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Tribological and mechanical characteristics of AA6082/TiC/WC -based aluminium composites in dry and wet conditions

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ABSTRACT

The tribological and mechanical characteristics of hybrid metal matrix composite on aluminium alloy 6082 reinforced with titanium carbide (TiC) and tungsten carbide (WC) particles was studied for automotive applications. The hybrid composites were fabricated using stir casting techniques by varying TiC and WC particles. Fabricated samples were prepared as per ASTM standard dimensions to conduct mechanical test such as ultimate tensile strength and hardness. The tribological behavior of the hybrid composites was examined using pin on disc tribometer. Distribution of reinforced particles in hybrid composite was examined with scanning electron microscope (SEM) analysis. The tribological characteristics of specific wear rate and coefficient of friction were examined under dry and wet lubricated conditions. Mechanical characteristics and tribological characteristics of the hybrid composites have significantly improved by the presence of reinforced particles (TiC and WC) respectively.
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1. Introduction

Aluminium is commonly used as the matrix in metal matrix composites(MMCs) because it provides a wide variety of mechanical properties at low productions costs and is commonly used in a number of engineering fields, including aerospace, automotive, marine and military[1,2,3]. Pure aluminium metal strength is improved when reinforced with hard ceramic particles such as Al_2O_3, Si3N4, B4C, Tic, Sic, etc. with increased wear resistance and decreased weight to strength ratio [4]. AMCs are developed by a variety of processes, such as stir casting, spray casting, squeeze casting, powder metallurgy, ball milling and friction stir processing, depending on the size, volume fraction, form and morphology of reinforcement particles [5,6]. K.R.Ramkumar et al. [7] an attempt was made to study the synthesis, characterization, mechanical properties, and wear properties of AA7075/TiC composites using stir casting. The composites had enhanced TiC by 0, 2.5, 5 and 7.5 wt%. The mechanical and wear behavior was investigated and reported with the role of the reinforcement particles.

Arumugam Thangarasu et al. [8] reported when increasing weight percentage of TiC particles in aluminium matrix there was an improvement in mechanical properties such as microhardness tensile strength, and wear resistance. K.Ravikumar et al. [9] an attempt was made to investigate the mechanical properties of aluminum (AA6082)/tungsten carbide composites and related mechanisms.Yashvir singh et al. [15],the friction and wear characteristics of pongamia oil based mixed lubricants were studied at different sliding speeds and ensuring its suitability as a bio lubricant for the automotive industry. Milena Chanes et al. [10] reported the vegetable Tung and Jatropha bases oils can be used as a bio-based to formulate and grow environmentally friendly MWFs for the metal-mechanical sector, primarily for Al-7050-T7451 alloys machining. Lekatou et al [16] reported the alloy's sliding wear efficiency was remarkably improved by introducing the carbide phase through a direct effect derived from the TiC and WC particles as such and as intermetallic clusters, and an indirect effect derived from the intermetallic hard particles. H.Meng et al. [11]found by adding CNTs under dry sliding and water- lubricated condition, the friction coefficient and basic wear rate of PA6 were reduced. CNTs were attributed to the reinforcing effect, self-lubrication, and excellent thermal conductivity of CNTs in PA6. In the present investigation, the Al6082 aluminium alloy was reinforced with a

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different weight percentage of TiC and WC particles (3,6,9, and 12 wt%) to prepare the hybrid composites using stir casting techniques. mechanical and tribological properties under dry and wet lubricated condition was examined.

2. Materials and methodology

In this work, hybrid composites were fabricated by varying reinforcement particles (3, 6, 9 and 12) by weight percentage basis. 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 [12]. Al6082 aluminium alloy was used as matrix material. Selected reinforced particle are TiC and WC. The required quantity of Al6082 aluminium alloy was melted in a graphite crucible using an electrical furnace. The reinforcement particles were preheated at 450 °C temperature to remove the moisture. The measured quantity of reinforcement particles (3, 6, 9 and 12 wt%) were added to molten aluminium. The hybrid composite mixture maintained was stirred frequently. The hybrid composite maintained at a temperature of 820 °C were poured in to preheated die and then allowed to solidify at room temperature. The manufactured hybrid composite and base alloys were subjected mechanical test and tribological test.

2.1. Mechanical test

As per ASTM standard the base alloy and hybrid composites samples were machined and three set of tests were conducted and the average value was consider to minimize the possibilities of error in calculate mechanical properties of samples. Brinell hardness tetster with a 5 mm ball diameter and a load carrying capacity of 300 kg is engaged to find the hardness of samples. The tensile test was conducted on a base alloy(Al6082) and hybrid composites using the Universal testing machine, for a gauge length of 36 mm and 6 mm diameter.

