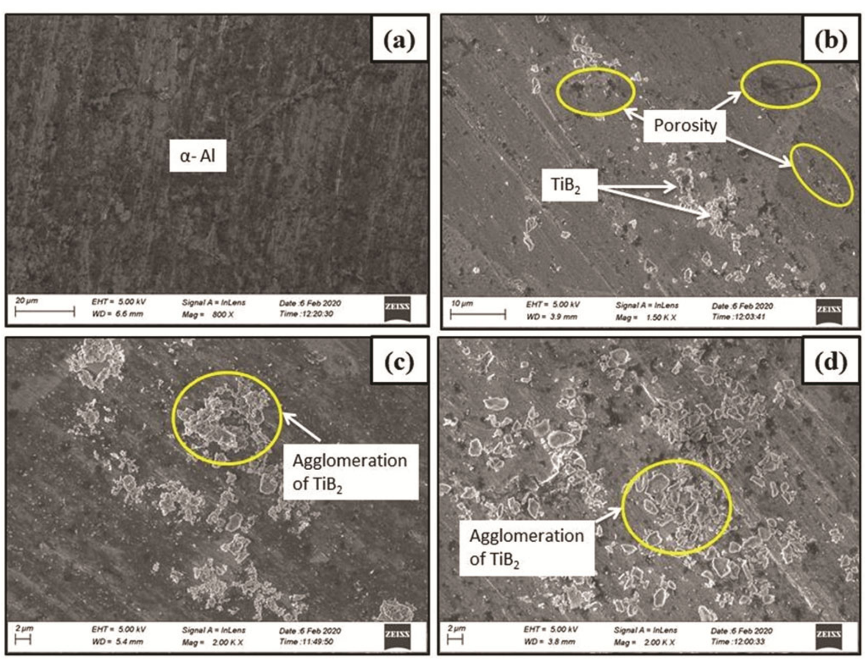

Fig. 3 — SEM micrographs of composites: (a) Al7075, (b) Al7075-3% TiB_2, (c) Al7075-6% TiB_2, (d) Al7075-9% TiB_2

dispersion caused by mixing adequately.[14] It is observed that minimal content of TiB_2 reinforced composite generate porous formation not obstructed like higher content of TiB_2 of reinforced composite and comparatively better fluidity of molten metal that permit better movement of reinforced particulates and clustering with some porous content depicts in Fig. 3(b). Certain amount of particles turns to agglomerate with enhancing TiB_2 content in aluminium matrix which impacts viscosity and surface tension of molten matrix shown in Fig. 3 (c) and (d). Inappropriate stirring speed established particulates agglomeration. Hard and rigid agglomerate particulates make shear stress in the fluid that supports break up and mixing uniform.

Wear Analysis

The graphical representation between wear rate and sliding velocity (0.5, 1, 1.5 and 2 m/s) of various weight percentages TiB_2 (0, 3, 6 and 9 wt.%) reinforced aluminium matrix composite under steady state condition depicts in Fig. 4(a). Remaining sliding test parameters are fixed like sliding distance (1000 m) and load (20 N). Wear rate of unreinforced and reinforced composites reduced with enhance in sliding velocity from 0.5 to 2 m/s. The greater and lower amount of wear rate found at unreinforced Al7075 matrix at 0.5 m/s sliding velocity and Al7075-9%TiB_2 composite at 2 m/s sliding velocity respectively. Indeed, TiB_2 particles are very hard and rigid compared to aluminium matrix which enhanced wear resistance capacity of filled composites.[15–17] It is exposed that TiB_2 dispersed composite containing wear rate in a decreasing manner due to huge amount of heat generated in between two surfaces that form self-lubricated tribo-layer which reduces wear rate of composites.[18] Although, coefficient of friction (COF) enhanced with increase in sliding velocity and reduced with decrease in weight percentages of TiB_2 particles shown in Fig. 4(b). Experimentation revealed that unreinforced Al7075 alloy have maximum COF which is 0.44 at 2 m/s sliding velocity and Al7075-9% TiB_2 composite have minimum COF which is 0.19 at 0.5 m/s sliding velocity. Enhancement of friction in between contact surfaces due to existence of hard phase raise stick slip matter which significantly develop frictional force.

