Journal of Information Systems Engineering and Management
2025, 10(4)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Dry Sliding Wear Behavior of nano-SiO_2 Filled Jute Fabric Reinforced Epoxy Composites

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ARTICLE INFO

Received: 12 Nov 2024

Revised: 27 Dec 2024

Accepted: 25 Jan 2025

ABSTRACT

The effect of filler nano-SiO_2 on wear behavior of jute fabric reinforced epoxy composite has been experimentally investigated. The laminates of jute fabric reinforced epoxy composites with fillers in 2%, 3% and 5% based on weight of resin were prepared using hand layup technique. The dry sliding wear tests were conducted using pin-on-disc friction and wear test machine. Tests were conducted for a constant sliding distance of 707 m and a track radius of 30 mm. For each composition, wear tests were conducted for sliding velocities (2.35619 m/s) by applying normal loads of 5 N, 10 N and 20 N. The wear loss and coefficient of friction were plotted against the normal load and sliding velocity for composites with fillers. The results reveal that incorporation of fillers leads to significant improvement in the wear resistance of jute fabric reinforced epoxy composite. It is observed that nano-SiO_2 filled composite has better wear resistant.

Keywords: Jute fabric, Epoxy resin, Nano-SiO_2, Pin on disc, Wear Properties, Coefficient of friction.

1. Introduction

There has recently been an expanding demand for new materials with high performance at affordable cost. Over the past decade, rising environmental concerns and international treaties along with the resultant changes in the content of governing policies have boosted interest on natural fibres in various fields [1, 2].

Natural fiber reinforcements in the form of short fiber, filament, or fabric have become better alternatives to synthetic fibers as reinforcements. They cost less, are lighter in weight, lower in density and higher in specific strength as well as renewable, non-corrosive and easier to manufacture. These, and their biodegradability have helped in their widespread application including in the automotive, aerospace, and transportation industries [3-6].

Fabrics are mainly used with tribological mechanisms such as seals, cams, and bearings because their higher thermal as well as dynamic mechanical stability, higher strength and rigidity as well as suppleness [7]. Natural plant fiber reinforced polymer composite components can be applied in many situations for tribological loading conditions. An important part of tribology deals with materials selection and surface processing in as much as they affect wear and tear. Among, the natural fibers, jute is most popular one due to its distinctive characteristics like high initial strength & secant modulus, good dimensional stability, high roughness co-efficient, ease of availability, low extension at break etc. Significant work has been reported on wear behavior of fiber reinforced composites [8-11].

Ahmed et al. discussed the effect of ceramic fillers on friction and wear properties of Al_2O_3 and SIC filled jute–epoxy composites. Incorporation of ceramic fillers significantly improves the wear properties of jute epoxy composites [8]. Suresh et al. utilized the Hybrid (BPSF/JF) composite and investigated from wear test. The sudden weight losses presented when increasing load value and frictional force was increase. [9]. Yallew et al. fabricated woven Jute fabric into polypropylene matrix which shows increment in wear resistance properties of polypropylene based composites by 3.5-45% reduction in the coefficient of friction values [10]. Zhu et al. investigated nano-SiO_2/epoxy composites cured by T-31 higher filler loading is not recommended according to experiment conditions because of the poor dispersion of nanoparticles in the matrix. The tribological performances were improved by the addition of nano-SiO2 at a mass percent of 3%. The addition of nano-SiO_2 is an effective way to enhance the performance of epoxy resin cured by Mannich Amine [11].

A review of the literature reveals that, despite several advantages of natural fibers, investigation on tribological behavior of natural fiber composites is scanty. One of the reasons for this could be poor wear resistance of

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natural fibers. However, by incorporating suitable wear resistance filler materials, it can be expected that the wear properties of natural fiber composites may significantly improve. The purpose of our research focused on the changes in performance resulting from nano-SiO2 loading used with jute fabric reinforced epoxy composites. Tribological performance of the materials were evaluated from wear tests.

2. Experimental

2.1 Materials

The materials used in the study consists of untreated woven jute fabric of 130 cm × 100 cm of woven jute fabric (14 weft and 14 warp yarns per inch) with an average thickness of 0.77 mm, procured from local jute vendor. Nano-SiO_2 powders of 15nm size, procured from Sisco Research Laboratories Pvt. Ltd. (SRL) were used as filler materials. Epoxy (LY 556) with 10% hardener (HY 951) as matrix material both supplied by Araldite Pvt. Ltd, India.

