

# Processing and characterization of aluminium 2014-10Wt% SiC composite

**MD Obaidur Rahman<sup>1</sup>, Saif Nawaz Ahmad<sup>2</sup>, Neeraj Priyadarshi<sup>3</sup>, Raman Kumar Singh<sup>4</sup> and Akash Kr Bhoi<sup>5</sup>**

<sup>1,2,3,4</sup> Millia Institute of Technology, Purnea, Bihar, INDIA-854301

<sup>5</sup>SMIT, Sikkim, INDIA-737136

Corresponding authors: [obaid475@gmail.com](mailto:obaid475@gmail.com)<sup>1</sup>, [saif.nawaz.ahmad@gmail.com](mailto:saif.nawaz.ahmad@gmail.com)<sup>2</sup>, [neerajrjd@gmail.com](mailto:neerajrjd@gmail.com)<sup>3</sup>, [ramanmech85@gmail.com](mailto:ramanmech85@gmail.com)<sup>4</sup> [akash.b@smit.smu.edu.in](mailto:akash.b@smit.smu.edu.in)<sup>5</sup>

**Abstract.** The present work focuses on development of hot extruded, hot forged and T6 heat treated Aluminium 2014-10wt% SiC composite. The developed composites on T6 heat treatment exhibit higher hardness when compared to composites before heat treatment. Friction and wear studies were conducted by varying load and sliding velocity parameters on both heat treated and non-heat treated specimens using pin-on-disc machines. The coefficient of friction of the developed composites is lowered on T6 heat treatment as compared to composites without heat treatment. By increasing load the wear rate increases before and after T6 heat treatment. Before and after heat treatment microstructure studies have been carried out on hot forged aluminum 2014-10wt% SiC composites. SEM, EDAX and Confocal studies have been done for the worn surface.

## 1. Introduction

Aluminum composites having excellent mechanical properties as well as corrosion resistance. They have extremely poor wear and seizure resistance. Secondary processes such as extrusion, forging, drawing, rolling etc are available that can be applied on aluminum alloys. Aluminum alloys are forged into a various range of shapes in both hot and cold working conditions by using recent techniques available. Since few years, the continuously increasing the demand for lightweight materials in production sector such as aerospace and automotive applications. In practice, the cold forming process is achieved using the known properties of materials through tensile testing. To heat ingot or billet a high-temperature furnace is used in case of hot forging/extrusion. To absorb the shock and vibration generated by the hammer some provisions are provided in the case of drop forging operation.

Kalyan Kumar Singh et al.,[1] performed SiC based aluminium metal matrix composite and aluminium matrix alloy possess better properties at slow sliding distance at lower load at room temperature. C.M.Abreu et al.,[2] attempted to form surface composite layer by friction stir processing of micro sized SiC particles into an AA2024-T351 aluminium alloy and also probe several strategies for reinforced on the particles distribution. Rajeshkannan Ananthanaraynan et al.,[3] used the hot forged aluminium metal matrix composites and conducted the tensile and impact testing hardness measurements and to get the changes in mechanical properties by the foreign elements and forming process. Purohit Rajesh et al.,[4] studied the MMC based aluminium alloys, its wear properties and the behaviour of hot forging process on it and observed the enhance in sliding velocity with the increment of wear rate. M Parchoviansky et al.,[5] evaluated the influence of volume fraction, size of SiC



particles, final microstructure on mechanical properties and dry sliding wear behaviour in ball-on-disc arrangement and observed the improvement in the vicker hardness with the addition of SiC. Diptikanta Das et al.,[6] observed the distribution pattern of the reinforced using optical microscopy of the SiC particulate reinforced aluminium matrix composite by stir casting method heat treated to T6 condition. Erturun Veysel et al.,[7] tried to enhance the mechanical properties of Al-based composite by a reciprocating extrusion process. R.S Rana et al.,[8] studied the fabrication of AA5083 alloy SiC composites by ultrasonic assisted stir casting and SEM micrographs were used for the distribution of SiC particles. C.S.Ramesh et al.,[9] studied microstructure and micro hardness and conducted tensile strength tests on hot extruded composites. The extrusion ratio increases with the increase of micro hardness and tensile strength of the composites. B Veeresh Kumar et al.,[10] used liquid metallurg route to prepare Al6061-SiC composites and presented its experimental result of the Mechanical and Tribological properties.

