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Experimental Analysis of Wear Characteristics in Natural Fibre Composite Materials

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Abstract

In mechanical systems, energy loss and material degradation due to attrition are frequently the consequences of sliding contacts, which frequently lead to premature system failure. In this study, at 50°C, 80°C, and 110°C, the hardness was tested; the results showed that the values were 350.7, 422.5, and 455.5 HV, respectively. After conducting a high-temperature wear test, the mass loss of the as-deposited composite coatings was assessed by an electrochemical approach utilising a solution comprising 3.5% by weight NaCl for the corrosion evaluation. The corrosion test findings indicated that the total mass loss per unit area of the as-deposited sample decreased by about 65.2% after 0.25 hours, 43.1% after 1.25 hours, and 32% after 2.25 hours of exposure. The mean COF values were 0.8 at ambient temperature, 0.75 at 50°C, 0.63 at 80°C, and 0.51 at 110°C for S1, S2, and S3, respectively. With the increase in temperature, the coefficient of friction decreased from 0.75 to 0.51. The average wear was documented as 200 µm at ambient temperature, 160 µm at 50°C, 125 µm at 80°C, and 80 µm at 110°C for S1, S2, and S3, respectively. The wear decreased from 160 to 80 µm with the rise in temperature. The coatings included a substantial amount of composite material, resulting in the creation of a solid lubricating layer.

Keywords: Composite, corrosion, wear test, micro-hardness, temperature.

INTRODUCTION

Energy loss and material degradation due to attrition are frequently the consequences of sliding contacts in mechanical systems, which frequently lead to premature system failure [1-6]. Various techniques, including surface nitriding [7], the integration of tribologically durable fillers in composites [8], and the use of liquid lubricants have been utilised to reduce friction and wear. Coatings have always been a preferred method for producing slippery and wear-resistant surfaces [9-10]. Historically, several coatings such as carbides [11-12], metal nitrides, oxides and carbon-based compounds [13-16] have been used to mitigate friction and wear. Recently, machine learning and simulations have demonstrated considerable potential in the design of systems and materials for various applications, while also attracting interest for their ability to identify new tribological materials, thus enhancing experimental capabilities. 2D/layered materials are increasingly being recognised for practical tribological applications [17-23]. Tungsten disulphide (WS2), a lamellar substance, has low shear strength, making it advantageous for tribological applications [24-26]. Graphene has attracted considerable interest in several domains owing to its remarkable physical, thermal,

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mechanical, and electrical characteristics. Nonetheless, the sliding characteristics of solution-based 2D/layered coatings, including WS2 and mGR, remain inadequately understood [27]. Uncertainties about their long-term friction and wear-controlling efficacy persist. Attaining enduring low friction and elevated wear resistance across prolonged frictional cycles using solution-based coatings continues to be problematic. Berman et al. documented an escalation in friction on few-layer graphene-coated surfaces over 2000 cycles [28-31].

Nevertheless, when graphene from a solution was applied intermittently every 400 cycles, the coefficient of friction (COF) consistently stayed below 0.2 during the full 2000 cycles [29-30]. A primary technical goal is to attain consistently low coefficients of friction over many thousand friction cycles without necessitating intermittent lubricant reapplication during sliding. Moreover, composites composed of a minimum of two materials with distinct properties often demonstrate improved qualities owing to synergistic effects [31-33].

This work intends to generate and describe composite coatings using the HVOF technique for uses requiring wear resistance. The aim is to predict the micro-hardness, corrosion and tribological behaviour of the composite coating.

EXPERIMENTAL PROCEDURE

First, the steel substrates were prepared by grinding them between 200 and 1000 grit using emery paper. They were then polished with a 45±2μm grain size. The micro-hardness of the steel substrate was determined to be 350±5HV, and its surface roughness was assessed to be 0.5±0.01μm. The steel substrate showed a wear rate of 200μm and a coefficient of friction (COF) of 0.8 during the sliding test. High-quality composite coatings were sprayed utilising the HVOF thermal spray method to improve the steel substrate's resistance to wear. The effectiveness of the composite covering was evaluated in harsh environments with dry lubrication, in which the tribological system functions without the use of outside lubricant. Table 1 shows the various wear test parameters.