2.2 Fabrication of laminates

Laminates of woven jute fabric and epoxy were prepared by hand layup technique in a open mold at room temperature. Candle wax used as release agent applied on the surfaces of the mold to facilitate easy removal of the laminate after curing. For preparation of filled composite laminates, filler was mixed to the known amount of epoxy resin and mechanically stirred to ensure uniform distribution of filler in the resin. Hardener in the 10% ratio is added to the resin with fillers and further stirred. The resin system impregnated jute fabric layers (50 X 50) mm were laid down on the surface of the mold one over the other until the desired thickness is reached. A roller was used to achieve uniform distribution of resin system throughout the layer surface. Each laminate was cured under a pressure bar for 24 h. The laminate was then removed from the mold and further cured at room temperature for at least 48 h before use. All the laminates were made with eight plies. All the composites were processed at a total fiber weight fraction of 50%. Table 1 shows different sample specifications.

Table 1. Sample Specification.

Designation	Composition
A	Epoxy
B	Epoxy + Jute
C	Epoxy + Jute + 2% SiO_2 (Epoxy wt%)
D	Epoxy + Jute + 3% SiO_2 (Epoxy wt%)
E	Epoxy + Jute + 5% SiO_2 (Epoxy wt%)

2.3 Test Procedure

Wear test were conducted using a pin-on-disc wear test machine in the laboratory in accordance with ASTM G99 [23]. The experimental set up for wear test is shown in Fig. 1. Specimens of size (8 X 4) mm were cut from the laminate using a cutter and contact surface was polished with an emery paper to ensure uniform contact with the rotating disc. Both the disc and the specimen surfaces were cleaned using acetone. The specimen-pin assembly was weighed using high precision digital electronic balance (0.0001 g accuracy) and then mounted on the specimen holder of the wear testing machine. All the tests were conducted for a constant sliding distance of 707 m and a track radius of 30 mm. For each composition, wear tests were conducted at sliding velocitie (t = 2.35619 m/s) by applying normal loads of N = 5 N, 10 N and 20 N. After each test, the specimen assembly was weighed again and wear loss was calculated. Five identical specimens were tested for each composition and average results are reported.

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Figure 1. Experimental setup.

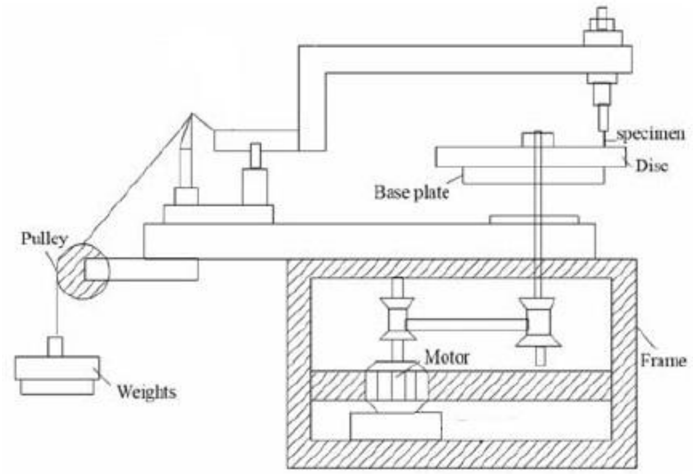

Figure 2. Working of Pin on disc tester.

3. Results and discussion

Wear properties of nano-SiO_2 unfilled and filled jute fabric reinforced epoxy composites have been studied in terms of wear loss (wear behavior) and coefficient of friction (friction behavior). Stainless steel is used as disk material.