## 2. Experimental Analysis

### 2.1 Preparation of Al-2014 10Wt% SiC Composites by Stir casting process

3.5kgs of Aluminium 2014 alloy is taken in a graphite coated crucible and by using a 6KW electric furnace it has been melted. The liquid metal was unsettled by utilization of mechanical stirrer which is rotating at a rate of 300rpm to make vortex. Preheated SiC powders of ten weight percent were added gradually into the vortex while proceeding with the stirring procedure. The composite was poured in preheated metallic moulds and there it is maintained at a temperature of 7000°C.

### 2.2 Extrusion and Forging of composites

The cast billet of Al 2014 –10wt% SiC composite was carried out to hot extrusion process. Figure 1 shows the 200T hydraulic press with extrusion die assembly. The cast billet was positioned inside the die and by using a split type die heater, billet was covered. The billet of diameter 325 mm and height 75 mm was extruded by adopting an extrusion ratio of 1:4. The extruded material of diameter 200mm was thus obtained. Thereafter the hot forging were carried out at 100 MPa Pressure and at a temperature of 450°C for duration of 40-45 seconds on extruded product.

### 2.3 Sample Preparation

The final specimens were prepared for various tests namely, micro structural studies, Pin on Disc wear tests, SEM, EDAX and Confocal microscopy analysis. The specimens obtained by wire cut EDM method are as shown in figure 3. The samples were prepared as per the ASTM standards for both the conditions of before and after heat treatment.



**Figure 1.** Hot extrusion press.



**Figure 2.** Al 2014-10wt%SiC composite after extruded it to 1:4 ratios.



**Figure 3.** Specimens of Al2014 10Wt% SiC composites.

### 2.4 Heat treatment of specimens

Solutionising of the specimens at a temperature of 550°C for 2 hours. The test specimens were subjected to T6 heat treatment. The procedure of T6 heat treatment includes the following steps.

- I. Ice quenching of the specimen.

## II. Artificial ageing at a temperature of 170°C for a duration of 6 hours

### 2.5 Pin on disc wear tests

B the use of a computerized pin on disc test rig dry sliding wear test was done out as per the ASTM G99-95 standards. The following variants of tests were carried out.

- I. The loads is varying from 10N to 60N and it is at a consistent sliding velocity of 0.523 ms<sup>-1</sup>
- II. The load is constant which is of 20N and the sliding velocity varying from 0.3 ms<sup>-1</sup> to 1.5 ms<sup>-1</sup>

At the room temperature all the wear tests were conducted and in presence of ambient air. A track radius of 100mm was used for all test runs, and also all the tests were conducted for a duration of 30minutes. The wear rate was found using the volume loss in terms of mm<sup>3</sup>m<sup>-1</sup>. The coefficient of friction ( $\mu$ ) was resolved from the frictional force being shown on the tester. The following formulae were used for the calculations

$$\text{Wear rate} = \frac{\text{height loss} \times \text{area}}{\text{sliding distance}} \text{ mm}^3\text{m}^{-1} \quad (1)$$

