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RESEARCH

Enhancing Abrasion Resistance in Jute/Epoxy Composites: The Role of Silicon Carbide Fillers in Wear Prevention

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A B S T R A C T

Natural fiber composites (NFCs) have garnered significant attention for their sustainability and cost-efficiency, particularly in applications demanding lightweight and eco-friendly materials. However, their mechanical and wear properties often require enhancement to meet the demands of structural and industrial applications. Hybrid composites, integrating fillers, offer a solution by improving the strength, stiffness, and abrasion resistance of NFCs. The current research investigates abrasive features of Jute fiber and silicon carbide (SiC) reinforced Epoxy based hybrid composites in a three-body abrasion scenario, examining various SiC loadings (0%, 5%, 10%, 15%). We conducted three-body abrasive wear tests to assess the specific wear rate across different combinations of these composites, taking into account filler content, abrasive distance, and applied load. The findings suggest that the incorporation of SiC as a filler in the composite leads to improved resistance against abrasion. To analyze the most influential factor affecting the abrasive behavior of these composites, we applied statistical methods, specifically Taguchi's L16 orthogonal array (OA). The statistical analysis revealed that the filler content is the primary factor influencing the abrasion resistance of the composites. Furthermore, we compared the experimental results with the predicted outcomes and found a strong agreement between them. Our SEM (Scanning Electron Microscope) micrograph studies provided insight into the dynamics of three-body abrasive wear and the underlying micro mechanisms that dictate the wear performance of these composites.

1. INTRODUCTION

The growing interest in sustainable materials has led to the development of natural fiber-reinforced polymer composites as a promising alternative to synthetic composites. Natural fibers such as jute, flax, sisal, and hemp have gained attention for their biodegradability, low cost, and relatively good mechanical properties.

The ever-increasing demand for materials capable of withstanding abrasive environments has led to the exploration of novel composite materials that combine the advantageous properties of natural fibers with the remarkable abrasion resistance offered by advanced ceramics. The many favorable attributes of natural fibers (NF), including their affordability, high specific strength, excellent strength-to-weight ratio, superior quality, biodegradability, and potential to substitute traditional materials, position them as promising candidates for reinforcement in polymer matrix composites (PMCs) [1]. However, the performance of the composites employing these natural fibres as reinforcements is determined by the characterisation of the natural fibres [2].

Among these, jute fibers have been extensively used due to their availability, high strength-to-weight ratio, and environmentally friendly characteristics. Jute-reinforced composites have found applications in a variety of industries, including automotive, construction, and packaging, where lightweight and eco-friendly materials are in high demand. However, one of the major limitations of natural fiber composites, particularly jute/epoxy composites, is their susceptibility to wear and abrasion, which restricts their use in applications requiring high surface durability [3].

Due to its superior qualities, such as tensile strength, elastic modulus, and density, jute has emerged as the most promising NF to be utilised as reinforcement in composite [4,5]. Jute fiber's natural roughness, moderate strength, and ability to interact effectively with matrix materials make it an ideal candidate for reinforcing composites in three-body abrasive wear applications, offering a balance between performance and sustainability. Researchers have employed jute to create composite materials for a variety of uses, including impact and wear [6,7].

Jute fibers, being abundant and biodegradable, have emerged as a prominent reinforcement material for polymer matrices, particularly in structural and semi-structural applications. Jute fibers possess good mechanical properties, including high tensile strength and modulus, making them a suitable alternative to synthetic fibers in certain applications. However, despite their many advantages, jute fiber-reinforced composites exhibit limitations, particularly in terms of abrasion and wear resistance. This limitation restricts their use in environments where surface degradation and material loss due to frictional forces are critical concerns [8].

Abrasion resistance is a critical property in materials used for various applications, including manufacturing, transportation, construction, and mining, where components are often subjected to abrasive wear under challenging operational conditions. Due to their affordability, high specific strength, favourable strength-to-weight ratio, biodegradability, and potential to replace traditional synthetic reinforcements in composite materials, natural fibres have attracted a lot of interest in recent years. However, the intrinsic vulnerability of natural fibers to abrasive wear has limited their broader utility in applications demanding durability under abrasive conditions.

