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RESEARCH

Abrasive Wear Performance of Coir Fiber Reinforced Polymer Composite

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ABSTRACT

In the current era, there is a high demand to develop and explore new eco-materials for different engineering applications. Most engineering components are subjected to tri-biological loading conditions during the service. The current study investigates fibres reinforced polymer composites under abrasive wear loading conditions naturally. Coir fiber-reinforced epoxy composites was fabricated with different fibre lengths such as 5 mm, 10 mm and 15 mm. Surface treatment methods such as alkali treatment are performed to improve the efficiency of coir and epoxy resin. Normally applied loads of 5 N, 10 N, 15 N, 20 N and sliding Normally durations of 0, 2 min, 4 min, 6 min, 8 min, and 10 min are varied accordingly. Abrasive wear behaviour is performed on Block on Ring (BOR) at average room temperature with a sliding velocity of 1.9 m /s. wear behaviour values are tabulated for different fibre lengths, applied loads and Grades. Also, surface topography is examined using scanning electron microscopy (SEM), and damaged features are classified. The highest wear rate is observed from a 10 mm coir fibre length of Grade 600 at 10N normal applied load with 0.0695. While lowest wear rate can be seen from Grade 1200 of 15mm coir fibre length at 5N applied load of 0.012.

1. INTRODUCTION

Natural fibre composites are biodegradable and are low cost than synthetic fibre composites. These natural fibres are easily available and best suited for manufacturing, making some researchers focus on reinforcements specifications for better-reinforced polymer composite [1] . Over the past few years, till now researchers are performed to substitute synthetic with natural fibers. These natural fibres have better qualities like high specific mechanical properties, renewable and biodegradable with low cost [2].

These natural fiber-reinforced polymer composites have better tri-biological properties than synthetic fibre material [3]. Even industrial applications like bearings, flooring materials, and brake pads require friction coefficient and Wear resistance [4]. The demand for polymer composite reinforced natural fibres has attained attention as these have excellent environmental properties, which are affordable and easy to manufacture than synthetic fibres [5,6]. Due to these excellent properties, polymer composites are used in the construction, automobile and furniture industries [7].

These natural polymer composites are distinguished by their unique low density and cost properties, flexible processing equipment, and best mechanical properties with high strength, chemically resistant than synthetic fibres [8,9]. For a polymer composite matrix, a better option than synthetic fibre would be natural fibres like sisal, coir, date palm corn, and silk for better reinforcement polymer composite in the current situation [10]. There is an increase in research on natural fiber-reinforced composites in both mechanical and tri-biological applications. [11-13]. These natural fiber-reinforced composite polymers can enhance their performance in tensile, impact, Wear, flexural, friction and other mechanical and tri-biological applications [14-16].

Research is being carried out on the effect of fibre materials, additives and their further modifications, and their content percentages on polymer composites' mechanical and tri-biological properties [17]. There is still a debate between many scholars' research on the relationship between mechanical and tri-biological performances of material [18-20]. However, carbon has specific selective effects on mechanical performance, while frictional properties are more favourable [21]. Aireddy et al. [22] Investigated coir epoxy composite with various ratios and stated that the wear resistance of coir fibre mainly focuses on their dust particle size and normal load applied. He also stated that the wear mechanism had been dominated by reinforcement due to high coir dust loading [23].

These natural fibre composites had many desirable properties, like yielding low-density material relative to composite properties. These are low in cost, and processing has also been a renewable resource. had researched rice husk-reinforced epoxy composite and found better results on abrasive wear loss by suitable treatment [24,25]. Palm and mangos dry leaves also improve tri biological properties of polymer composites [26,27].

Our work proposes coir and sisal fibres with reinforced polymer composites to improve their wear and friction behaviour for proposed composite materials. Three orientations, parallel, anti-parallel and normal, are tested for polymeric composite under different loads from 5 to 60 N and are applied through Various Grade papers and Time Intervals to find the abrasiveness of developed composites.

2. METHODOLOGY

2.1 Materials and methods

2.1.1 Alkali treatment for the fibre materials

These coir fibers are alkali treated for better improvements in their mechanical and physical characteristics. In this treatment, these fibres are prewashed with water and are shrivelled at normal room temperatures. This process involves immersing coir fibre with 5% to the weight/ volume ratio with Na OH aqueous solution for about 3 hours at a temperature of 700c. Then, these coir fibres are taken from the treated solution and immersed in 5% of acetic acid, which acts as a neutralizing agent. Then, these are soaked in water and dried under 1100 ^{0}c for about 2 hours in an electric oven.

