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# 3 BODY ABRASIVE BEHAVIOUR OF AL6061-WC METAL MATRIX COMPOSITE

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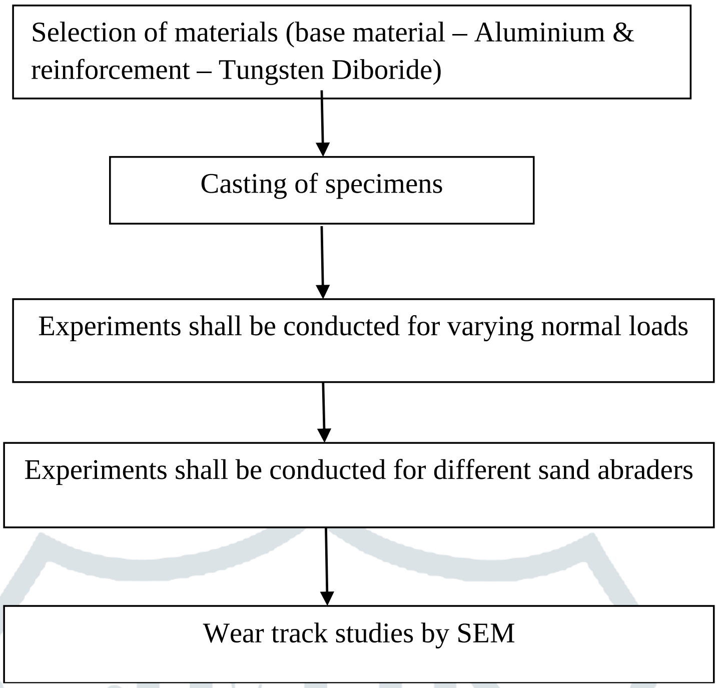
***Abstract :*** Men and materials have a symbolic relationship throughout the ages. Man has preferred new materials and these materials have changed the lifestyles of mankind. In fact, new materials have helped in an advanced state of human society. Metal matrix composites are the subcategory of metallic materials possesses better properties over monolithic materials such as high strength, stiffness, hardness, better weight to density ratios etc. Understanding and controlling of friction and wear is a strong need in the area of materials technology. In the present study Al-WC metal matrix composite by in-situ stir casting process by varying the weight percentage of reinforcement as 3%, 6% and 9%. Attempt has been made to understand the role of hardness, micro structural features abrader impact and levels of load on elastic and inelastic deformation. Hardness was found to increased with increase in percentage of reinforcement. The volume loss was found to be maximum at higher normal load and minimum at lower normal load. Volume loss is found to be sensitive at higher hardness and depends on the abrader size & increasing with increase in size.

## I. INTRODUCTION

**Metal matrix composites (MMCs)** are the materials consists of two or more constituents and act as one metal. Agent such as different materials like ceramic or organic compound is acting as one more material. MMCs are manufactured by means of adding or reinforcing an agent into a matrix. Al6061 is the form of aluminum alloy containing magnesium and silicon as major alloying elements, commonly used for aerospace, marine applications, cycling and automotive applications and to make gas cylinders [1]. Tungsten carbide (WC) is one of the hardest ceramic powders very good mechanical properties, when it is mixed with pure aluminium. It can be able to pressed and formed into any shape from the manufacturing process like powder metallurgy and casting [2].

Wear is the failure of surface in the form of losing from one surface to another when rubbing it with one another. Wear is progressive failure of material which results to permanent damage as continuous rubbing takes place between two metallic surfaces. As per the survey around 60% of failures are happened due to surface failures i.e., from tribological actions. In most of cases, addition to friction and wear, invariably the contacting surfaces will be of non-conforming type resulting in Hertztian types of stresses which lead stress analysis a complicated issue. It is difficult to understand the wear mechanism in the view of complexities occur in friction. There are many types of failures such as invariable displacement, unknown forces, unknown magnitude velocities creates failure both elastically & plastically happened in fracture in further stage of servile life of the components. It is important to identify all these failures by conducting laboratory level experiments to simulate wear conditions in the field. There are $10^{-15}$ to $10^{-1}$ $mm^3$/ N-m range wear rate was varied which was found that from different scientists in variety of lab simulated experiments. Nature of wear depends upon the condition of operation between the elements [3-9]. **Ronaldo, Camara Cozza** [10] postulated a variety modes of abrasive wear mechanism where a during rolling and identify the wedge mode of wear on Aluminum based MMC. **Yusuke Morioka et al** [11] co-relate abrasive wear with fatigue and tensile properties of filler dispersed polyimide and identified that the mechanism of abrasive wear was depends on various velocities during sliding. **Kenneth, Budinski** [12] studied the abrasive behaviour of non-metallic materials like plastics. Target materials were made of wide variety of plastics Test results indicated that only one type of polyurethane had better abrasive wear resistance & abrasion depends on material property. **XiaojunXu** et al [13] tried to understand the wear and subsurface deformation of construction steels indenter scratch tests were conducted abrasion resistance of a material depends on the nature of work hardened layer and its thickness formed beneath the abrader surface. **Sharath N et al** [14] used the Al-6061 reinforced with varied percentage of graphite and boron. Fabricated metal matrix composites shows the clear interface between the matrix and reinforcement and the wear rate decreases. **Hemaraju** [10] attempted to study the impact of normal load and abrader on metallic surfaces i.e., on En category steels. Results was found with the volume loss of the material will depends on normal load and the plastic deformation was increased due to increase in abrader size also found three modes wear namely cutting mode, wedge mode and ploughing mode. In the present investigation attempt has been made to understand the role of hardness, micro structural features abrader impact and levels of load on elastic and inelastic deformation. The tests are conducted using rubber wheel abrader following G-65 standards.

