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# Dry Sliding Wear Behaviour of AA6061-T6 Reinforced SiC and $Al_2O_3$ Particulate Hybrid Composites

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**Abstract**

Dry wear behaviour of AA6061 Aluminum alloy, reinforcement with fine particulates of Silicon Carbide (25µm) and Aluminium oxide(40µm) are existed and discussed here in research paper. The reinforcement of Al alloy hybrid metal matrix composite (HMMCs) with 5-25% vol. fractions of Silicon Carbide and Aluminium oxide particles are produced by stir casting methodology and test specimen were prepared by using them . The dry sliding behaviour of these hybrid metal matrix composite specimen and that of Al6061 unreinforced alloy at ambient temperature was examined by using pin-on-disk Wear Testing Machine over a weight range of 29.43N-49.05N (3-5 kgf) along a sliding distance of 1413m at constant sliding speed of 1.57m/s. The result confirms that, the reinforced metal matrix with Silicon Carbide and Aluminium oxide particles up to a vol. fraction of 25% reduces the wear in µm at ambient temperature. Increases the volume fraction of the reinforcement decreases the wear in µm. The result also displays that the wear in µm of test specimen increase with increase in load and sliding distance.


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*Keywords:MMC, Al6061alloys, hybrid composites, stir casting, wear, and volume fraction;*

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## 1. Introduction

Agreeing with modern upgradable in their production technology, metal matrix composites are now being progressively specified as fresh wear-resistant materials [1-4]. Extensive work has been focused towards the improvements of metal matrix composites (MMC) in last two decades. The reinforcement of composites causes substantial high strength, enhanced stiffness, creep & fatigue properties, wear and tear due to driving force when compared with usual engineering materials [5, 6]. The majority of reinforced metal matrix composites have high strength, high hardness and brittle phases which might be either regular in kind of fibre or irregular within the kind of whisker or particulates. Mostly the current works area unit are centered on discontinuously strengthened aluminium (DRA) or particulate strengthened aluminium MMC, as a result of their simple manufacture process and low production prices. [7,8]. The particulate strengthened metal MMC, area unit are suitable choice for selection for weight important application within the part and automotive industries because of their high specific strength, high specific stiffness, superior wear resistance and low density [9, 10]. The gettable enhancements within the properties are addicted to the intrinsic properties of composite constituents and also the size, shape, orientation, vol. fraction and division of the reinforcing phase introduced in the metal matrix [11, 12]. The aim of the current experimental analysis is assess the dry slippery metal-metal wear behaviour of Al6061 alloy, discontinuously strengthened with 2differing types of particles silicon carbide and aluminium oxide. This hybrid material is made by using stir casting methodology and also the impact of vol. fraction of the reinforcements and also the applied load on the dry slippery metal-metal wear behavior of composites were investigated employing a pin-on-disk wear tester. conjointly the small hardness of the specimens at normal temperature were measured before and once the wear and tear tests using Vickers hardness testing machine to check the impact of volume fraction of the reinforcement on hardness.

## 2. Manufacturing the hybrid composite material

The production of standard quality composites is responsible for proper selection of working parameters such as molten temperature, stirrer speed, preheating temperature of reinforcements etc. Preparation of the hybrid composite was carried out according to the following procedure:

About 1kg of Al6061 alloy is heated up to molten state in graphite crucible by induction type electric resistance furnace. The temperature of the melt is 725ºC.After complete melting of the alloy by nitrogen, the stainless steel stirrer consists of four blade coated with alumina is introduced into the molten alloy and start stirring process. The alumina coating is used to prevent the migration of ferric ions from the stirrer into the molten metal. The stirrer is rotates about 600 rpm for 20mins. The depth of immersion of the stirrer is maintain about 2/3 the depth of the molten metal. During stirring process, the mixture of preheated reinforcement particulates Silicon Carbide and Aluminium oxide in equal volume fraction was added inside the vortex formed due to stirring. Before that reinforcement particles were preheated to 600ºC for an hour. Their average diameters were 25 and 45 μm respectively. After completing the addition of the particulates into the melt, the composite alloy was poured into the preheated (250 ºC) permanent steel mould and allowed to cool in atmospheric temperature. The billet was then detached from the mould. The Al6061 hybrid composites of different volume fractions of reinforcement materials were thus produced and wear specimens were machined from them. The nominal chemical composition of Al6061 alloy is given in Table 1. The mechanical properties of matrix and reinforcement material are given in Table 2.