Incorporating fillers into the matrix has been widely recognized as an effective approach to improve the wear properties of fiber-reinforced composites.

Hybrid composites represent specialized subsets within the realm of composites, created through the fusion of two distinct types of fibers or the introduction of fillers into a polymer or metal matrix. Typically, one of these components is selected for its superior strength characteristics, aligning with the specific demands of the chosen application [9]. Additionally, the cost-efficiency of production further broadens their suitability for a diverse range of applications [10–12].

In a study of the tribo-mechanical characteristics of hybrid flax/pineapple reinforcement and peanut oil cake, it was discovered that 20% of the flax/pineapple reinforcement exhibited superior mechanical characteristics. Taguchi's L27 orthogonal array was used to optimise the tribological characteristics [13]. The tribological performance of the PMCs is significantly influenced by the fibre choice, and other natural fibres are being investigated to enhance these qualities [14]. The construction of wind turbine blades also uses PMCs reinforced with natural fibres. In order to improve the wear resistance of the PMCs, filler particles have been added in recent trends.

A basalt fiber/epoxy composite that has been effectively filled with the industrial waste flyash showed improved micro-hardness [15]. By including carbonised bone powder and raising the load, the polypropylene composite's three-body abrasive wear rate was reduced [16]. The wear resistance of neat epoxy was found to be extremely poor at higher working conditions.

However, it was enhanced by the addition of fly ash, boron carbide, and molybdenum disulfide (MoS_2) to epoxy resin [17]. Studying the impact of adding areca nut nanofiller to coir/epoxy composites revealed that doing so improves the wear resistance of the coir epoxy composite [18]. Wear-resistant polymer composites have been developed using redbrick dust effectively as a filler [19–21]. Researchers also showed that Lindz-Donawitz (LD) slag might be a useful filler option for composite materials that are resistant to wear [22–25]. In concrete-based composites, rubber crumb works well as a filler and has improved mechanical characteristics and damage resistance [26–28]. It has been demonstrated that the addition of filler to polymers improves the composites' tribological performance.

Silicon carbide (SiC) is renowned for its exceptional hardness, wear resistance, and mechanical properties. It is widely employed in industries where abrasive wear is a primary concern, such as cutting tools, automotive brakes, and armor materials. The integration of SiC particles into composite materials has been explored to enhance their abrasion resistance. Combining the advantageous properties of natural fibers with the exceptional abrasion resistance of SiC within a composite matrix presents a compelling opportunity to develop materials that excel in abrasive environments [29].

Among various fillers, silicon carbide (SiC) stands out due to its exceptional hardness, thermal stability, and abrasion resistance. SiC particles, when dispersed within a polymer matrix, can effectively inhibit surface wear by forming a hard barrier that resists material removal during frictional contact. Several studies have demonstrated the success of SiC fillers in enhancing the wear performance of polymer composites, but limited research has focused on their role in natural fiber-reinforced systems such as jute/epoxy composites.

This research endeavors to bridge this gap by developing a composite material that amalgamates the natural fiber strength of jute with the abrasion-resistant properties of silicon carbide (SiC) within an epoxy matrix. The manuscript presents a comprehensive investigation into the development and three-body abrasion characterization of the resulting hybrid composite material. The primary objectives of this research are to fabricate abrasion-resistant SiC-reinforced jute epoxy composites, evaluate their performance under three-body abrasive wear conditions, and elucidate the underlying mechanisms governing their abrasive behavior. This work not only contributes to the expanding field of composite materials but also holds promise for the development of sustainable and robust materials for a wide range of practical applications.

2. MATERIALS AND METHODS

2.1 Materials

In this study, jute fabric and SiC are employed as reinforcing elements, in conjunction with an epoxy L12 matrix and K6 hardener. The properties of Jute fabric, SiC and epoxy matrix are presented in Table 1-3 respectively.

Table 1. Properties of jute.