2.1.2 Materials and their preparation

Materials that are used for the preparation of coir fibres are obtained from local Indian sources. Thixotropic Laminating Epoxy of (R246 TX) is a matrix binder manufactured by Kintex Ltd. The common epoxy found in the market has poor mechanical and thermal properties. But this type of resin is rigid, with low reactivity. These will be cured for a reaction where linear epoxy resin is structured to be changed to a three-dimensional thermoset cross-linked structure to improve their properties. Here it is hand layered for easy air release. These also have advantages like normal temperature curing ability, transparency, and lower pressure mould ability at a very low cost. An agent named hardener will be added to the resin for this curing. This Laminating hardener or curing agent is H160, manufactured by Kinetix Ltd. This epoxy with the corresponding hardener is thoroughly mixed in a ratio of 1: 4. As a result, no by-products are formed in this curing reaction, so this resin can be cast and laminated under lower temperatures also pressures. To easily remove the prepared fibre material mixture, mould release powder will be spread within the container. This releasing agent helps easily remove the prepared mould composite from the container after curing.

2.1.3 Natural fibre fabrication

The coir fibres collected from coconut husks were pre-treated using the alkali method. Then, these coir fibres were classified to an approximate length of 5, 10, and 15mm. as shown in Figure 1.

Figure 1. Showing purchased coir fibre from the market and fabricated coir fibre.

2.1.4 Material preparation

Epoxy resin of R246TX is mixed with a hardener of H160 before reinforcement in 1: a 4 ratio. Then, the required weight for 2% of coir fibre was added to polymer with a predetermined amount of hardener and accelerator and stirred well in a container. The mixture is then poured into the container, where the inner walls are coated with mould release powder. A maximum amount of the paste was poured into a container to avoid voids. The prepared composites were then left for at least 24 hours for hardening. Then after, the sample is removed from the mould container. After that, this prepared sample was placed in an oven and programmed for 24 hours at a temperature of 90 degrees. After post-curing for 24 hours in an oven, these samples are removed and gradually cooled to room temperature. After acquiring normal room temperature, these samples are ready for further testing. The samples were then cut into different pieces of about 40mm* 20mm*20mm by water jet methods, as shown in Figure 2.

Figure 2. Shows dimensional samples

Using abrasive grade papers, these samples were polished for better finishing on their surfaces (top & bottom). Each sample is polished by constantly adding water to the equipment for ease of grinding. After rough grinding, these are polished again using a fine grinder by replacing it with a finer grinder wheel. The samples are to be grinded till a polished smooth surface appears.

2.2 Block on ring test and scanning electron microscope

Mostly Block on Ring test is used to conduct an abrasive wear test. Dimensional samples of 40mm*20mm*20mm are placed again on the stainless steel of AISI 304, Hardness- 1250 HB. All wear tests are performed under ASTM G-99 standards under unlubricated conditions and in a closed laboratory environment of ambient atmosphere conditions at 20-30 0c and 30-40% relative humidity on Block on ring test. After each test, proper care must be taken by thoroughly cleaning it with woollen cloth to avoid wear debris, entrapment and uniform experimental procedure. Weight loss for each specimen after measuring the weight of the specimen before and after each test. Weight loss is calibrated using an electronic digital balance weigh machine with précised accuracy of + or – 0.00001mg. Abrasive papers of different grit sizes of 400, 600, and 1200 are pasted on hardened steel discs of 60mm diameter by double-sided adhesive tape. Prepared 5mm, 10mm and 15mm specimens are placed against different grade papers of 400,600,1200 grits, and a normal load is applied against the lever mechanism.

Some of the wear parameters that are involved in the wear test are coir fiber weight to the volume percentage of 5mm, 10mm, 15mm, abrasive Paper Grit sizes of 400, 600, 1200 grits and, Sliding velocity and normal loads (5N, 10N, 15N, 20N). The wear behavior of samples is due to the combined effect of the above parameter and the effect of each parameter, which are studied and graphs plotted in this experiment. Finally, samples after the abrasive test are investigated using a scanning electron microscope.

3. RESULTS AND DISCUSSION

In this chapter 3, the Experimental results of coir fiber-reinforced polymer composites are explained. The abrasive wear behaviour of these composite experimental values is tabulated, and graphs are plotted for their wear rate and weight loss to the load and time variants. Surface topologies, worn surfaces and their behaviour after the test are observed, and their experimental Wear and results are explained.