2.2. Tribological test

Tribological properties of base alloy and hybrid composites were evaluated under dry and wet conditions using pin on disc tribometer. The pin samples of 10 mm diameter and 25 mm length were used to conduct tribological test. EN 32 steel was used for disc material. The experiments were conducted under dry and wet conditions at sliding velocity 1 m/s, load 40 N and sliding distance 1000 m. For wet condition pongamia oil was used as lubricant, pongamia oil was purchased from authorized oil shop at Coimbatore. The specific wear rate and coefficient of friction was measured at room temperature.

3. Results and discussion

3.1. SEM analysis

Fig. 1 shows the SEM images of fabricated hybrid composites reinforced with 3, 6, 9, and 12 weight percentages of TiC and WC particles. The intentionally added reinforcements particles were distributed uniformly over the matrix material (Fig. 1(a)–(d)). These uniformly distribution of reinforcement particles was necessary to enhance the mechanical and tribological properties of materials.

3.2. Mechanical test analysis

3.2.1. Hardness test

The effect of reinforcement particles in aluminium composites is shown in Fig. 2. The results clearly indicates that the hardness value has been increase with increasing weight % of TiC and WC particles in base alloys and it is significantly higher than the hardness of the base alloy. Reason behind increasing hardness was reinforcement particles and base alloys were having good interfacial bonding between them and it was aid to improves the hardness of the hybrid composites [13]. The maximum value of hardness was 83 BHN and it was observed for 12 wt% of (TiC + WC) addition with base alloys.

3.2.2. Tensile strength

Influence of TiC and WC reinforced particles on ultimate tensile strength (UTS) of aluminium composites is shown in Fig. 3. It can be observed that the strength of hybrid composites increased with increasing TiC and WC particles in base alloys. The UTS of hybrid composites increased up to 23.97% for combination of 12 wt% of (TiC and WC) addition with base alloys, due to strong bonding nature between the reinforcement particles and alloy, the reinforcement particles was distributes uniformly throughout the matrix and it was increase the ultimate tensile strength of hybrid composites. From Fig. 4 it was observed that the elongation of the hybrid composites decreases with increase in reinforcement particle content. Elongation of base alloy is 5.3 and this value decrease to 3.3. This represents 37.75% reduction of elongation for hybrid composite for 12 weigth % of (Tic and WC) addition with base alloys.

3.3. Tribological properties test

3.3.1. Coefficient of friction

The variation of the friction coefficient under dry and wet lubricated condition against hybrid composites and base alloys were shown in Figs. 5 and 6 respectively. In both dry and wet lubricated conditions the fabricated base alloy has higher coefficient of friction than hybrid composites. In both condition the coefficient of friction value was reduced gradually by increasing weight % of reinforcement particles addition from 3% to 12% in base alloys. Because of presence of reinforced particles in aluminium matrix alloy which will restrict the flow of metal during sliding [14]. The maximum reduction in coefficient of friction was under wet lubricated condition for base alloy and hybrid composites. Under wet lubricated condition there was an tremendous changes in coefficient of friction, because of long carbon chains,polar, heavy, and bipolar nature molecules present in pongamia oil, provide a bio film between the contact areas. It was examined that base alloy with 12 wt% of (TiC and WC) addition hybrid composites shows better results in both dry and wet lubricated conditions.

3.3.2. Specific wear rate

The variation of specific wear rate under dry and wet lubricated condition against hybrid composites and base alloys were shown in Figs. 7 and 8 respectively. From the graph it was noticed that the specific wear rate for base alloy was high compared to hybrid composites in both dry and wet lubricated conditions. The specific wear rate was reduced by addition of TiC and WC particles in 3, 6, 9, and 12% weight to base alloys. However maximum reduction of specific wear rate was obtained under wet lubricated condition and it shows in all samples considerably greater than that of dry condition samples because of thin lubricating film formation over contact area surfaces, and this thin lubricating film decreases the adhesion of small broken particles of base alloy and hybrid composites and leads to lower specific wear rates[14].