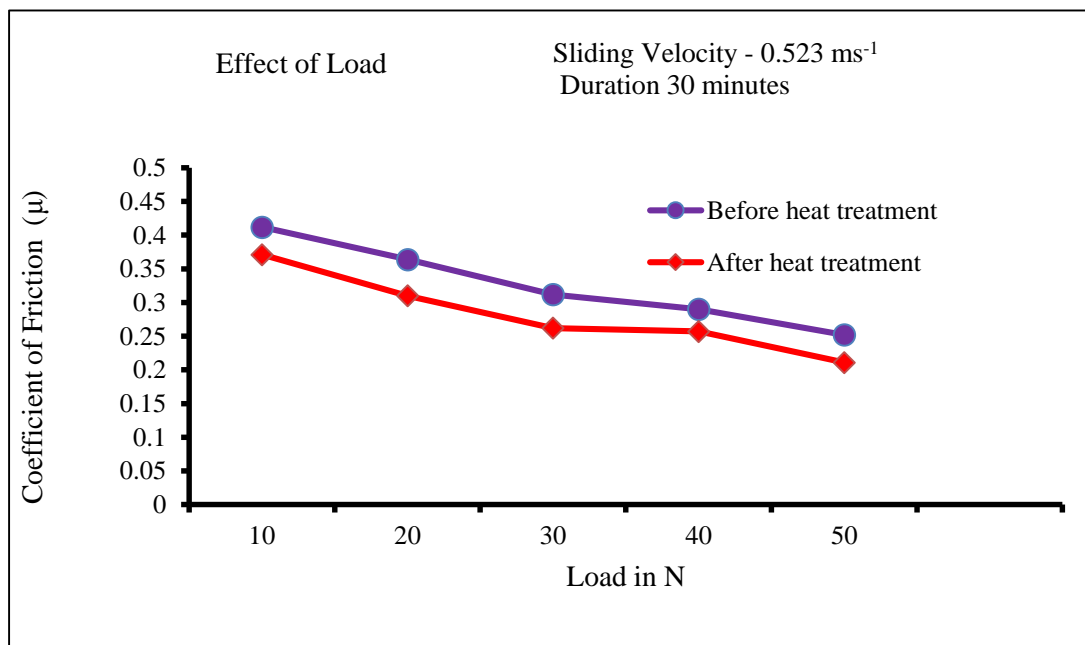
$$\text{Coefficient of Friction } (\mu) = \frac{\text{Frictional force}}{\text{load}} \quad (2)$$

## 3. Results and Discussion

### 3.1. Co-efficient of Friction

#### 3.1.1 Effect of Load

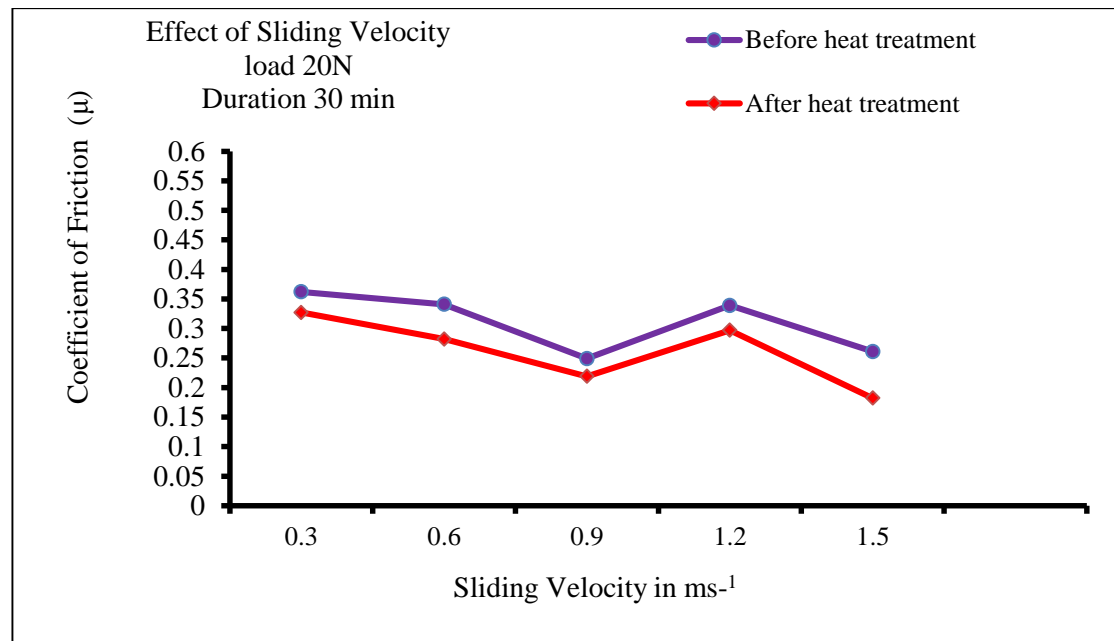
Figure 4 shows the variation of Co-efficient of friction ( $\mu$ ) of Al2014-10wt% SiC Composite at different loads and at a constant sliding velocity. It is examined that for all the loads, heat treated composites is having the lower co-efficient of friction as compared to non-heat treated composites and also the co-efficient of friction decreases for the both non-heat treated and heat treated composites. Further lower friction at higher load can be attributed to the excellent self-lubricating property of SiC.