Properties	Unit
Density (g/cm^3)	1.4-1.5
Elongation at break (%)	1.8
Cellulose content (%)	50-57
Hemicellulose (%)	13.6-20.4
Lignin content (%)	8-10
Ash (%)	0.5-2
Pectin (%)	0.2
Wax (%)	0.5
Moisture (%)	12.6
Tensile strength (MPa)	300-700
Youngs modulus (GPa)	10-30
Diameter (µm)	160-185
Lumen size (µm)	12

Table 2. Properties of SiC.

Properties	Unit
Density (g/m^3)	3.1
Flexural strength (MPa)	550
Elastic modulus (GPa)	410
Poisson's ratio	0.14
Compressive strength (MPa)	3900
Hardness (kg/mm^2)	2800

Table 3. Properties of epoxy matrix.

Properties	Unit
Density (kg/m^3)	1162
Tensile Strength (MPa)	50-60
Compressive strength (MPa)	110-120
Flexural strength (MPa)	130-150
Viscosity (m. Pa.s)	9000-12000 at 25^{0}C

2.2 Composite preparation

The components employed in crafting the envisioned composites are illustrated in Figure 1.

Fig. 1. Components employed in the creation of the intended composites.

The jute fabric is subjected to drying in an oven at 70°C for a duration of 3 hours. The weight ratio of the epoxy L12 and K6 hardeners is 10:1. The foundation material is prepared and the composites are built utilising the hand layup method with a 30% fibre weight percentage. The increased bonding power of epoxy aids in preventing delamination. In order to reduce the creation of bubbles, the epoxy and hardener are carefully mixed for 3 minutes with the beaker at an inclined angle. The mixture is then poured into the mould, working its way from the outer edge into the centre. For a whole day, the entire setup is allowed to cure. In the same way, three more samples are created with filler amounts of 5 weight percent, 10 weight percent, and 15 weight percent of SiC. The suggested composites' compositions are described in depth in Table 4.

Table 4. Composite nomenclature and their corresponding composition.

Composite Nomenclature	Composite Composition		
	Resin (wt %)	Jute (wt %)	SiC (wt %)
J	70	30	0
JS5	65	30	5
JS10	60	30	10
JS15	55	30	15

2.3 Hardness

A clear correlation exists between a material's hardness and its resistance to wear. To determine the hardness of the envisioned composites, Rockwell hardness testing was conducted in accordance with ASTM D 785-98 standards. The indentation size was measured when the composite samples were placed directly beneath the diamond cone ball indenter. Each sample was subjected to five measurements at various points, and the material's hardness was determined by averaging these data.

2.4 Three body wear test

As per the ASTM G 65 standard, three-body abrasive wear tests were performed. The created abrasive samples, measuring 75 mm x 25 mm x 3 mm, were cleaned before mounting on the specimen holder, and their initial weight was precisely determined using a high-precision digital balance. The sample specimen and the test rig used for abrasion testing are presented in Figure 2.

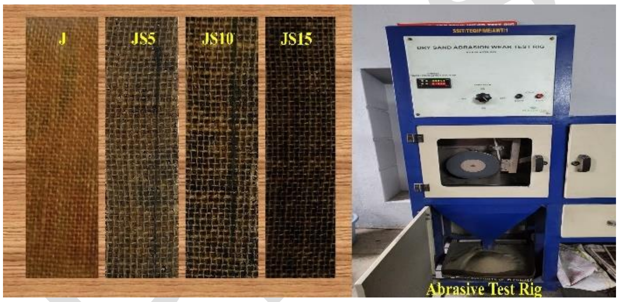

Fig. 2. Sample specimen and test rig used for abrasive testing.

AFS 60 silica sand, which has an angular form and sharp edges, was used as the testing's abrasive medium. Figure 3 shows the look and shape of the sand.

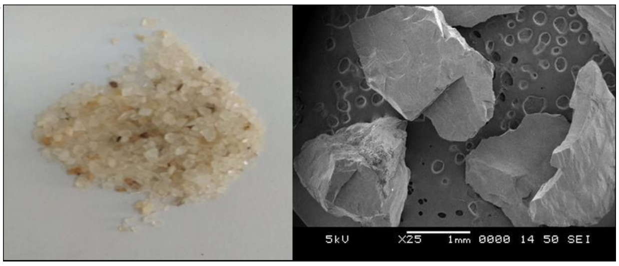

Fig. 3. Abrasive material and its morphology utilized in the current investigation.