**Table 1. Nominal chemical composition of Al6061 alloy**

| **Elements** | **Si** | **Cu** | **Ni** | **Zn** | **Sn** | **Mn** | **Mg** | **Pb** | **Fe** | **Cr** | **Ti** | **Al** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Percentage %** | 0.43 | 0.24 | 0.05 | 0.25 | 0.001 | 0.139 | 0.802 | 0.24 | 0.7 | 0.25 | 0.15 | Balance |

**Table 2. Mechanical properties of matrix and reinforcement material**

| **Material** | **Type** | **Tensilestrength,$\sigma_u$ (MPa)** | **Modulus ofelasticity,E (GPa)** | **Massdensity,ρ ($mg/m^3$)** | **Meltingtemperature(°C)** |
|---|---|---|---|---|---|
| Al6061-T6 | Matrix | 310 | 68.9 | 2.7 | 620 |
| SiC | Reinforcement 1 | 2068 | 482 | 4.09 | 2700 |
| $Al_2O_3$ | Reinforcement 2 | 2068 | 172 | 3.95 | 2015 |

## 3. Experimental procedure

The experimentations were performed in air at ambient temperature in a pin-on-disk Wear Testing Machine (Wear and Friction monitor TR-201). The dead weight loading system is used to load the pin against disk. The pin specimens are flat ended having 8mm in diameter and 40 mm in vertical height. The dimension of the wear test specimen is shown in Fig. 1.

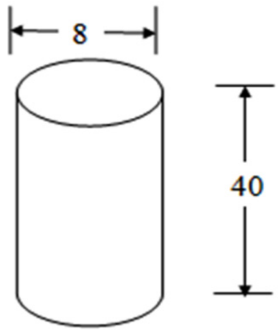



**Fig. 1 Dimensions of the wear test specimen in mm**

The disk test material has 100mm diameter and 10mm thickness. The pin slide on the disk at a radius of 50mm.The counter disk is a material of high quality hardened steel with hardness HV256. Before the wear test, each specimen was ground by 1µm alumina powder and the counter disk was ground by 2000 grit paper Wear tests on composite specimens and unreinforced Al alloy takes place in dry sliding condition of three different applied loads of 29.43N (3kgf), 39.24N (4kgf) and 49.05N (5kgf) for overall sliding distance of 1413m at a constant sliding speed of 1.57 m/s for all sample. The length (displacement) of the material is continuously measured using LVDT(Linear Variable Differential Transformer) of accuracy 1µm during the wear test and the height loss is taken as wear of the specimen. The pin-on-disk wear tester used in this research is shown in Fig.2.

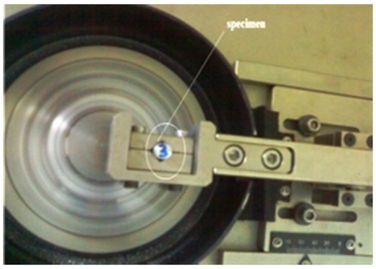



Fig. 2 Top view of the pin-on-disk type wear testing machine

An investigational graph shows the height loss or wear in µm against slippery time in sec (which is proportional to sliding distance) taken from wear testing machine is shown in Fig.3. The micro hardness of the composite test specimen at ambient temperature was measured previous and later wear tests using Vickers micro hardness testing machine. The photography of the wear test specimen are shown in Fig.4.