**Figure 4.** Variation of Co-efficient of friction ( $\mu$ ) of Al2014-10wt% SiC Composite at different loads and a constant sliding velocity.

### 3.1.2 Effect of Sliding Velocity

It is observed that in figure 5 initially up to 0.9m/s the co-efficient of friction decreases with sliding velocity for both non-heats treated and heat treated specimens. This can be attributed to the fact that at smaller sliding velocities, the contact areas are quite high resulting in high friction. However beyond 0.9m/s and 1.2m/s the increase in co-efficient of friction can be due to destruction of the tribo film formed between the two sliding surfaces. Between 1.2m/s and 1.5m/s with increase in sliding speed the co-efficient of friction decreases for both heat treated and non-heat treated composites.



**Figure 5.** Variation of Co-efficient of friction ( $\mu$ ) of Al2014-10% wt SiC Composite at different sliding velocities and constant load.

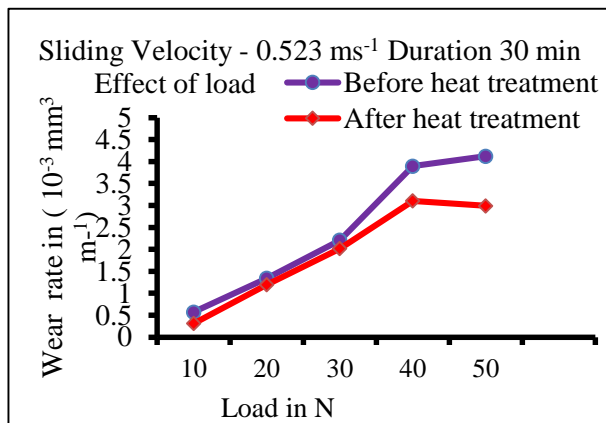
## 3.2 Wear

### 3.2.1 Effect of load

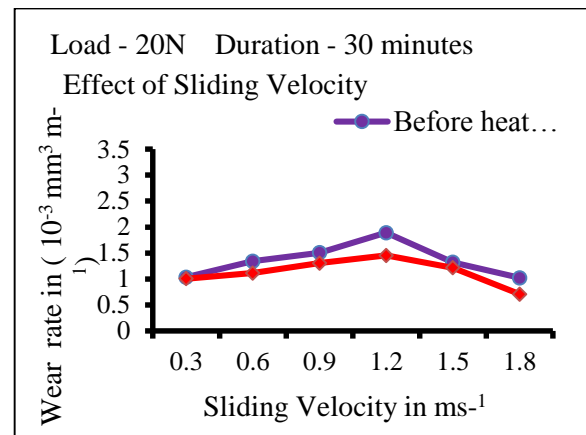
It is observed that in figure 6 there is a linear increase in wear rate of the developed composites by increasing load. Higher the load the extent of plastic deformation of the developed composite increases. This in turn results in formation of surface and sub surface cracks which results in the formation of wear debris causing higher wear rate.

### 3.2.2 Effect of Sliding Velocity

From the figure we observed that with sliding velocity up to 1.2m/s the wear rate increases gradually and then it decreases with sliding velocity for both heat treated and non-heat treated developed composites. For sliding velocity greater than 1.2m/s the decrease in wear rate, can be attributed to the squeezing out of tribo layers of combination of metallic oxides and spinals (complex metal oxide). However for all sliding velocities studied also in load studied heat treated composite exhibit excellent wear resistance compared with non-heat treated composites.