The specimens were subjected to varying loads ranging from 10-40 N in increment of 10 N, in accordance with the designated run conditions prior to commencing the experiment. Subsequent to the test, the ultimate weight of the specimens was ascertained, and the specific wear rate was calculated using Eq. 1.

$$K_s = \frac{V_l}{LxD} \qquad (1)$$

In Eq. 2, V_l represents the volume loss (m^3), with L denoting the applied load (N), and D indicating the sliding distance (m). Equation 2 serves as the method to calculate the volume loss of the composite.

$$V_l = \frac{M_l}{\rho} \quad (2)$$

where ρ is density (g/m^3).

3. RESULTS AND DISCUSSIONS

3.1 Hardness

Figure 4 furnishes data on the hardness of the envisioned composites. It is evident that the inclusion of SiC leads to an ` hardness, with a notable peak observed when incorporating 15 wt% of SiC, resulting in the highest hardness for the composites.

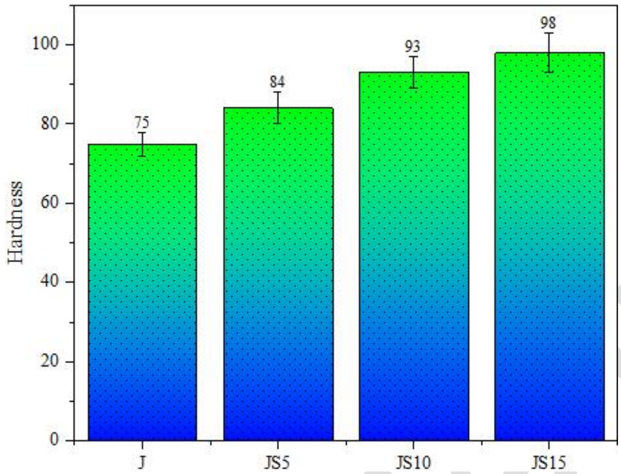

Fig. 4. Variation in hardness of the composites developed.

The enhancement in hardness of the proposed composites stems from the incorporation of SiC as a filler. This improvement is attributed to the even distribution of SiC particles within the matrix, which reduces the interparticle spacing and consequently bolsters the composites' resistance to indentation.

The hardness values presented for the different composite formulations (jute epoxy, jute epoxy with 5wt% silicon carbide, jute epoxy with 10wt% silicon carbide, and jute epoxy with 15wt% silicon carbide) reveal a clear trend of increasing hardness with the incremental addition of silicon carbide. 'J' represents the base composite without any silicon carbide reinforcement. It has the lowest hardness value among the tested samples, indicating its susceptibility to indentation and wear. The natural jute fibers and epoxy matrix alone provide limited resistance to mechanical forces. The introduction of 5wt% silicon carbide leads to a notable increase in hardness. This improvement is due to the reinforcing effect of silicon carbide particles, which enhance the composite's ability to resist deformation and indentation. A further increase in silicon carbide content to 10wt% results in a significant boost in hardness. The higher concentration of silicon carbide particles contributes to the composite's hardness, making it more robust and resistant to indentation. JS15 composite exhibits the highest hardness value among the tested formulations. The addition of 15wt% silicon carbide particles further reinforces the composite, making it exceptionally resistant to indentation and wear.

Overall, the trend suggests that silicon carbide is highly effective in improving the hardness of the jute epoxy composite. The increased hardness is desirable in applications where the material needs to withstand abrasive or high-stress conditions, enhancing its suitability for various engineering and industrial applications.

3.1 Three body wear and optimization

The experimental analysis of the samples was conducted using a three-body wear test rig. For all the run conditions, the wear loss of the samples was measured to determine the specific wear rate. The Taguchi optimization technique is a robust methodology that enables the design of high-quality systems [7,30]. To evaluate the impact of various parameters on the tribological response of the composite in the current work, we used Taguchi's L16 orthogonal array. Table 5 gives a summary of the major criteria and their corresponding weights used in this study.