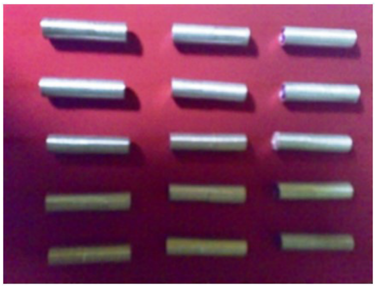
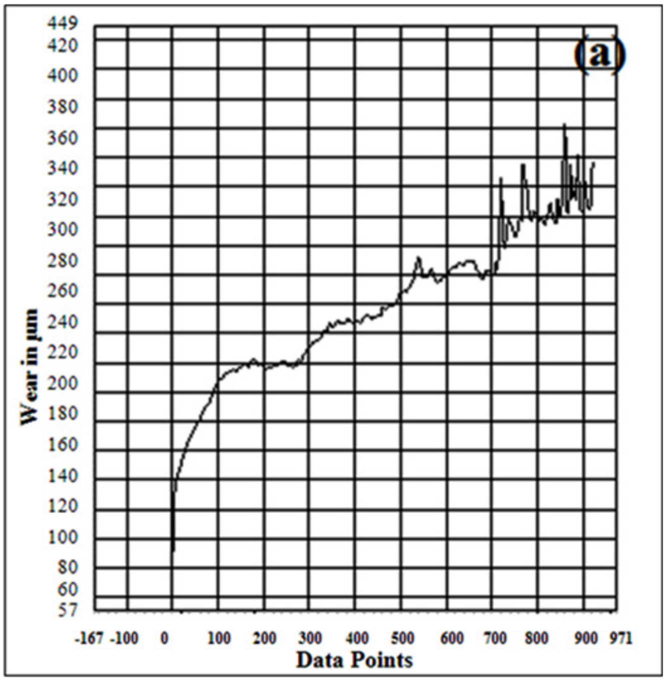
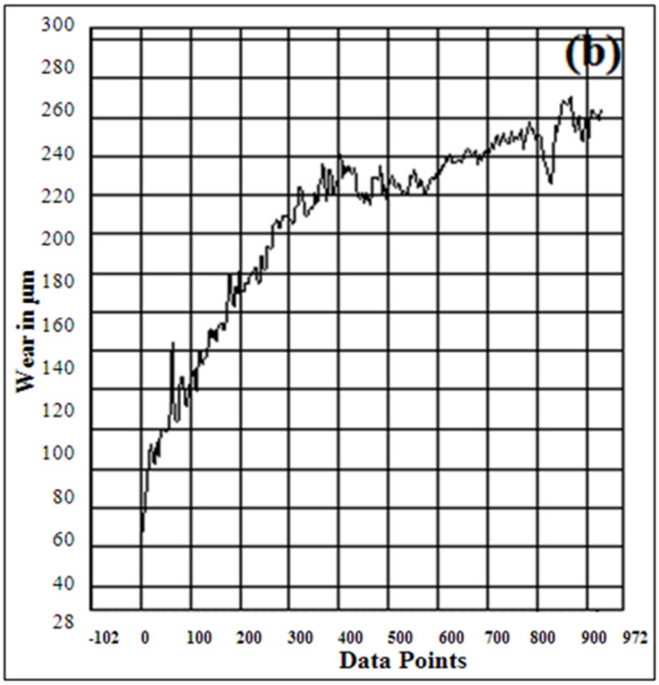