3.1.1 Wear behaviour of coir fibre-reinforced polymer composite

To find the wear characteristics of 2% coir fibre reinforced composite of 5mm, 10mm and 15mm fibre length, repeated tasks are performed using different abrasive grit papers, time durations and under different load conditions.

3.1.2 The influence of the sliding time

The influence of the sliding duration on the weight loss of the prepared coir epoxy composites (10 mm) is presented in Figure 3(a-c) under different grade sizes. The weight loss vs. time is displayed for the different applied loads of 5-20N. In general, there is an increase in weight loss with the increase of the sliding duration for all the applied loads and the selected grades. Since there is running in process, this is well-known that materials start to wear away to adapt to a new counter face. Under this process, the soft material (composite surface) will be transferred onto the Sic papers to create a film on the surface. According to the literature, some works support this, such as abrasive stream resistance methods for coat breaking, as reported by Miyoshi [28]. In those works, it has been reported that single spots are abraded for a few seconds and switched after some spot and sample is worn out. Therefore, the current study agrees with the published work by [28].

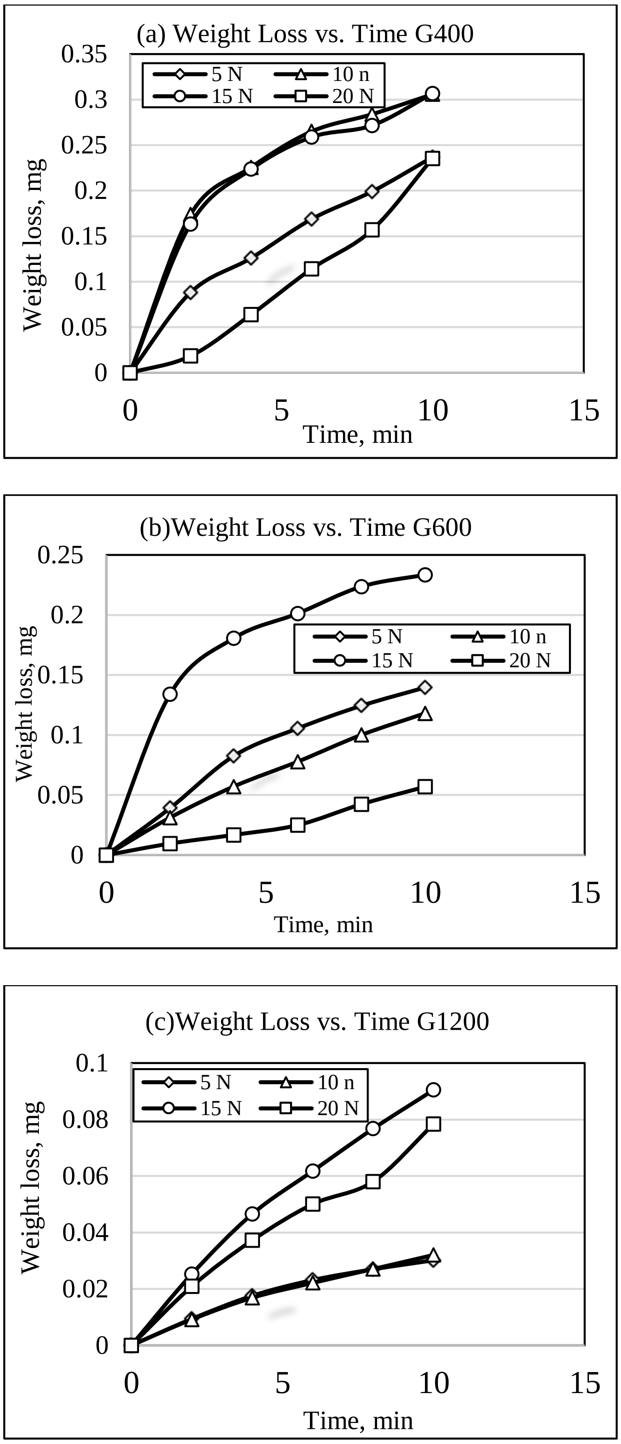


Figure 3. (a-c) Shows graphs for sample weight loss to time duration with different grit sizes.

3.1.3 Influence of wear rate on the sliding time

The influence of the sliding duration on the wear rate of the prepared coir epoxy composites (10 mm) is listed in figures 4 (a-c) under different grade sizes. The wear rate vs. time is displayed for a different applied load of 5-20N. In general, there is an increasing trend till a certain time, and at a certain stage, there is a decrement in wear rate with the increase of the sliding duration for all the applied loads and the selected grades.