Table 5. Elements and Configurations Employed in Taguchi L16 Orthogonal Matrix.

Factor	Particular	Unit	Level			
			1	2	3	4
A	Filler Percentage	Wt%	0	5	10	15
B	Load	N	10	20	30	40
C	Time	min	5	10	15	20

According to Taguchi's L16 orthogonal array, three-body wear tests were performed for all run circumstances, and the resulting specific wear rates are listed in Table 6 for convenience.

Table 6. Calculating Wear Rate under L16 Orthogonal Array Experiment Conditions.

Filler (wt%)	Load (N)	Time (min)	Density (g/cm^3)	Mass loss (g)	Sp. Wear rate x10^{-8} (mm^3/Nm)	SN Ratio
0	10	5	1.21	0.18	2.083	-6.37
0	20	10	1.21	0.42	1.210	-1.66
0	30	15	1.21	1.28	1.640	-4.30
0	40	20	1.21	2.15	1.550	-3.81
5	10	10	1.28	0.18	0.984	0.14
5	20	5	1.28	0.15	0.820	1.72
5	30	20	1.28	0.3	0.273	11.28
5	40	15	1.28	0.2	0.182	14.80
10	10	15	1.32	0.15	0.530	5.51
10	20	20	1.32	0.17	0.225	12.96
10	30	5	1.32	0.09	0.310	10.17
10	40	10	1.32	0.12	0.159	15.97
15	10	20	1.375	0.16	0.407	7.81
15	20	15	1.375	0.13	0.220	13.15
15	30	10	1.375	0.1	0.169	15.44
15	40	5	1.375	0.08	0.203	13.85

The study investigates the impact of different factors on the specific wear behavior of the proposed composites using a signal-to-noise (SN) ratio analysis. Figure 5 shows the SN ratio plot, emphasizing how different parameters influence the particular wear rate of the suggested composites.

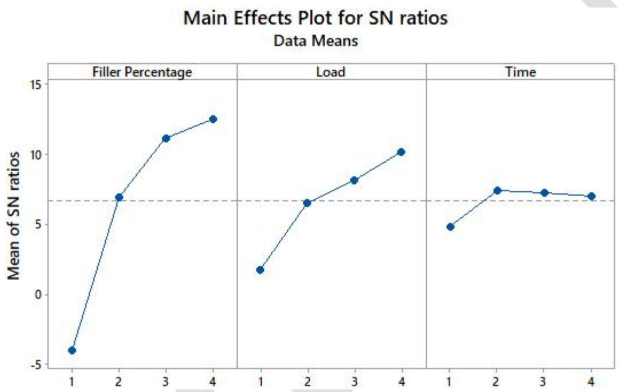

Fig. 5. Signal-to-Noise Ratio (SNR) for Different Factors.

The objective of this study is to identify the ideal factor levels that result in the lowest specific wear for the proposed composites. To achieve this goal, we have adopted the "smaller the better" criterion for the SN ratio, which is mathematically expressed in Eq. 3.

$$S/N = -10log_{10}\left(\left(\Sigma y^2\right)/_n\right) \quad (3)$$

In this context, 'y' represents the responses corresponding to the specific factor level combination, and 'n' signifies the total number of responses within that combination. For the computational aspects of this study.

Figure 4 unequivocally shows that maintaining a higher filler % is necessary to achieve the suggested composites' minimum specific wear rate. We looked to Table 7 to find the overall mean of each input parameter.

Table 7. Importance of parameters.

Level	Filler percentage	Load	Time
1	-4.033	1.772	4.843
2	6.985	6.544	7.475
3	11.154	8.149	7.292
4	12.563	10.204	7.059
Delta	16.596	8.431	2.631
Rank	1	2	3

Table 7 shows that, in descending order of importance, time, load, and filler weight % all have a significant impact on the particular wear rate. Additionally, the particular wear rate increases when the abrading distance is increased. The suggested composites' wear resistance is improved by the addition of SiC particles. The hardness values obtained in our investigation, which show that JS15 stands out with the maximum hardness compared to its rivals, support this conclusion. The results of the tribological research further support the fact that JS15 exhibits a lower specific wear rate, which is a sign of its improved wear resistance properties. ANOVA is a statistical method used to determine the importance of numerous factors and how much the response is impacted by various process parameters. The ANOVA values for particular wear rates are provided in Table 8. In the table, a larger F value denotes a stronger effect of the related factor on the answer.