Fig. 3 The photographs of the wear test specimen




(a) 5% Vol. fraction

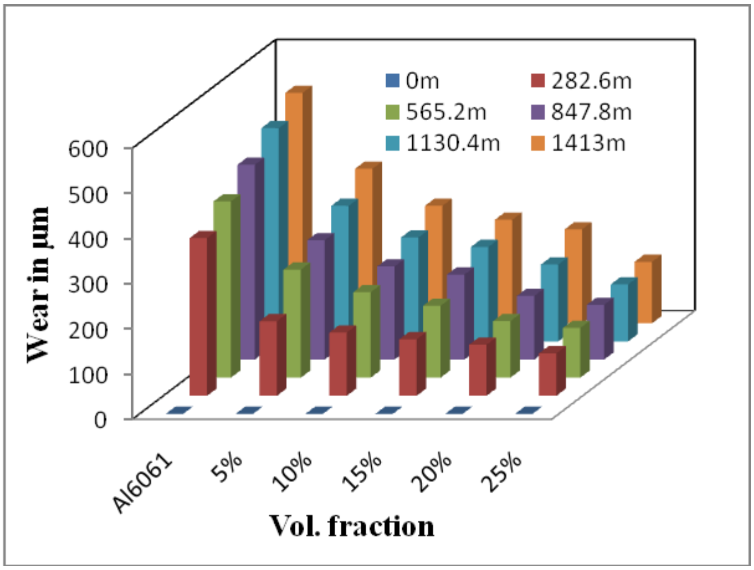



(b) 10% Vol. Fraction

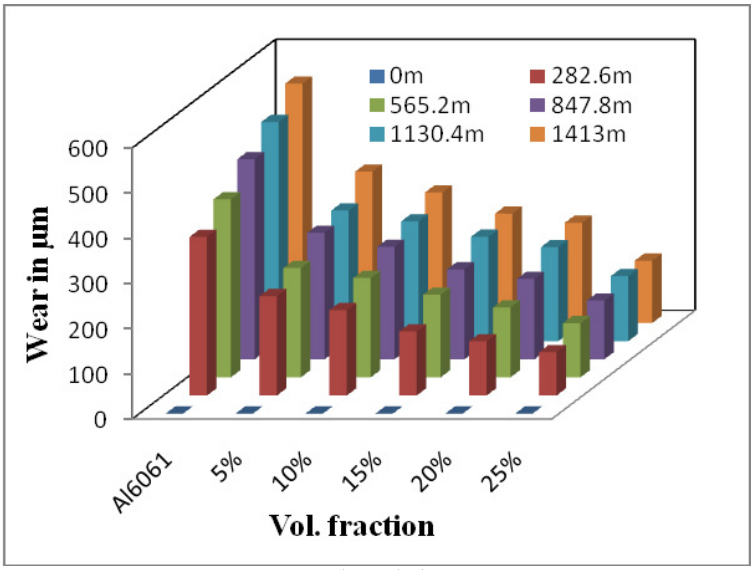
Fig. 4 Typical graphical result of experimental wear in µm from pin-on-disc type wear testing machine of different Vol. fraction reinforced of HMMCs at applied load of 39.24N.

#### 4. Results and Discussion

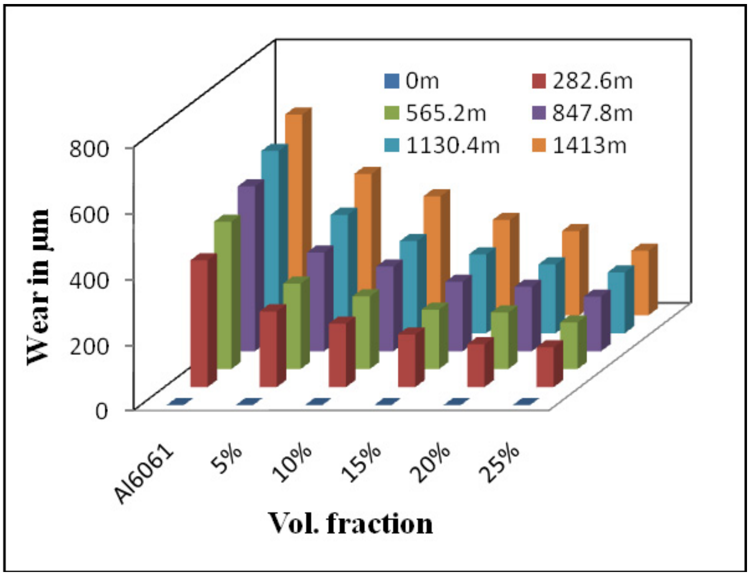
The wear test results of the Al6061 hybrid composites and unreinforced specimens under dry sliding condition are shown in Fig. 5 for overall slippery distance of 1413m at a rated sliding speed of 1.57 m/s for all samples. In each Figure, wear of the unreinforced alloy and five different composite specimens under varying vol. percentage of particulates reinforcement (5 to 25%) are shown. The wear of test specimen was obtained from the height loss of the specimen during slippery is plotted against sliding distance shown in Fig.5(a) to 6(e) for varying applied loads are 29.43N (3kgf), 39.24N (4kgf) and 49.05N (5kgf).