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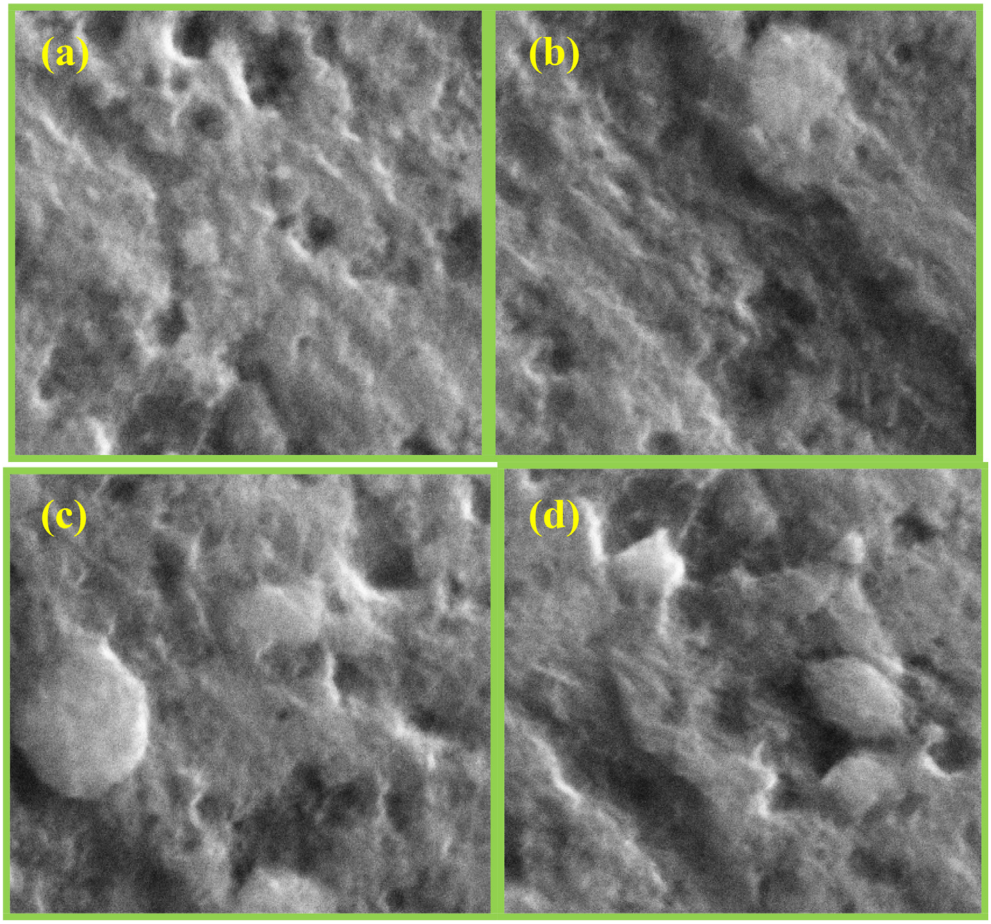

Fig. 1. SEM images of hybrid composites (a) 3% of TiC + WC(b) 6% of TiC + WC (c) 9% of TiC + WC (d) 12% of TiC + WC.

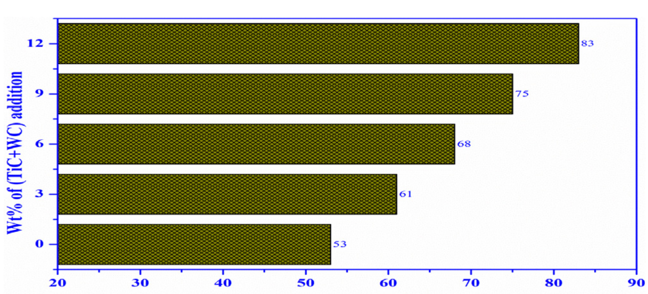

Fig. 2. Variation of hardness with weight % of reinforcemnt particles.

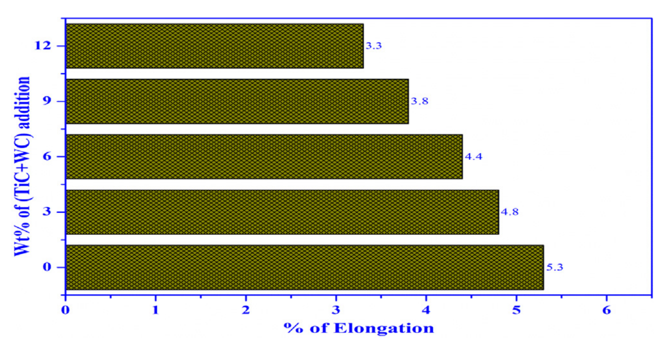

Fig. 4. Variation of % of elongation with weight % of reinforcemnt particles.

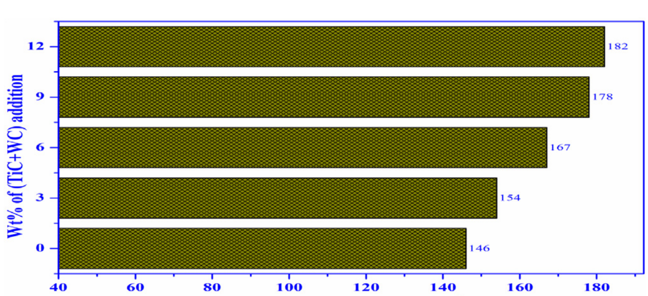

Fig. 3. Variation of tensile strength with weight % of reinforcemnt particles.