## II. Methodology




## III. Material selection & fabrication

Al6061 was used as a matrix material with density 2.8 gram/centimeter$^3$, tensile strength of 310 MPa and modulus of elasticity 70 GPa. Tungsten carbide (WC) is one of the hardest ceramic powder particles, used as reinforcement with aluminium alloy. Different weight percentage (3%, 6% & 9%) of tungsten carbide was used as a reinforcement material.

Stir casting is a process and it is one of the classifications of liquid state method, which is used to manufacturing the composites in order to make sure the uniform allocation of reinforcements material. First Aluminium 6061 was melted in a electrical furnace. The reinforcement WC was preheated and then it was added to a molten metal and mixed frequently. The mixing was takes place at 460 rpm for 6 minutes by with the help of impeller in order to make sure the consistent inclusion of a WC particles into Aluminium 6061.The stir casting process as shown in the fig 1.

Fig. 1. Fabrication process by stir casting

After pouring the using surface grinding machining to the dimensions shown in the figure.3. molten metal into a mould of diameter 28 mm and length 250 mm, the specimens were machined using horizontal axis milling machine and grinding

Fig.2.Fabricated Samples

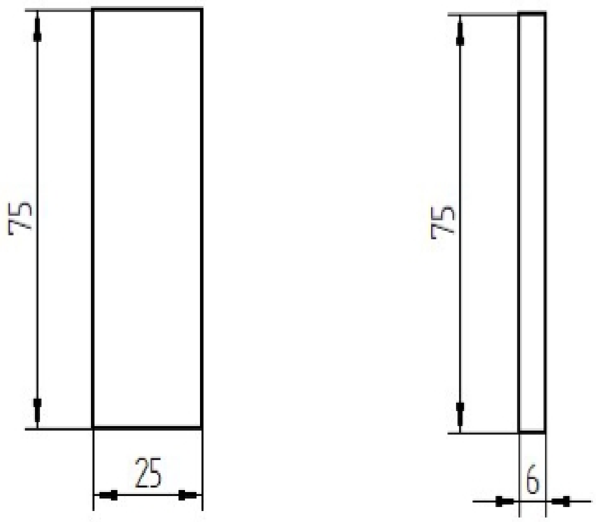



Fig. 3. Fabricated samples after machining

## IV. EXPERIMENTATION

Brinell hardness test was conducted in order to measure the brinell harness of the Al-WC metal matrix composites as per the standard ASTM E10.The indenter of diameter 10mm is placed on the specimen and the force of 5000 kg is applied to the indenter. The force is applied for 10 seconds. Now the indenter is removed after 10 seconds. The diameter of the indentation is measured, the surface area of the circular indent is determined, and then the hardness is calculated.

**Dry sand abrader test**

For carrying out three body abrasion test dry sand rubber wheel abrasion test rig was selected for conducting the experiments. The dry sand wheel abrasion experiments were conducted in the material science laboratory in the department of Industrial & Production engineering, The National Institute of Engineering, Mysuru.

The test involves the rubbing the specimen of standard dimensions. The abrader is selected as sand of known size distribution. The test specimen was fitted in to the specimen holder. Leverage load was calculated and obtained load was applied to loading pan. Then the abrader was allowed to flow between rubber wheel and the target specimen. This procedure was conducted to the desired time. After that the specimen was removed from job holder. The abraded area of the specimen was cleaned using acetone and it was dipped in to oil. The specimen is weighed before and after the experiments, in order to determine the weight loss of the specimen which occur due to wear. Dry sand abrasion tester is shown in the figure 4.


