Assessment of Wear rate and Coefficient of Friction of Al6262 WC/MoS2 under wet sliding condition

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Abstract. The present paper aims at the results of an experimental examination of hybrid metal matrix composites using stir-casting technique. Aluminum alloy (Al 6062) samples reinforced with Tungsten Carbide (WC) and Molybdenum diSulphide are given. 2wt.%, 4wt.%, 6wt.% of MoS2 and 3 wt.%, 6 wt.%, 9 wt.% tungsten carbide were mixed together with the aluminum alloy to create the hybrid composite. The tribological aspects of aluminium composites were studied using Pin on disc Method under wet sliding condition. Testing the hybrid composites’ hardness revealed that raising the weight percentage of tungsten carbide might raise the hybrid composites’ hardness. To examine the wear behavior of hybrid composites, the Taguchi method was utilized in the design of experiments (DOE) approach. The factors that were found to affect wear rate included load, sliding speed, and reinforcing percentage of WC and MoS2 are the most influencing parameters.

Keywords: Tribological Assessment, Wear Rate Measurement, Coefficient of Friction Analysis, Al6262 Alloy, WC/MoS2 Composite

1. Introduction

The wear and frictional behaviour of metals has been described in a number of research works. But there's still a need to comprehend the metal behaviour in many tribological contexts [1-3]. Studies on the tribological characteristics of several metal types have been published recently, including as brass, aluminum, and steel grades. Research on tribological characteristics of WC and Al alloy composites are in demand as machine weight reduction becomes more and more necessary in automobile sector [4]. Japan is one of the first countries in the automotive industry to adopt fiber-reinforced composites for cylinder liners, piston rings, and pistons because of their lower weight and resilience to wear [5]. However, because of the abrasive action of the fragmented fibers, fiber-reinforced composites frequently have a negative effect on the mating material. In these circumstances, materials with great strength and low weight have taken on a unique significance [6]. Nearly all composites are lightweight, yet depending on the kind of reinforcements used, strength may be compromised. Occasionally, providing service in environments with greater temperatures and significant part friction is also necessary [7]. However, it is discovered that the majority of published works concentrate on the usage of metals, with experiments carried out to meet particular operational parameters, such as applied load, environmental temperature, sliding speed, and sliding distance [8]. Because operational parameters have a major impact on how metals behave whether in dry or wet lubricant contact, understanding the wear and frictional behavior of the metals is therefore difficult and incomparable [9]. By combining Al2O3/graphite composite in the material structure, wear resistance of Al6061 alloy is improved. According to the research, dual ceramic composites outperform than pure Al6061 in terms of wear enhancement [10]. The density, hardness, and wear resistance qualities of Al6061 alloy increase as the weight percentage of SiC increases when 2–6% SiC is added [11]. The better wear characteristics of the hybrid composite Al7075/Al2O3, which contains 2-8% Al2O3 and 5% graphite, wear resistance qualities. Additionally, when the quantity of alloying elements grows, the tribological characteristics such as compressive, flexural, and tensile strength in relation to the base alloy [12]. Wear happens when material is moved as debris or when hard particles slip off the surface.

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The best wear parameters for MMCs can be found using the Taguchi approach, according to published research [13]. A wear test on aluminum alloys that had 20 wt% Al2O3 particles added. They consequently concluded that the wear resistance was influenced by the following parameters: wear path, wear rate, wear load, and reinforcement particle ratio [14].

2. Experimental Setup

Al 6262 has been chosen as a base material due to its excellent weldability, strong corrosion resistance, and superior material properties. MoS2 is employed as reinforcement due to its natural capacity for self-lubrication. The tungsten carbide is chosen as a primary reinforcement for its superior strength. The reinforcements are heated to 500°C for 25 minutes prior to casting. The reinforcement was warmed before the Al6262 was melted at 550°C to 650°C in a graphite furnace. After the reinforcement, magnesium is added at a rate of 2% to the aluminum matrix, and the mixture is agitated for 10 minutes at 800 rpm to avoid explosions [15]. The experiments were carried out using a computerized Pin-on-Disc wear test machine shown in Fig. 1. The 4T 20W40 Green Engine Oil lubricant was employed between the rotating disc and pin during the testing, which were conducted under wet sliding conditions. Under varied operating conditions of sliding velocity, sliding distance, and applying load, the frictional force and coefficient of friction of the various sliding surfaces were measured. The Wirecut machined sample was shown in Fig. 2. The chemical combination of the base material is shown in Table 1.