EXPERIMENTAL RESULTS

Micro-Hardness

The composite coating's micro-hardness data are shown in Figure 1. At 50°C, 80°C, and 110°C, the hardness was tested; the results showed that the values were 350.7, 422.5, and 455.5 HV, respectively. The higher bonding strength between the micron-sized coated particles and the changes in grain alignment at elevated temperatures are responsible for this improvement in hardness. A crucial part is played by the surface tribolayer development, which provides superior anti-wear qualities.

Corrosion Test

The composite coating's corrosion data are shown in Figure 2. After conducting a high-temperature wear test, the mass loss of the as-deposited composite coatings was assessed by an electrochemical approach utilising a solution comprising 3.5% by weight NaCl for the corrosion evaluation. Coatings exhibiting a crystalline structure demonstrated enhanced corrosion resistance relative to those with an amorphous structure. The corrosion test findings indicated that the total mass loss per unit area of the as-deposited sample decreased by about 65.2% after 0.25 hours, 43.1% after 1.25 hours, and 32% after 2.25 hours of exposure.

Table 1. Wear test parameter.

No.	Parameter	S 1	S 2	S 3
1	Temp. (ºC)	50	80	110
2.	Sliding velocity (m/s)	2	2	2
3.	Load (N)	80	80	80

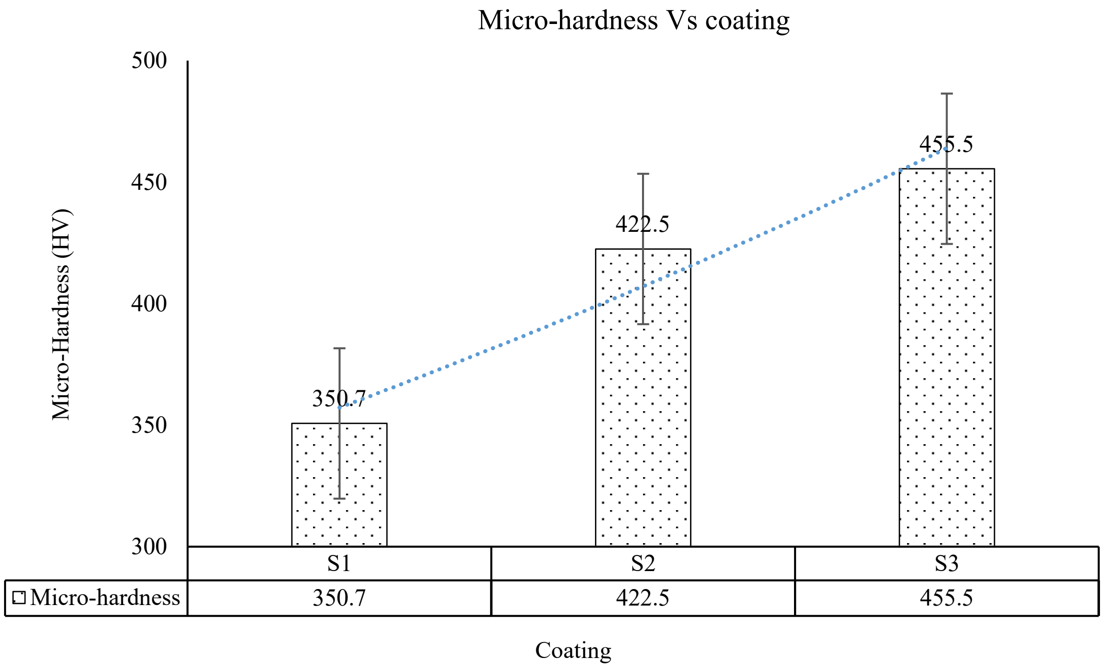

Figure 1. Micro-hardness result.