Table: 10 Normal loads at 5, 10, 20 N

Sample	5 N			10 N			20 N		
	Wear rate (mm^3 /Nm)	COF	Actual weight loss (mg)	Wear rate (mm^3 /Nm)	COF	Actual weight loss (mg)	Wear rate (mm^3 /Nm)	COF	Actual weight loss (mg)
A	8.10	0.185	0.3	13.24	0.193	0.8	48.99	0.189	0.9
B	13.17	0.012	0.2	18.13	0.092	0.3	17.01	0.185	0.6
C	17.94	0.013	0.6	14.10	0.139	0.9	53.17	0.379	1.2
D	62.12	0.163	1.4	50.55	0.566	2.1	43.32	0.603	4.5
E	75.91	0.507	1.5	81.62	0.595	2.8	88.39	0.651	5.0

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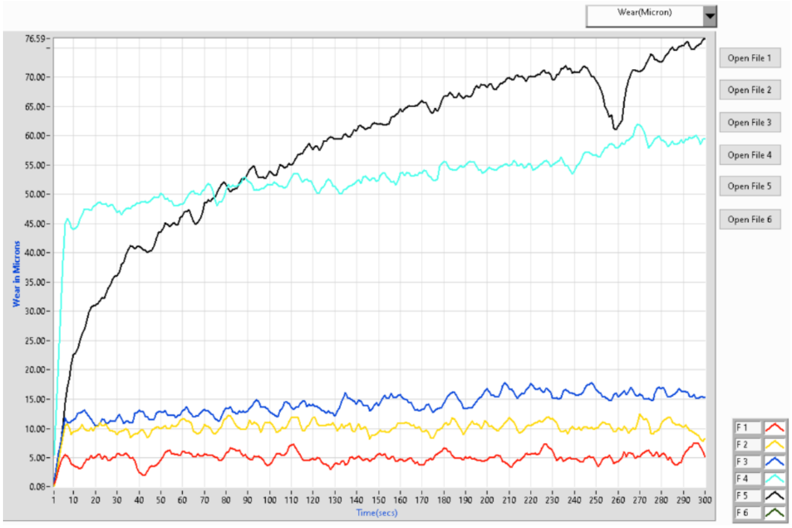