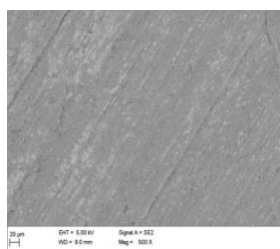
**Figure 6.** Variation of wear rate of Al2014-10wt% SiC composite at different load and constant sliding velocities.



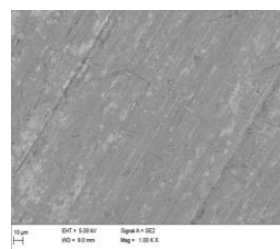
**Figure 7.** Variation of wear rate of Al2014-10wt% SiC composite at different sliding velocities and constant load of 20N.

### 3.3 Scanning Electron Microscopic (SEM) Studies

Figure 8 and figure 9 showing the SEM images of the weary surface of the pins, at 50N of load, 0.523 ms<sup>-1</sup> sliding velocity and a test duration of 30 minutes before and after heat treatment respectively. It is observed that the damage to worn surface of the developed composite after heat treatment is significantly lower. It appears smoother when compared with non-heat treated composites.

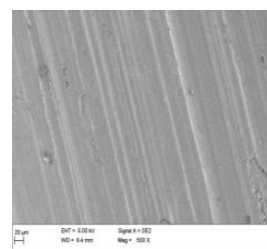


(a) 500X

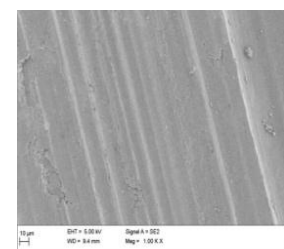


(b) 1000X

**Figure 8.** Scanning Electron Microscope image of worn surface of Al2014-10wt% SiC composite before T6 heat treatment.



(a) 500X

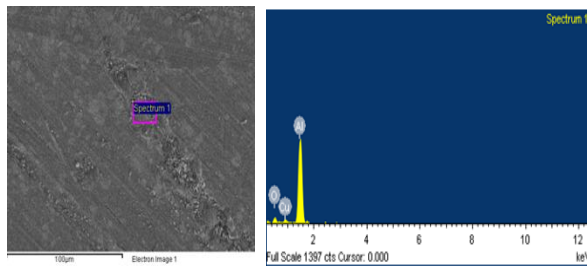


(b) 1000X

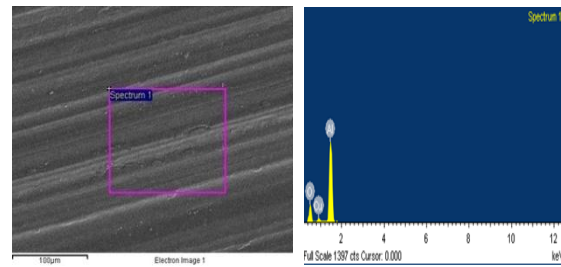
**Figure 9.** Scanning Electron Microscope image of worn surface of Al2014-10wt% SiC Composite after T6 heat treatment

### 3.4 EDAX Analysis

Figure 10 and Figure 11 describing the EDAX spectrum of the weary surface of the pins, at 50N load, sliding velocity of 0.523 ms<sup>-1</sup> and a test duration of 30 minutes. It is observed that the oxide films of aluminium are dominating the friction and wear behaviour of developed composites in both heat treated and non heat treated cases. The formation of oxide films is clearly evidence by the conformation of elements of aluminium, copper and oxygen in the EDAX spectrum of weary surface of developed composite.



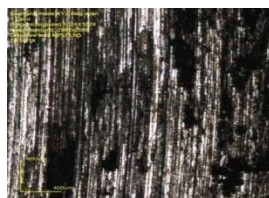
**Figure 10.** EDAX spectrum of the weary surface of Al2014-10wt% SiC composite before T6 heat treatment.



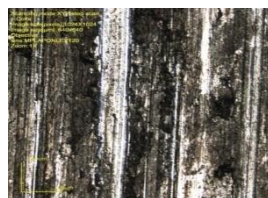
**Figure 11.** EDAX spectrum of the weary surface of Al2014-10wt% SiC composite after T6 heat treatment.