Fig.4. Dry sand abrader test rig

The parameters such as normal load, wheel speed, flowing time, abrader flow and materials with different reinforcement are shown in the table 1.

Table.1. Parameters selected for experimentation

| Sl no. | Reinforcement Percentage in Weight Grams | Load in N | Rubber Wheel speed in rpm | Flowing time in minute | Abrader flow in grms/min | Grain size |
|---|---|---|---|---|---|---|
| 1 | 3% | 53.22<br>102.4 | 200 | 8 | 100 | 102 |
| 2 | 6% | 53.22<br>102.4 | 200 | 8 | 100 | 212 |
| 3 | 9% | 53.22<br>102.4 | 200 | 8 | 100 | 425 |

## V. Result and Discussions

In the present study a sand abrader was used to conduct the experiments in order to simulate field conditions. 3% weight percentage of Al-WC MMC (46.834 BHN), 6% weight percentage of Al-WC MMC (49.714 Brinell hardness number) and 9% weight percentage of Al-WC MMC (58.645 Brinell hardness number).

The volume loss of target specimens were calculated and tabulated in the table.2.

Table.2: Volume loss of different reinforcements with respect to hardness

| Weight % of tungsten carbide | Brinell Hardness number | Volume loss for a normal load of 53.5 N | Volume loss for a normal load of 102.4 N |
|---|---|---|---|
| 3 | 46.834 | 0.85 | 0.41 |
| 6 | 49.714 | 0.57 | 0.28 |
| 9 | 58.645 | 0.15 | 0.078 |

The estimated hardness for 3 weight percent tungsten carbide reinforced MMC is 46.834 BHN. In the same manner the estimate hardness for the 6-weight percent tungsten carbide is 49.714 BHN. The estimated hardness for 9 weight percent of tungsten carbide is 58.645 BHN. From the graph it is found that, the hardness is maximum for 9 weight percent tungsten carbide and minimum for 3 weight percent tungsten carbide. The estimated volume loss with respect to the hardness & normal load for different percentages of reinforcement as shown in figure 6.1.

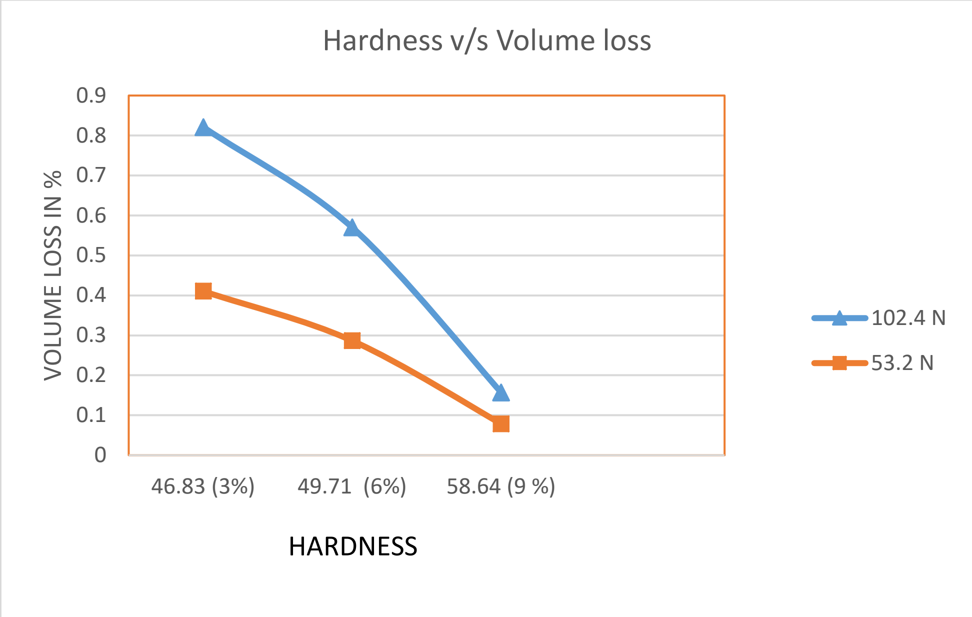



Fig 5. Dependency of hardness on weight percentage of tungsten carbide

The estimated volume losses for different percentage of reinforcements at different loads are shown in figure 5.