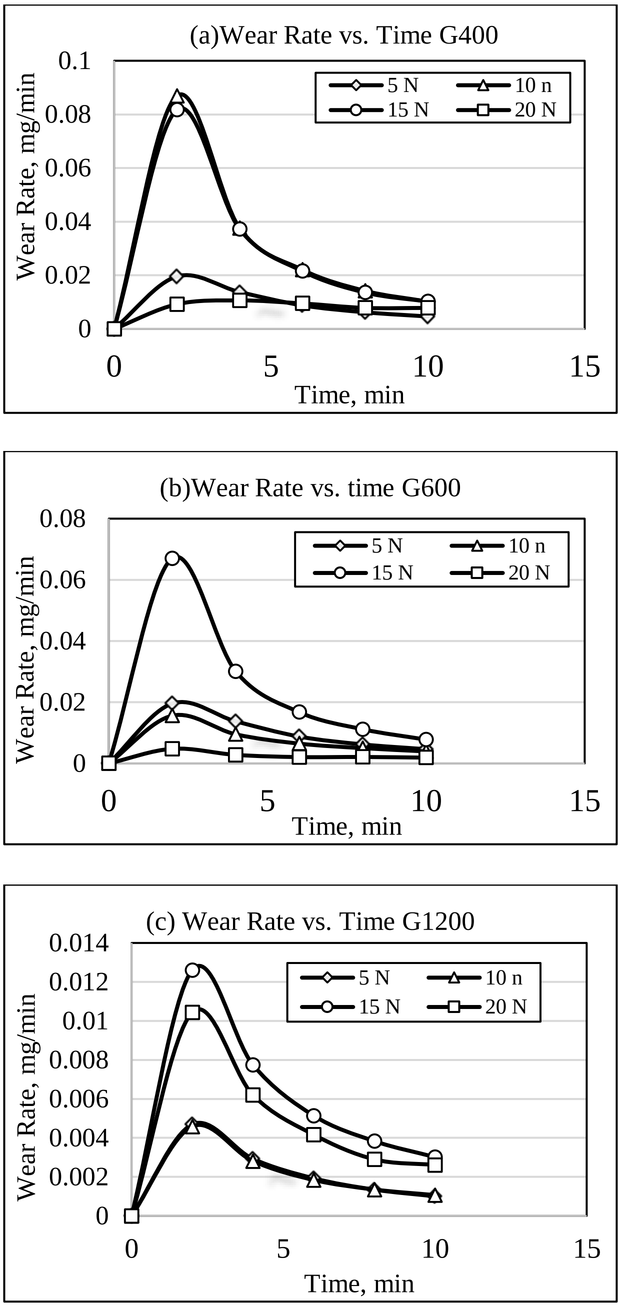


Figure 4. (a-c) Shows graphs for sample weight loss to time duration with different grit sizes.

The graphs show that materials wear out as the applied load increases. So, any outer layer material is eroded by grit papers. This can also be compared to the literature reviews that the abrasive wear volume of material through a certain distance is lower than soft materials. So, Richardson's findings can justify the graph and values obtained from coir fibre reinforced polymer composite.

3.1.4 The influence of the applied Load

The influence of the applied load on the weight loss of the prepared coir epoxy composites (10 mm) is presented in Figure 5 (a-c) under different grade sizes. The weight loss vs. load is displayed for different applied loads of 5-20N. In general, there is an increase in weight loss with the increase of the sliding duration for all the applied loads and the selected grades. Weight loss for the preparedsample.