### 3.5 Confocal Microscope

Figure 12 and figure 13 shows the 2D Confocal images of the worn surface of the pin specimen at 50N of load,  $0.523 \text{ ms}^{-1}$  sliding velocity and a test duration of 30 minutes. It is clearly evident that the surface damage of the weary face of heat treated composite is significantly lower when compared with non-heat treated composites. This observation is similar to the observation of SEM of the worn surfaces, suggesting superior wear resistance of the developed composites on heat treatment. Confocal studies of worn surfaces confirm minimal surface damage to heat treated composites when compared to non-heat treated composites

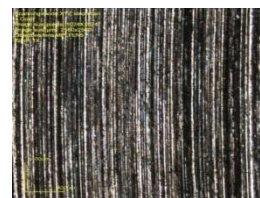


(a) 5X



(b) 20X

**Figure 12.** 2D Confocal images of the worn out surface of Al2014-10wt% SiC composite before T6 heat treatment.



(a) 5X



(b) 20X

**Figure 13.** 2D Confocal images of the worn out surface of Al2014-10wt% SiC composite after T6 heat treatment

## 4. Conclusions

Al2014-10wt% SiC Composites have been heat treated successfully to achieve the optimal hardness and the micro structural studies reveal very fine grain size after forging of Al2014-10wt% SiC Composites. The co-efficient of friction of Heat treated Al2014-10wt% SiC composites is lower at all the loads and speed studied when compared to non-heat treated composites. Similarly the wear rate of heat treated Al2014-10wt% SiC composite is lower at all the loads and speed studied when compared to non-heat treated composites. SEM and Confocal studies of worn surfaces confirm minimal surface damage to heat treated composites when compared to non-heat treated composites.

## 5. References

- [1] Singh K K, Singh S, Shrivastava 2017 Comparison of wear and metal matrix composite under dry condition at different sliding distance *Materials today* **4** 8960-70.

- [2] Abreu C M, Acuna R, Cabeza M, Cristóbal M J, Merino P, Verdera 2017 Microstructure and mechanical properties of Al/SiC composite surface layer produced by friction stir processing *Ciencia and Tecnologia dos materiais* **29** 82-86.
- [3] Rajeshkannan A, Narayan S 2017 Hardness, tensile and impact behaviour of hot forged aluminium metal matrix composite *Journal of materials research and technology* **6** 213-19.
- [4] Purohit R, Qureshi M and Rana R S 2017 The effect of hot forging and heat treatment on wear properties of Al 6061-Al<sub>2</sub>O<sub>3</sub> nano composites *materials today* **4** 4042-48.
- [5] Parchoviansky M, Balko J, Svancarek P, Sedlacek J, Dusja J, Lofaj F and Galusek D 2017 Mechanical properties and sliding wear behaviour of Al<sub>2</sub>O<sub>3</sub>-SiC nanocomposites with 3-20 vol SiC *Journal of the European ceramic society* **37** 4297-06.
- [6] Das Diptikanta, Patk Swati, naik, Routara Chandra, Mishra Purna Chandra and Samal 2017 dry sliding wear behaviour of SiC<sub>p</sub> reinforced Zn-Mg-Cu based aluminium matrix composite *materials today* **4** 2965-74.
- [7] Erturun Veysel, Karamis Baki M 2016 effects of reciprocating extrusion process on mechanical properties of AA 6061/SiC composites *Transactions of nonferrous metals society of china* **26** 326-38.
- [8] Rana R S, Purohit Rajesh, Soni V K, Das 2015 Characterization of mechanical properties and microstructure of aluminium alloy-SiC composites *materials today* **2** 1149-56.
- [9] Ramesh C S, Keshavamurthy R, Naveen G 2012 Effect of extrusion ratio on wear *Wear* **271** 1868-77.
- [10] Kumar G B Veeresh, Rao C S P, Selvaraj 2012 Studies on mechanical and dry sliding wear of Al6061-SiC composites *Composites Part b: Engineering* **43** 1185-91.