Table 1. Typical chemical composition for aluminum alloy 6262

<table>
<thead>
<tr>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Zn</th>
<th>Ti</th>
<th>Cr</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.12</td>
<td>0.25</td>
<td>0.08</td>
<td>0.75</td>
<td>1.05</td>
<td>0.15</td>
<td>0.10</td>
<td>0.23</td>
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Fig. 2. Wet Sliding Pin On Disc Setup

Fig. 2a. Wet wear test samples

3. Design of Experiments

The experiment design employed in this investigation, which has three levels and five factors, is displayed in Table 3. The weight % of tungsten carbide, weight percent of molybdenum disulphide, load, sliding velocity, and sliding distance are the input parameters. Table 2 displays the composites' hardness value. Hardness values rise with an increase in the weight % of the composites and an intermediate level of MoS2 percentage [16-19]. Table 3 displays the selection of the L27 orthogonal array for the studies based on these criteria. The hardness of the composites is displayed in Table 2. The level and factors of input parameters are shown in table 3.

Table 2. Hardness of the composites

<table>
<thead>
<tr>
<th>WC</th>
<th>3</th>
<th>3</th>
<th>6</th>
<th>6</th>
<th>9</th>
<th>9</th>
<th>9</th>
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<tbody>
<tr>
<td>MoS2</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>BHN</td>
<td>76</td>
<td>80.2</td>
<td>75.6</td>
<td>81.5</td>
<td>84.3</td>
<td>80.2</td>
<td>87.6</td>
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<thead>
<tr>
<th>WC</th>
<th>MoS₂</th>
<th>BHN</th>
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</thead>
<tbody>
<tr>
<td>3%</td>
<td>2%</td>
<td>57</td>
</tr>
<tr>
<td>6%</td>
<td>4%</td>
<td>58</td>
</tr>
<tr>
<td>9%</td>
<td>6%</td>
<td>60</td>
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</tbody>
</table>

#### Table 3. L27 Levels and Factors

<table>
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<th>Factors</th>
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<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>WC</td>
<td>%</td>
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<td>6</td>
<td>9</td>
</tr>
<tr>
<td>MoS₂</td>
<td>%</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Load</td>
<td>N</td>
<td>15</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>Sliding Speed</td>
<td>m/sec</td>
<td>1.2</td>
<td>1.6</td>
<td>2</td>
</tr>
<tr>
<td>Sliding Distance</td>
<td>m</td>
<td>500</td>
<td>1000</td>
<td>1500</td>
</tr>
</tbody>
</table>

### 4. Result and Discussion

![Main Effects Plot for SN ratios WEAR LOSS](image)

Fig. 3. displays the wear rate signal to noise ratio. Reduced wear rate is correlated with a reduced tungsten carbide weight percentage. The findings indicate that the maximum wear rate is offered at 3% of WC. The composite material's hardness is to blame for this. Hard particles are generally thought to contribute significantly to the wear resistance of the base alloy when added to aluminum alloys. The composites' hardness decreases to 3% tungsten carbide. This tendency causes the material to have a lower density, which increases wear loss. Apart from 6% and 9%, there is an increase in hardness and a decrease in wear loss. The material has a higher hardness when MoS₂ is at 6% and WC is at 9%. The self-lubricating qualities of the materials improve as the amount of MoS₂ increases, reducing the friction between the pin and the disc and ultimately leading to material loss. As the applied stress increases, more of the softer pin surface is penetrated by the harder deformation of the counter surface [25-28]. When the applied load reaches 20 N, which occurs shortly after each composite's critical load, the wear rate begins to increase [29-30]. The wear rate jumps to an extremely high degree at 30N of stress. The optimum combination for reducing wear rate is 9 wt% of tungsten carbide, 2 wt % of MoS₂, and 15N of applied load, 1.6 m/sec of sliding speed, and 500 m of sliding distance.
Fig. 4. S/N ratio graph for Coefficient of Friction