(a) Load of 29.43N




(b)Load of 39.24N




(c)Load of 49.05N

Fig. 5 The wear of unreinforced alloy and composites at different applied load as a function of sliding distance at constant V=1.57m/s.

As expected, the wear loss of the composite specimens increases with increase in sliding distance. From graph it is clear that wear loss of unreinforced alloy increases suddenly with applied weight or load compared with composite alloy specimen. The graphs exhibit two regions, one is 'running-in' period and other one is 'steady state' periods. Inrunning-in period, the wear loss increases more rapidly with increasing sliding distance. For steady state period, the wear increases very slowly with increase in sliding distance. The wear in µm of the composite specimen decrease with increasing volume percentage of particulate reinforcement. Thus the wear loss in µm of a composite specimen with a permanent vol. percentage increases gradually due to applied load.

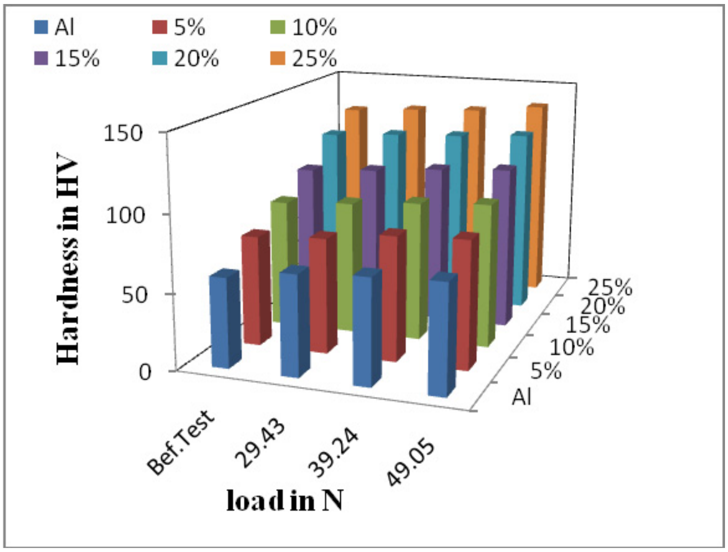



Fig. 6 Microhardness of unreinforced alloy and composites before and after wear tests.

The results of micro hardness measurements of the composite specimens before and after the wear tests are shown in Fig.6. It is clearly shows that the hardness (HV) of the composite specimens is directly proportional to the volume percentage of reinforced particles. This may be attributed to the solid solution hardening of the matrix by the addition of reinforcements to the alloy.Fig. 7.shows the photograph of the wear surface at different vol. fraction at a sliding distance of 1413m at a weight or load of 39.42N. From this photograph, it is observed that the width of the scratches decreases with increase in vol. fraction of reinforcements and many broad lines are shown. This is due to the resistance offered by the reinforcements to the wear of the specimens.

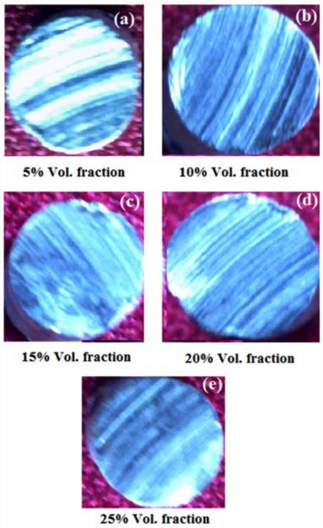



Fig. 7The photographs of the wear surfaces of different Vol. fraction reinforced of HMMCs at a load of 39.42N.

## 5. Conclusion

The present investigation on the effect of reinforced Silicon Carbide and Aluminium oxide content on the dry sliding metal-metal wear behavior of Al6061 alloy hybrid composites lead to the following conclusions:

1. The reinforcement of Al6061 alloy with Silicon Carbide and Aluminium oxide particles up to a vol. fraction of 25% has a noticeable effect on the wear.
2. The wear decreases with increase in vol. content of reinforcements. (for the fixed size of SiC and $Al_2O_3$ particulates)
3. The micro hardness of the composite specimens measured after the wear test increases with the increase in vol. content of the reinforcements.
4. The width of the scratches decreases with increase in vol. fraction of the reinforcements.

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