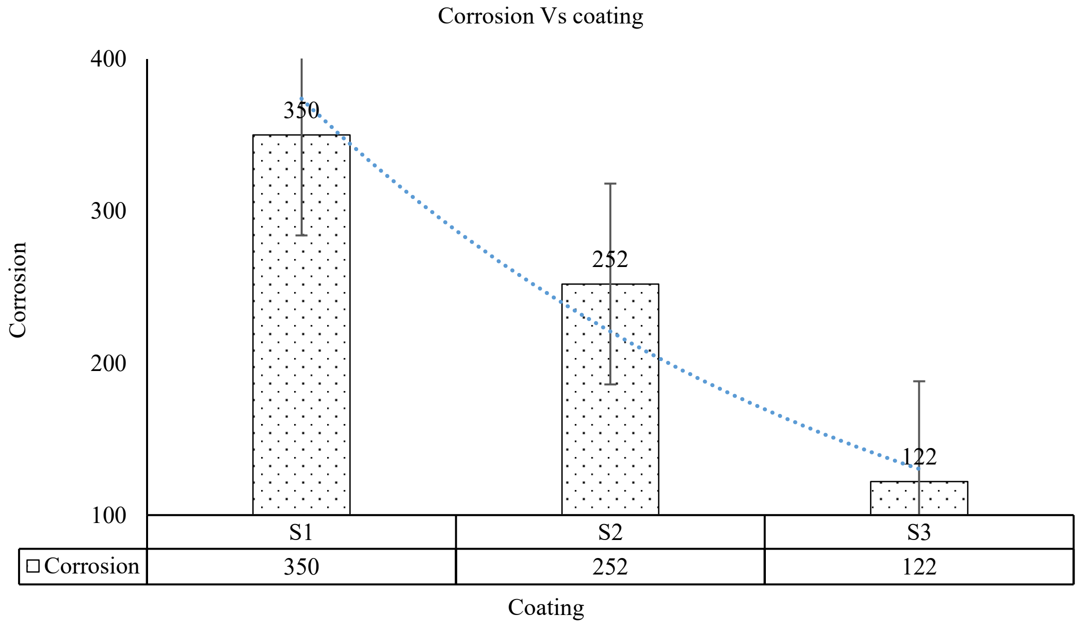

Figure 2. Corrosion test result.

Tribological Behavior

The experimental research aimed to evaluate the wear and coefficient of friction (COF) properties of composite coatings, focussing on their efficacy in wear-resistant applications. The evaluation of the coating's efficacy is primarily contingent upon both the coefficient of friction (COF) and wear, since both serve as critical indications. Figure 3(a) illustrates the fluctuation in coefficient of friction (COF) values for composite coatings evaluated at various temperatures. A cast iron cylinder liner served as the counter body in the experiments. The mean COF values were 0.8 at ambient temperature, 0.75 at 50°C, 0.63 at 80°C, and 0.51 at 110°C for S1, S2, and S3, respectively. With the increase in temperature, the coefficient of friction decreased from 0.75 to 0.51.

Figure 3(b) illustrates the relationship between wear and sliding distance under identical testing circumstances. The average wear was documented as 200 µm at ambient temperature, 160 µm at 50°C, 125 µm at 80°C, and 80 µm at 110°C for S1, S2, and S3, respectively. The wear decreased from 160 to 80 µm with the rise in temperature. The coatings included a substantial amount of composite material, resulting in the creation of a solid lubricating layer. The interaction between the coating and the counterpart induced graphitisation effects [29-34]. This lubricating layer is essential for decreasing the coefficient of friction and mitigating wear. In the preliminary stage of the running-in process, both the coefficient of friction (COF) and wear showed a transient rise prior to achieving stability.