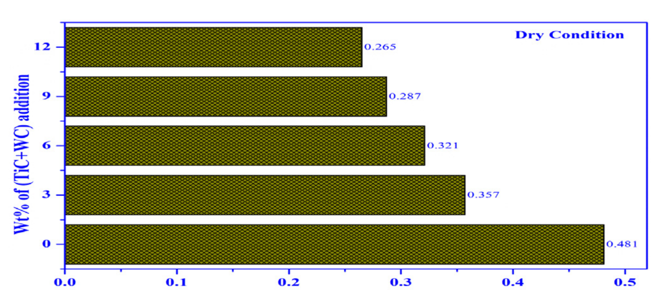

Fig. 5. Variation of COF with weight % of reinforcemnt particles under dry conditions.

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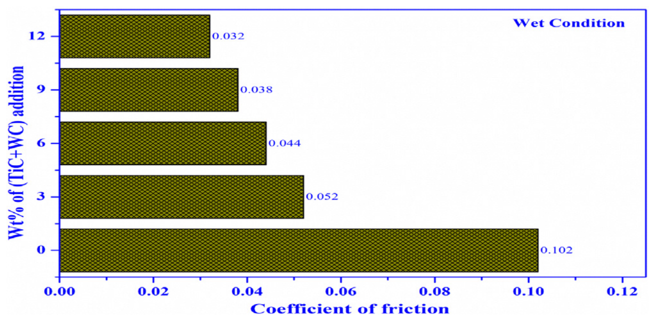

Fig. 6. Variation of COF with weight % of reinforcemnt particles under wet conditions.

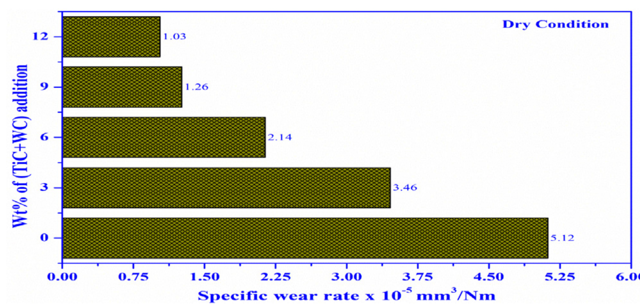

Fig. 7. Variation of specific wear rate with weight % of reinforcemnt particles under dry conditions.

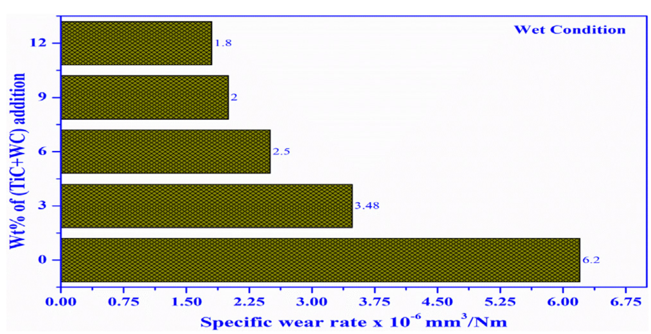

Fig. 8. Variation of specific wear rate with weight % of reinforcemnt particles under wet conditions.

4. Conclusions

In this present study, AA6082 reinforced by 3, 6, 9, and 12 wt% of (TiC and WC) particulates was fabricated using stir casting techniques and tests were conducted to evaluate the tribological and mechanical characteristics of hybrid composites based on experimental results following conclusions were obtained: mechanical test revealed addition of reinforcement particles (TiC and WC) was significantly improved the hardness and ultimate tensile strength (UTS) of fabricated hybrid composites. Good dispersion of reinforced particles was observed in SEM analysis. In tribological test uniform distribution of TiC and WC reinforced particle in aluminium alloy reduces the coefficient of friction and specific wear rates for hybrid composites compared with base alloy under dry and wet lubricated condition which prolongs the life of composites for longer duration. However the values of coefficient of friction and specific wear rates base alloys and hybrid composites were minimum under wet lubricated condition compared with dry condition. From above discussions we conclude that TiC and WC reinforced hybrid composites will serve as a technical data base for automotive and commercial applications.

CRediT authorship contribution statement

C. Rajaganapathy: Conceptualization, Data curation, Formal analysis, Investigation, Methodology. **D. Vasudevan**: Writing review & editing. **A. Dyson Bruno**: Supervision, Validation, Project administration. **T. Rajkumar**: Resources.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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