Table 8. ANOVA for Specific wear rate.

Source	DF	Adj SS	F value	P-value	Percentage contribution
Filler percentage	1	3.822	30.17	0.000	65.16
Load	1	0.422	3.33	0.093	7.20
Time	1	0.100	0.79	0.391	1.71
Error	12	1.520			
Total	15	5.865			
R-Sq: 95.81%					

Accordingly, the filler shows the highest F value of 30.17, showing that the filler fraction has the greatest impact on wear in the composite, followed by load and time. The created model produces positive results and accurately predicts weight loss values under experimental settings, as evidenced by the R-squared value over 90%. Regression models are created for the output produced, and the regression equation is shown in Eq. 4.

$$\text{Sp. Wear Rate} = 2.319 - 0.4372\ \text{filler percentage} - 0.1453\ \text{load} - 0.0708\ \text{time} \tag{4}$$

As evidenced by the coefficients assigned to the control parameters, an elevation in filler content, load and time leads to an increase in specific wear rate. Notably, the filler boasts the most substantial coefficient, underscoring its greater influence on the specific wear rate compared to the other two factors. To validate the model generated, experimental data is compared with the predicted outcomes, as depicted in Table 9. This analysis confirms the suitability and effectiveness of the created model in predicting weight loss due to abrasion across a range of testing conditions.

Table 9. Comparison of experimental and predicted results.

Filler (wt%)	Load (N)	Time (min)	Sp. Wear rate x10^{-8} (mm^3/Nm)	
			Experimental	Predicted
0	10	5	2.083	1.6657
0	20	10	1.210	1.4496
0	30	15	1.640	1.2335
0	40	20	1.550	1.0174
5	10	10	0.984	1.1577
5	20	5	0.820	1.0832
5	30	20	0.273	0.7255
5	40	15	0.182	0.651
10	10	15	0.530	0.6497
10	20	20	0.225	0.4336
10	30	5	0.310	0.5007
10	40	10	0.159	0.2846
15	10	20	0.407	0.1417
15	20	15	0.220	0.0672
15	30	10	0.169	-0.0073
15	40	5	0.203	-0.0818

Silicon carbide is an extremely hard material, ranking very high on the Mohs scale of mineral hardness. This hardness makes it highly resistant to abrasion and wear. When incorporated into composites or coatings, SiC particles can act as abrasive-resistant reinforcements. SiC particles can form a protective layer of wear particles on the surface when they come into contact with abrasive materials. This layer can act as a sacrificial shield, reducing direct contact between the abrasive and the underlying material, thus minimizing wear. Silicon carbide can also possess a level of toughness that complements its hardness. This toughness can help prevent cracking or chipping when subjected to impact or repeated mechanical stresses, further enhancing its abrasion resistance. Higher loads are known to cause increased volume loss in epoxy composites, however SiC reinforcement lowers the wear rate by reducing surface asperities by efficiently absorbing the load. The wear rate is further decreased by increasing the SiC concentration.

3.2 Fractographic study

The sample specimen being abraded in abrasion test rig and the sample abraded specimen are presented in Figure 6.

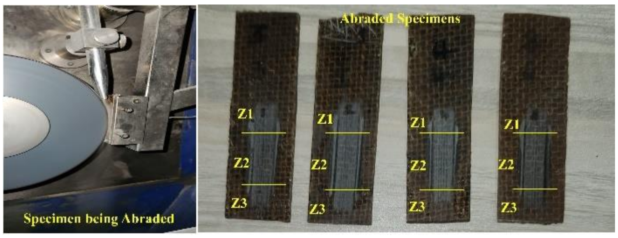

Fig. 6. Abrasion test process and sample abraded specimen.

Figure 7 shows the optical image of the abrasion pattern in the proposed composites.