Fig. 14 Wear rate analysis of composite sample at 5 N load on Stainless steel

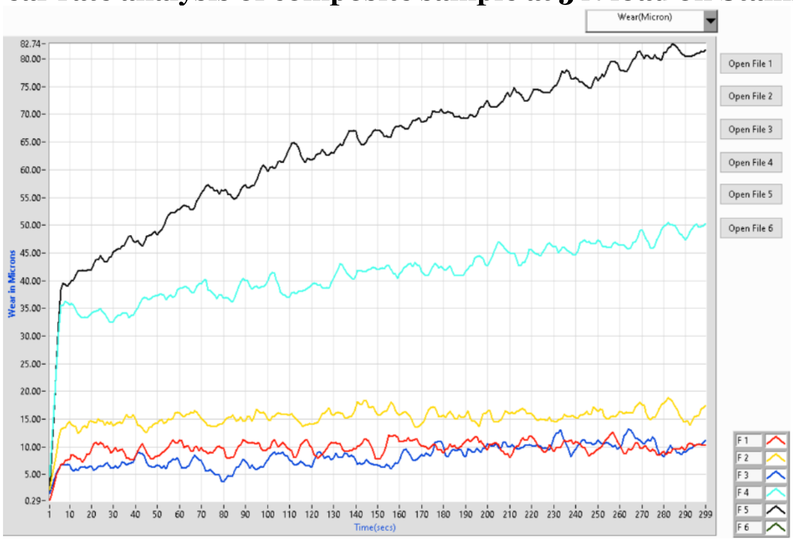

Fig. 16 Wear rate analysis of composite sample at 10 N load on Stainless steel

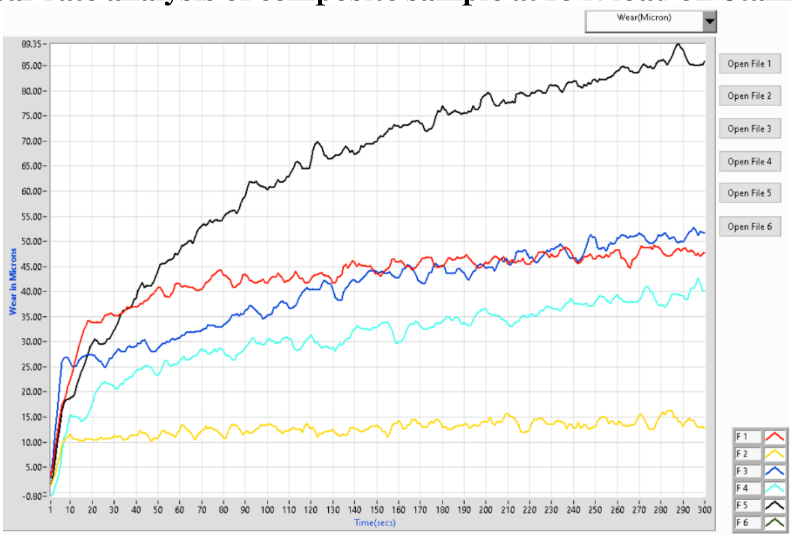

Fig. 18 Wear rate analysis of composite sample at 20 N load on Stainless steel

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https://www.jisem-journal.com/

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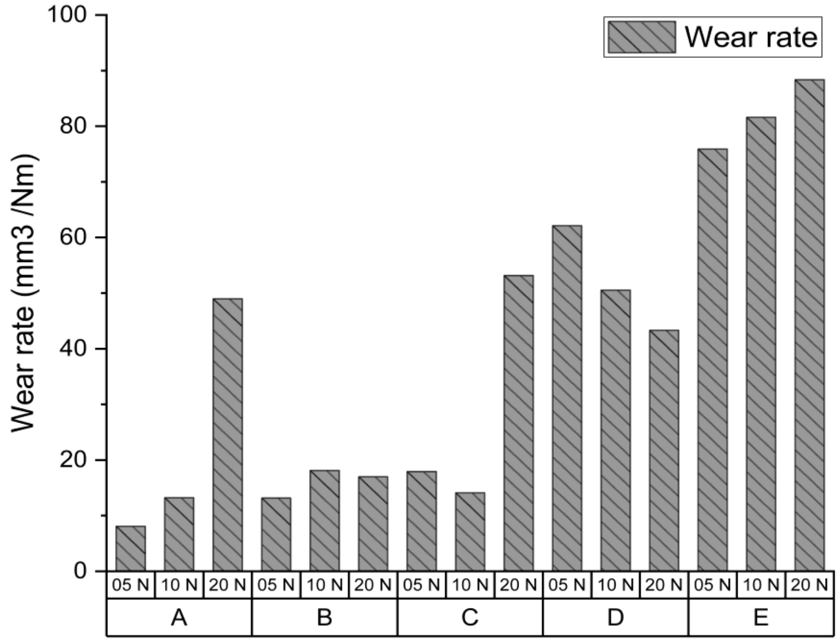