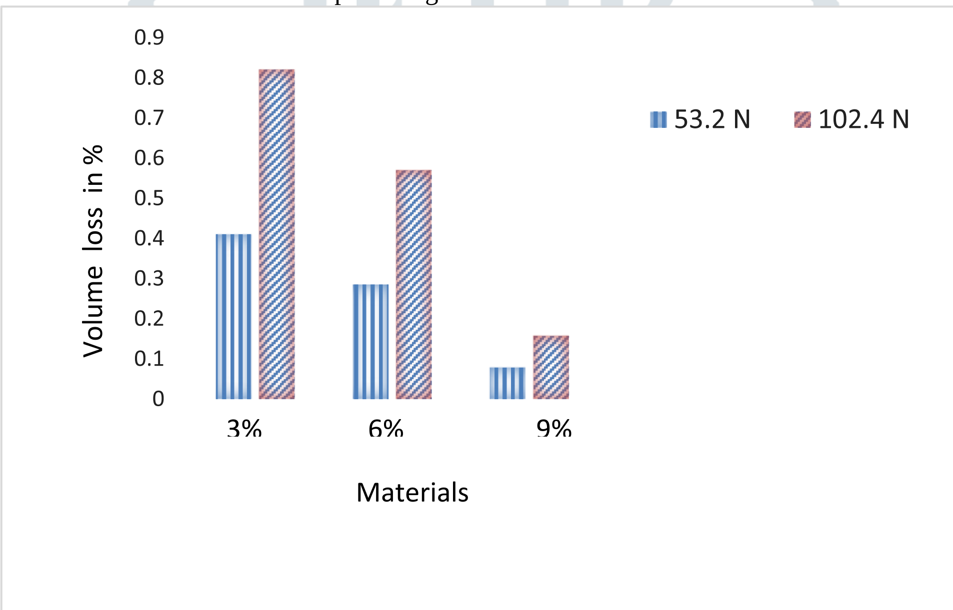
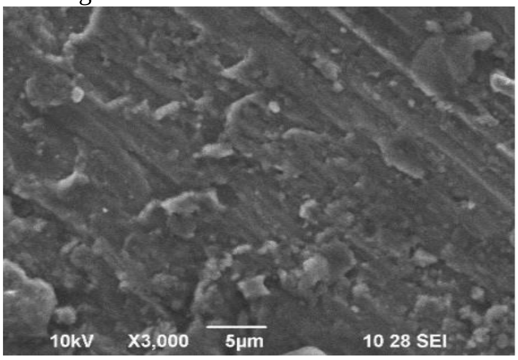



Fig 6. Bar graph of volume loss for 3 varied reinforcements for normal loads.

The estimated volume loss for 3 % reinforcement is 0.41 at a normal load of 53.22 N and 0.85 at a normal load of 102.46 N. The estimated volume loss for 6 % reinforcement is 0.28 at a normal load of 53.22 N and 0.57 at a normal load of 102.46 N. The estimated volume loss for 9 % reinforcement is 0.078 at a normal load of 53.22 N and 0.15 at a normal load of 102.46 N. The volume loss was minimum for 9 % reinforcement and maximum for 3 % reinforcement.

Morphological analysis was done using Scanning electron microscope in order to find the weight loss under different normal loads and graded abraders.



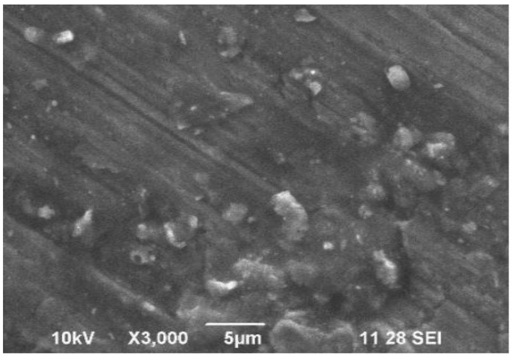




Fig.7 - 3% Reinforcement for a constant load of 53.2 N & 102.4 N

Figure 7. (a) & (b) Shows the micrograph of 3% reinforcement loaded Al-Wc MMC in the magnification of 3000 x. The micrograph (a) of figure 7 corresponds to a normal load of 53.2 N The surface of the specimen was viewed

with sample of small deep grooves with crushing of soft layer by penetration of asperities. The micrograph (b) of figure 6.3 corresponds to a normal load of 102.4 N, showing the ploughing marks and delaminated area. The worn-out area also shows the severe inelastic deformation which confirms the nature of abrasive mode of wear.