Fig. 4. displays the coefficient of friction's signal to noise ratio. The optimum combination for reducing COF is 9 wt% of tungsten carbide 6 wt % of MoS2 and 15N of applied load 1.6 m/sec of sliding speed and 1000 m of sliding distance. The most important factor influencing the friction coefficient is the weight fraction of tungsten carbide. The first conclusion to be drawn from the data is the decrease in coefficient of friction that occurs when the weight percentage of the reinforcement increases. The aluminum 6262 alloy and reinforced AMMNCs were found to have a reduced coefficient of friction. It is explained by the composite's higher hardness, which comes from the abrasive particles mixed in and acts as a more resilient material inside the matrix [17-18]. When refractory bits are securely attached to the matrix, there is good surface adhesion between the matrices and non-reinforcing material. Numerous investigations have shown that the COF of crystalline MoS2 is normally modest, at 6% in a dry sliding state. Because of its self-lubricating qualities, MoS2 has a special lubricating capacity. One explanation for this is that MoS2 particles have strong adhesion in a dry environment, and smaller particle sizes can fill the rough surface of the substrate with ease. As sliding speed rises, a tribo layer at the contact surface continues to grow. Even while temperature rises with increasing sliding velocity, heat has some positive effects on the formation of an interracial layer that is enriched in WC, which in turn affects the formation of compact layers at the contact area. But if the sliding speed is increased above 1.5 m/s, a significant amount of heat is generated, which causes the composite pin to become softer and causes friction to rise.

4.1 ANOVA Analysis

The experimental findings were analyzed using Analysis of Variance (ANOVA), which is used to examine the impact of the wear parameters that are taken into consideration, namely, weight percentage of tungsten carbide, MoS2, applied load and sliding distance, sliding speed on the performance measurements. One can determine which independent factor predominates over the other and what percentage of that specific independent variable is contributed by using analysis of variance. The significance level of $\alpha = 0.05$, or a 95% confidence level, is used for this study. Sources were deemed to have contributed statistically significantly to the performance metrics if their P-value was less than 0.05.
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5. Worn Out Microscopic Analysis

The worn-out surface, determined by optical microscopic images, is seen in Fig. 5. Fig. 5a displays the 15N load, 4% of MoS2, and 9% of WC. Fig. 5b illustrates that 9% of WC, 6% of MoS2, and a 15N load are present. There is less wear loss in Fig. 5b as compared to Fig. 5a. Because of its hardness value, it is also discovered that the WC particles have less worn-out regions. It is widely acknowledged that...
incorporating hard particles into aluminum alloys significantly increases the underlying alloy’s resistance to wear. When refractor bits are securely attached to the matrix, there is good surface adhesion between the matrices and non-reinforcing material. When reinforced particles are securely attached to the matrix, there is good surface adhesion between the matrices and non-reinforcing material. Numerous investigations have shown that the COF of crystalline MoS2 is normally modest, at 6% in a wet sliding state. Because of its self-lubricating qualities, MoS2 has a special lubricating capacity. The 6% of WC, 6% of MoS2, and 25N load are displayed in Fig. 5c. Fig. 5d illustrates that 4% of MoS2, 6% of WC, and a 35N load are present. Figure 4e shows a superior surface polish than Fig. 5d. This is because the production of low shear strength thermo on the rubbing surfaces was aided by the higher surface temperatures at the contact area [20]. The 35% N load, 4% of MoS2, and 3% of WC are displayed in Fig. 5e. Fig. 5f illustrates that 2% of MoS2 and 3% of WC are present along with a 35N load. Because there is less MoS2 particle addition in Fig. 5f than in Fig. 5e, there is a noticeable loss of tungsten carbide particles.

6. Conclusion

In this current experiment Al 6262/WC/MoS2 with different weight percentage was successfully fabricated through stir casting technique. The Tungsten Carbide was chosen with different weight percentage of 3%, 6% & 9% and MoS2 was taken at 2%, 4% and 6%. Pin-on-Disc wear test machine was used to find the wear rate and COF for the developed composites in wet condition. At 9% of WC and 4% of MoS2 the hardness values is 92.2 BHN. From Taguchi optimization results the optimum combination for minimum COF is 9 wt% of tungsten carbide 6 wt% of MoS2 and 15N of applied load 1.6 m/sec of sliding speed and 1000 m of sliding distance. The ANOVA results shows the maximum percentage of contribution is weight percentage of WC 46.37 % for wear rate and applied load 35.75 % for Coefficient of friction.

References