Worn Surface Morphology

The rubbing surface of composite pins which rotating against the counter plate with variation of sliding velocity and reinforcement content at constant

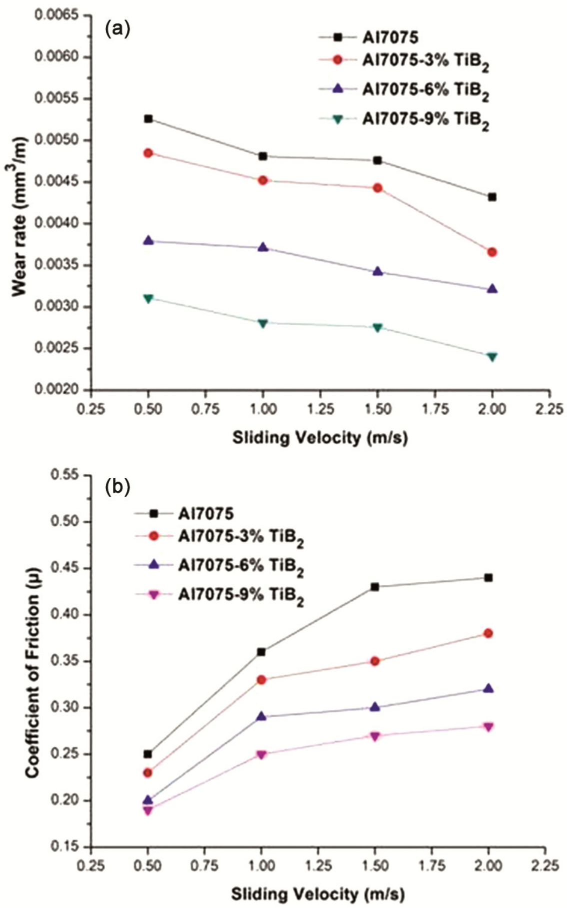

Fig. 4 — Graph representation of Al7075-TiB_2 composites: (a) Wear rate vs sliding velocity and (b) Coefficient of Friction vs sliding velocity

load (20N), sliding distance (1000 m) and ambient room temperature depicts in Fig. 5. Composites exhibit higher mechanical properties that enhanced endurance limit of material removal rate. As it is seen in Fig. 5(a–c), mechanically mixed layer forms with enhancing sliding velocity; remaining factors are constant. Larger grooves and accelerates frictional heat and deforms plastically that also called adhesive wear shown in Fig. 5(a).[19–23] Mechanically mixed layer (MML) generate because of the combination of oxide surface immediate after the crucial plastic deformation of rubbing surface at very high temperature and it is obtained due to higher sliding velocity.[24] A burned spot recognized in Fig. 5(b) caused by enormous quantity of flash temperature at contact surface for the period of cover huge distance. According to worn micrograph depicts in Fig. 5(d–f), it is witnessed that an even layer of pin contact surface produced with enhancing weight percentage of TiB_2 reinforcement in aluminium matrix remaining