Abrasion resistance of composite materials, such as jute-reinforced composites, can be significantly improved by incorporating materials like silicon carbide (SiC). In a jute-reinforced composite without SiC, the primary mechanism of abrasion involves the degradation and wear of the composite's matrix and jute fibers. The matrix material, is susceptible to wear and abrasion when subjected to friction and mechanical stress. As abrasive forces act on the surface, the matrix material may undergo wear, deformation, and even surface cracking. The jute fibers, while providing reinforcement, can also experience wear and breakage. Over time, the repeated abrasive forces can weaken and break individual fibers, reducing the composite's overall strength and integrity. During abrasion, small wear debris particles are generated, which can exacerbate the abrasive process and potentially accelerate wear.

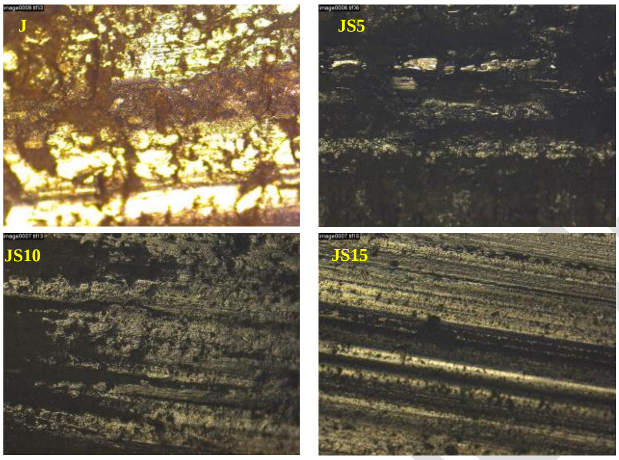

Fig. 7. Analyzing Wear Mechanisms in the Newly Developed Composites.

When silicon carbide (SiC) particles are added to the jute-reinforced composite, they can significantly enhance abrasion resistance. SiC is a hard and abrasion-resistant material itself. SiC particles act as a protective layer for both the matrix and jute fibers. When abrasion occurs, SiC particles absorb and distribute some of the abrasive forces, reducing direct contact with the composite's softer components. While SiC is highly wear-resistant, it may undergo some abrasive wear itself. However, SiC's hardness allows it to withstand abrasive forces much better than the matrix or jute fibers. With SiC reinforcement, the matrix material is less prone to wear and surface damage because a portion of the abrasion is transferred to the SiC particles.

Adding silicon carbide (SiC) to jute-reinforced composites enhances abrasion resistance by providing a hard, wear-resistant phase within the composite. This helps protect the matrix and jute fibers from abrasive wear, reducing degradation and improving the composite's durability in applications subject to abrasive forces.

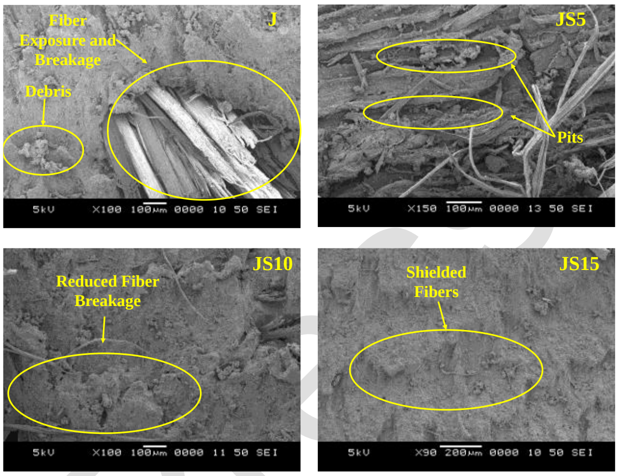

Fig. 8. SEM morphology of proposed composites.

SEM pictures shown in Figure 8 support Taguchi's findings. The SEM images provided illustrate the surface morphology of a jute fiber-reinforced epoxy composite subjected to three-body wear. The images correspond to different sample conditions, labeled J, JS5, JS10, and JS15, and show varying levels of fiber damage and filler interaction.