Figure Wear rate

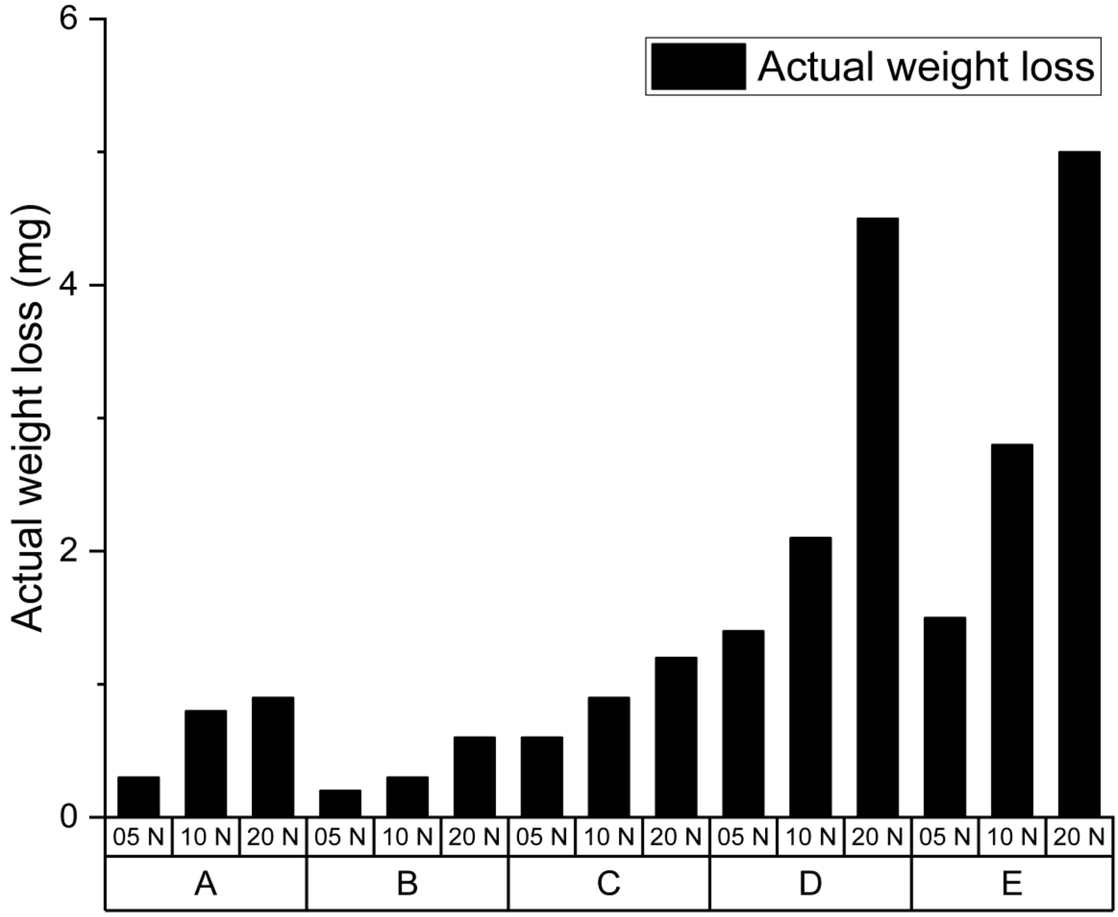

Figure Weight loss

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Weight loss of the sample tested in milligrams given in table. Wear rate in micron and mm^3/Nm, Coefficient of friction details of the experiment were given in Fig

- Actual weight loss in sample E (1.6 mg) is maximum and B is minimum (0.2 mg).
- Lesser weight loss is due to the anti-wear properties.
- Wear rate and Coefficient of friction for the sample E (76.59) is maximum and A is minimum (7.5) are obtained.
- It is understood that sample A composite exhibits better wear resistance property in respect to Stainless steel.

10 N

Weight loss of the sample tested in milligrams given in table. Wear rate in micron and mm^3/Nm, Coefficient of friction details of the experiment were given in Fig

- Actual weight loss in sample E (2.9 mg) is maximum and B is minimum (0.3 mg).
- Lesser weight loss is due to the anti-wear properties.
- Wear rate and Coefficient of friction for the sample E (82.74) is maximum and A is minimum (12.74) are obtained.
- It is understood that sample A composite exhibits better wear resistance property in respect to Stainless steel.

20 N

Weight loss of the sample tested in milligrams given in table. Wear rate in micron and mm^3/Nm, Coefficient of friction details of the experiment were given in Fig

- Actual weight loss in sample E (4.9 mg) is maximum and B is minimum (0.6 mg).
- Lesser weight loss is due to the anti-wear properties.
- Wear rate and Coefficient of friction for the sample E (89.35) is maximum and B is minimum (16.41) are obtained.
- It is understood that sample B composite exhibits better wear resistance property in respect to Stainless steel.

For disk material of stainless steel, the wear test performed at different load 5N, 10N and 20N and as the different result we study in terms of wear rate, coefficient of friction and actual weight loss. As per the result:

- Epoxy sample A have the constantly lowest wear rate at all the different load on stainless steel disk.
- Jute reinforced epoxy composite sample B have lowest weight losses in wear and low wear rate as compare to nano filler added composite sample.
- Jute reinforced epoxy/ 2% nano-SiO_2 composite sample C having the gradually increasing wear rate compare to load on use of stainless steel.
- Jute reinforced epoxy/ 3% nano-SiO_2 composite sample D having the high wear rate on lower load but increase in load decreasing the wear rate and obtaining optimum results.
- Jute reinforced epoxy/ 5% nano-SiO_2 composite sample E having the highest wear rate and weight loss at different load which can be seen and observe that higher filler loading also affect wear rate at different load.
- As per result we can say at low load sample A perform good wear behavior but as increasing the filler material not improve the wear behavior optimum percentage of filler contain can give a better performance so higher filler particles not suitable for wear behavior.