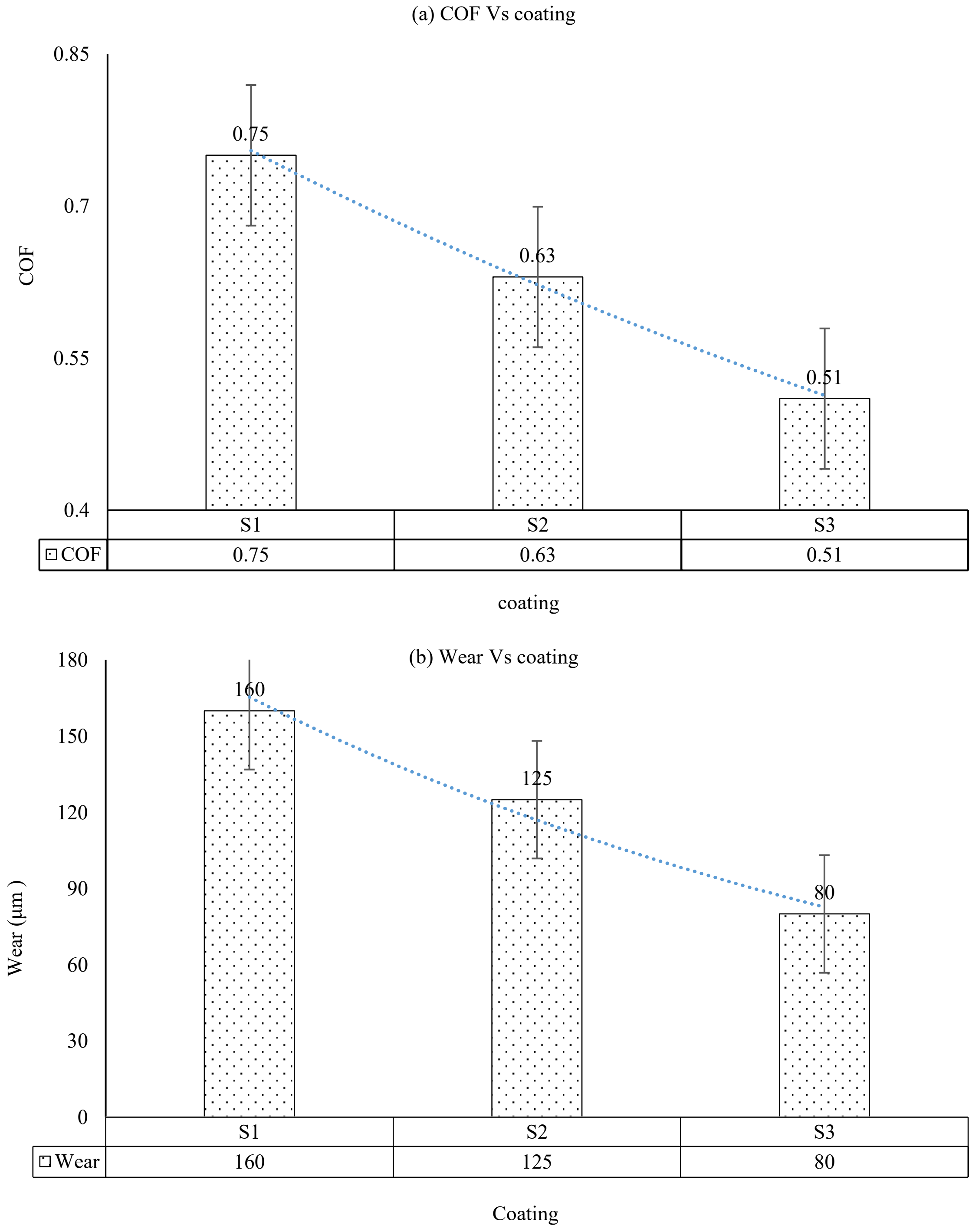

Figure 3. (a) COF (b) Wear result.

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CONCLUSIONS

We have effectively created and analysed composite coatings with the HVOF technology to improve wear resistance. This study presents new opportunities for the use of composite coatings on steel substrates, especially in sectors requiring superior mechanical strength, increased corrosion resistance, and higher performance regarding friction and wear. The main findings of the present investigation may be encapsulated as follows:

- At 50°C, 80°C, and 110°C, the hardness was tested; the results showed that the values were 350.7, 422.5, and 455.5 HV, respectively. Interestingly, compared to room temperature, 50°C, and 80°C, the hardness at 110°C was much greater. The higher bonding strength between the micron-sized coated particles and the changes in grain alignment at elevated temperatures are responsible for this improvement in hardness.
- The mean COF values were 0.8 at ambient temperature, 0.75 at 50°C, 0.63 at 80°C, and 0.51 at 110°C for S1, S2, and S3, respectively. With the increase in temperature, the coefficient of friction decreased from 0.75 to 0.51.
- The average wear was documented as 200 μm at ambient temperature, 160 μm at 50°C, 125 μm at 80°C, and 80 μm at 110°C for S1, S2, and S3, respectively. The wear decreased from 160 to 80 μm with the rise in temperature. The coatings included a substantial amount of composite material, resulting in the creation of a solid lubricating layer.
- The corrosion test findings indicated that the total mass loss per unit area of the as-deposited sample decreased by about 65.2% after 0.25 hours, 43.1% after 1.25 hours, and 32% after 2.25 hours of exposure.

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