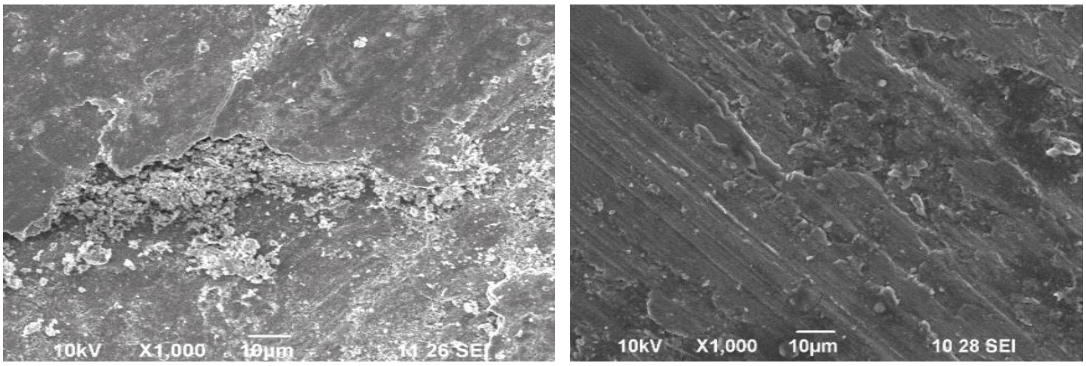



Fig.8. - 3% Reinforcement for a constant load of 53.2 N & 102.4 N

Figure.8. (a) & (b) Shows the micrograph of 6 % reinforcement loaded Al-Wc MMC in the magnification of 1000 x. The micrograph (a) of figure 8 also corresponds to a normal load of 53.2 N shows the indication of removal of oxide layer with small shallow grooves at the right side of the micrograph. The micrograph also revealed small pits all over the area which confirms the nature of adhesive wear. This may be due to the increase in the temperature caused due to friction, softening the matrix. The micrograph (b) of figure 8 also corresponds to a normal load of 102.4 N. The worn surfaces of sample dipping type of shallow grooves running parallel to the sliding direction and layer removal in chipped form indicate the main wear mechanism as abrasive.

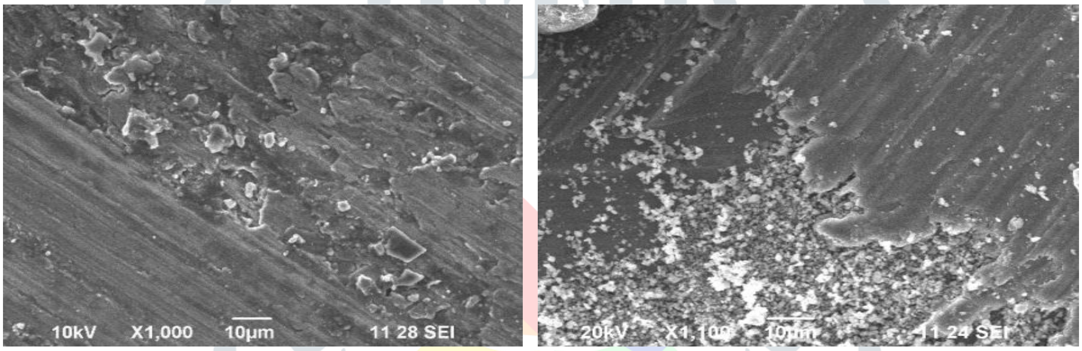



Fig. 9- 9 % Reinforcement for a constant load of 53.2 N & 102.4 N

Figure 9 (a) & (b) shows the micrograph of 9 % reinforcement loaded Al-Wc MMC in the magnification of 1000 x. The micrograph (a) of figure 9 also corresponds to a normal load of 53.2 N. The presence of cracks in 9 (a) is shows the nature of removal of reinforcement particles due to low bonding strength between the reinforcement and matrix. Deepest groove in terms of severe elastic deformation was spread all over the area of micro-graph due to main mechanism of abrasive wear. The micrograph (b) of figure 9 (b) also corresponds to a normal load of 102.4 N. The presence of crack, broken oxide layer-flaky debris, and pores in the worn surface shows signs of abrasive wear.

## VI. CONCLUSIONS

1. **CC** Matrix was successfully fabricated using stir casting processes with varying percentages of reinforcement.
2. Hardness was found to increased with 3 Al-WC MMC (46.834 BHN), 6% weight Al-WC MMC (49.714 BHN) and 9% Al-WC MMC (58.645 BHN) .
3. The volume loss of the material minimum at a normal load of 53.2 N & maximum at 102.4 N.
4. At higher hardness, wear loss was found to be not much sensitive to normal load.
5. Increasing the reinforcement content from increases the hardness and wear resistance of the composites but reduces its ductility.
6. Similar nature of wear was found throughout the experiment hence coefficient of friction was found to constant with applied normal load.

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