Comparative study

Suresh et al. (2020) using untreated banana and jute fiber with epoxy resin for tensile test perform on wear testing machine with ASTM G – 99 standards. Three test sample were prepared by including the necessary measure of epoxy resin in various compositions like 30 % Banana pseudo-stem fiber + 20% JF + 50% Epoxy resin (C1), 30% BPSF + 30% JF + 40% Epoxy resin (C2) and 30% BPSF + 10% JF + 60% Epoxy resins (C3). Three of the sample are tested on parameter of 10, 20 and 30 N load with rpm of 385. The sample (C3) has high wear, which may be on account of the high load and moderate speed. With the increase in addition of epoxy resin, the abrasion loss of the composite was found to be increased, wherein the sample 1 and 2 had shown minimum abrasion loss of.0024 g, 0.0061 g respectively. The sudden weight losses presented when increasing load value then the changes of wear and friction performance of the BPSF and JF composite have been investigated.
Ahmed et al. (2011) experimentally investigates the effect of ceramic fillers like SiC and Al_2O_3 on wear behavior of jute/epoxy composite reinforced with epoxy (LY556) and hardener (HY951). The laminates of jute/epoxy composites with fillers in 5%, 10% and 15% based on weight of resin were prepared using hand layup technique.

The dry sliding wear tests were conducted using pin-on-disc wear test machine. Tests were conducted for a constant sliding distance of 1800 m and a track radius of 50 mm with different load 30, 40 and 50 N. For 15% Al_2O_3 filled composites, the maximum wear loss at 50 N normal load is found to be 2.9 X 10^{-3}g and for 15% SiC filled composite, it is 3.3 X 10^{-3}g. For 15% filled composites, the coefficient of friction at 50 N normal load is 0.5 and 0.54 for Al2O3 and SiC respectively. Lowest coefficient of friction in 15% filled jute–epoxy composites indicate their higher wear resistance. Al_2O_3 filled jute epoxy composites exhibit low coefficient of friction and wear loss compared to SiC filled for all compositions.

Yallew et al. (2014) experimented the tribological behavior of woven Jute fabric reinforced polypropylene composite material. The tribological behavior was assessed with a computerized pin-on-disc wear and friction tester at an operating dry condition and different working parameters of sliding speed (1–3 m/s), applied load (10–30 N), and sliding distance (1000–3000 m) with the agreement of ASTM G-99-55 standard procedure, a ground hardened steel disc. The addition of woven Jute fabric into PP matrix increases the wear resistance properties of polypropylene based composites by 3.5-45% reduction in the coefficient of friction values.

Zhu et al. (2006) prepared and studied nano SiO_2 / epoxy composite cured by mannich amine (T-31). Wear test were carried out on MM-200 tester under 20 constant pressure and 0.5 m/s velocity on a carbon steel ring plate of 45 mm dia. The 3% composite presents the best performance with lowest friction coefficient and wear rate. As the mechanical performance, higher filler content is also useless for enhancing the tribological performance of composite of composite because of aggregation of nanoparticles.

4. Conclusion

Based On the data collected from the study and literature review following conclusions can be made:

- Growing demand for high-performance, cost-effective, and eco-friendly materials has led to increased interest in natural fibers.
- Natural fibers (like jute) are lightweight, renewable, biodegradable, and have good mechanical properties.
- Jute is widely used due to its high strength, dimensional stability, and availability.
- Tribological applications (e.g., bearings, seals) benefit from natural fiber composites.
- Prior studies show that adding ceramic or nano fillers (e.g., SiO_2) can improve wear resistance.
- Natural fiber composites can be enhanced with nano-fillers, but optimal filler content is crucial.
- Excessive nano-SiO_2 (5%) leads to poor wear performance due to agglomeration.
- 2–3% nano-SiO_2 may offer a balance between improved properties and material stability.
- Jute-reinforced epoxy composites without fillers (Sample B) show good wear resistance at higher loads.
- Pure epoxy (Sample A) performs best under low-load conditions.

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