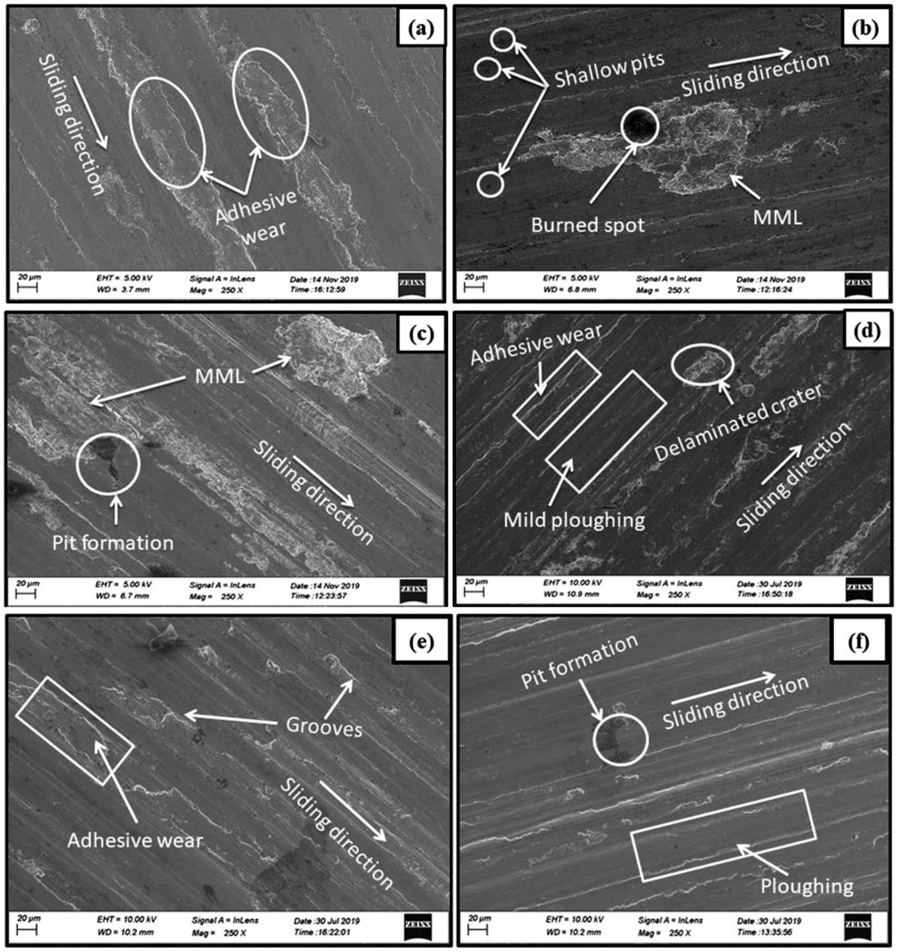

Fig. 5 — Microstructure of worn surface with constant load 20 N and sliding distance 1000 m: Effect of sliding velocity of Al7075-6%TiB_2 composite — (a) 0.5 m/s, (b) 1.5 m/s, (c) 2 m/s; Effect of TiB_2 content of composites at 1 m/s sliding velocity — (d) 3% (e) 6% (f) 9%

constant all other factors. Wear debris that formed throughout sliding play as a task of rough particulates and enhance abrasive wear which influence on material loss from that surface. Ploughing and pit development are found in these surfaces.[18] Worn micrograph of filled composites illustrate the existence of unstructured craters depicts in Fig. 5(d) which indicate of delamination mechanism at the time of abrasion. Each worn micrographs identified groove marks displays in Fig. 5(e) that urged by the rubbing of TiB_2 particles towards sliding direction.[25]

Conclusions

Al7075 matrix composite reinforced with TiB_2 micro-sized particles successfully fabricated by stir casting process. EDX analysis observed the presence of TiB_2 particles all over the aluminium matrix. From SEM analysis it is revealed that stir casting route establishes a uniform distribution of TiB_2 all over aluminium matrix and minimises the level of porosity within the composite with enhancing TiB_2 content. As increasing TiB_2 particles, wear rate reduced significantly but accordingly enhanced coefficient of friction due to hard and rigid ceramic particle reinforcement. It is also noticed that as enhancing sliding velocity wear performance enhanced and coefficient of friction reduced due to higher frictional force formation. Worn micrograph revealed the surface damage by adhesive wear found at lower sliding velocity and mechanically mixed layer and pitting marks identified at higher sliding velocity. It is also notable that lower grooves and smoother surface formed with more incorporation of reinforcement content contain remaining factors are fixed.

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