In composite without SiC content, The fiber exposure and breakage is clearly visible, with the fibers protruding from the worn surface due to poor resistance to abrasion. A significant amount of debris is observed on the surface, which indicates heavy material removal during wear. The absence of fillers leads to minimal protection for the fibers, resulting in high wear. The exposed fibers break under the applied forces, contributing to rapid wear and a rough surface finish.

In JS5, pits are visible along with partially exposed fibers. The surface shows signs of degradation, but there is some evidence of filler interaction that may have started providing minor wear resistance. The addition of silicon carbide fillers (5%) seems to have reduced the direct exposure of fibers, as some fibers are embedded in the matrix. However, the formation of pits indicates localized wear, suggesting that the filler concentration is not sufficient to provide significant protection against wear.

The image pertaining to JS10 shows reduced fiber breakage and a smoother surface compared to the previous images. Fewer fibers are exposed, and the wear debris is less prominent. The addition of 10% silicon carbide fillers appears to have improved the wear resistance of the composite. The fibers are more shielded from the abrasive forces, reducing breakage and material loss. The fillers act as a protective barrier, which enhances the composite's overall wear performance.

The "JS15" image shows shielded fibers and a significantly smoother surface with minimal debris and fiber exposure. The wear marks are less pronounced, and the surface appears to be protected. The incorporation of 15% silicon carbide fillers provides the highest level of protection among the samples. The fibers are well embedded in the matrix, and the surface shows minimal wear. This indicates that higher filler content significantly improves the composite's resistance to three-body wear by shielding the fibers and reducing the overall material removal.

The series of SEM images shows a clear trend: as the content of silicon carbide fillers increases from 0% (J) to 15% (JS15), the wear resistance of the composite improves. The fillers help shield the jute fibers, reducing fiber breakage and surface degradation. The presence of pits and debris in the lower-filler-content samples suggests localized wear, which is mitigated as the filler content increases, leading to a more uniform and protected surface at higher filler percentages.

4. LIMITATIONS AND FUTURE SCOPE

The current study focuses on evaluating the wear behavior of jute/epoxy composites reinforced with silicon carbide fillers under a fixed-speed condition. While this approach effectively isolates the influence of filler content on the material's wear performance, it is important to acknowledge that speed is a critical factor in wear studies, influencing both the rate of wear and the wear mechanisms involved.

The absence of speed as a variable is a limitation in the current experimental design. Speed variations can significantly impact the wear characteristics of composite materials, particularly in dynamic applications where the operating conditions fluctuate. It is suggested that future research should explore the effect of different sliding or rotational speeds on the wear performance of these composites. Such an investigation would provide a more comprehensive understanding of the wear mechanisms under varying operational conditions and enhance the applicability of the material in real-world environments.

5. CONCLUSIONS

In this research, we investigate the impact of introducing silicon carbide (SiC) into a jute epoxy composite. We aim to identify the optimal operating conditions and factors that influence the specific wear rate of these composite materials. The key findings derived from this study are summarized as follows:

- The inclusion of SiC as a filler in the composite leads to enhanced hardness. This improvement is attributed to the hardness of SiC particles. The hard SiC particles resist deformation under load and provide a solid, incompressible phase within the composite, increasing its overall hardness. The higher concentration of silicon carbide particles contributes to the composite's hardness, making it more robust and resistant to indentation.
- It is found from the statistical analysis that SiC percentage plays a major role in deciding the specific wear rate of the proposed composites with filler percentage contributing 65.16% followed by load and time which contributes for 7.2% and 1.71% respectively.
- SiC particles forms a protective layer of wear particles on the surface when they come into contact with abrasive materials. This layer act as a sacrificial shield, reducing direct contact between the abrasive and the underlying material, thus minimizing wear. Higher loads are known to induce more volume loss in epoxy composites, but reinforcement with SiC particles reduces the surface asperities by absorbing the load effectively, thereby assisting in lowering the wear rate.

- It is found that when the SiC content is low, the polymer matrix is the predominant phase, and abrasion primarily affects the matrix. As SiC content increases, SiC particles become more distributed throughout the composite. SiC particles start to play a role in reducing abrasive wear on the matrix.
- In composites with high SiC content, SiC particles become the dominant phase, and the composite's abrasion resistance is significantly enhanced.

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