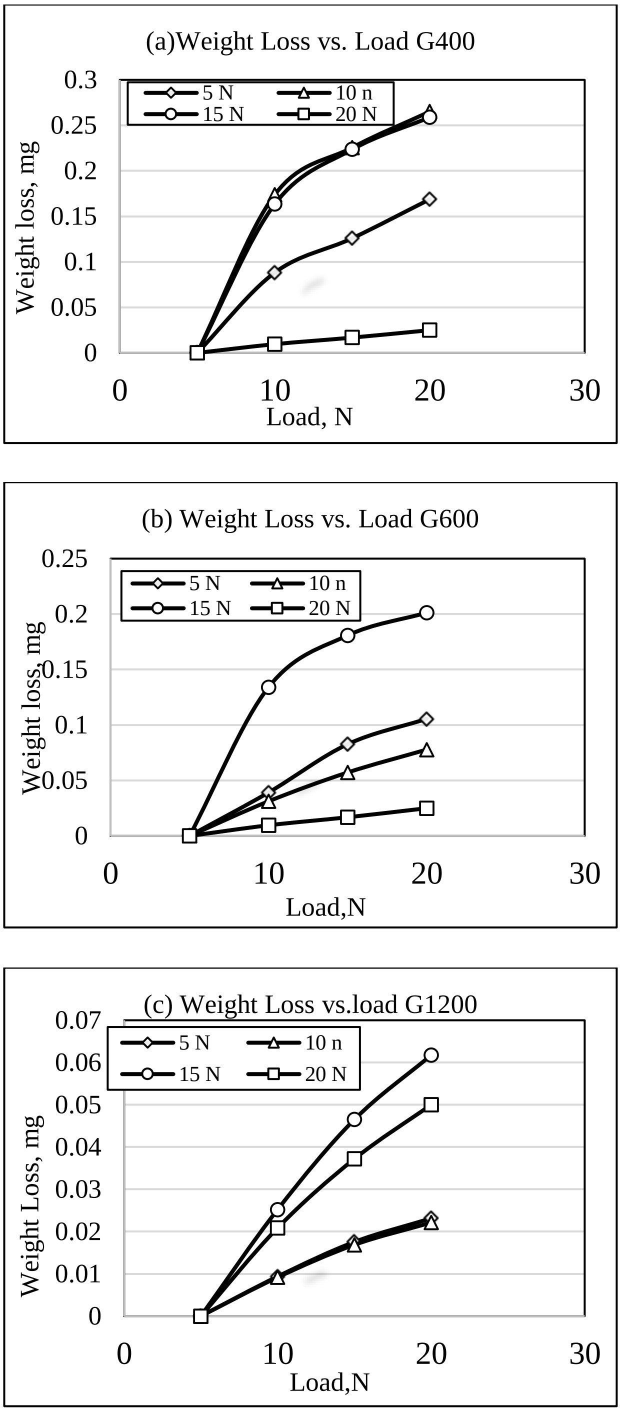
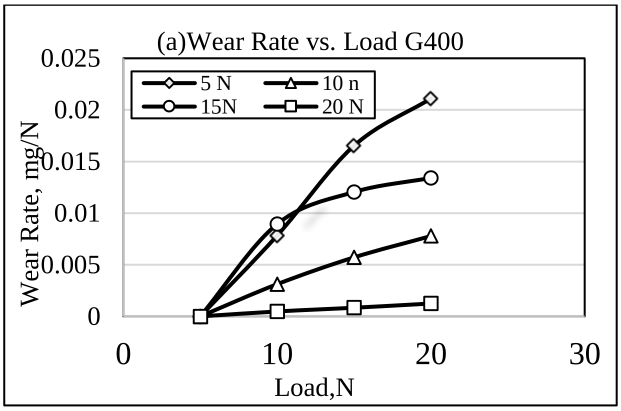


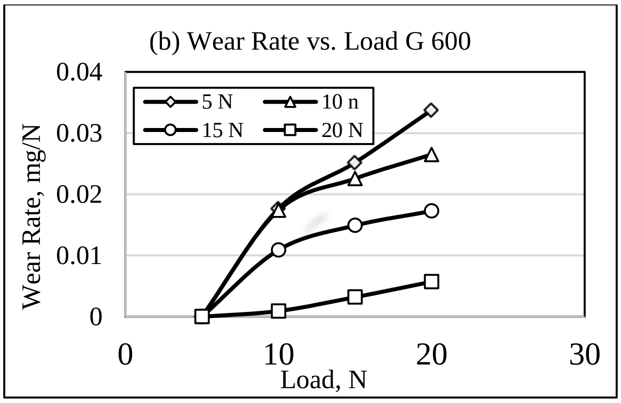
Figure 5. (a-c) Graphs showing weight loss vs. applied load (5-20N) with grits (400, 600, and 1200).

It is observed from the below figures as there is an increased applied load for each sample, weight loss increases. This loss may be due to the pressure between the surfaces of the sample and the grinding wheel. Due to this, weight loss for the sample may incur due to the repeated iterations with the Sic papers on the surface of the specimen. From the past literature, Deal studied the abrasive wear behaviour of coir fibre with different percentages and found that weight loss increases as the specimen is repeatedly counter-faced to sic papers. He reported that weight loss might vary with the applied load due to surface wear out in those works. So, from this, it can confirm that weight loss may vary depending upon the load given to the sample.

3.1.5 Influence of wear rate on the applied load

The influence of the wear rate on the applied load for prepared coir epoxy composites is presented in Figure 6(a-c) under different grade sizes. The wear rate to applied load is displayed for different grit sizes of 400,600,1200G. In general, there is an increase in the wear rate increases with an applied load of 10N and the selected grades.





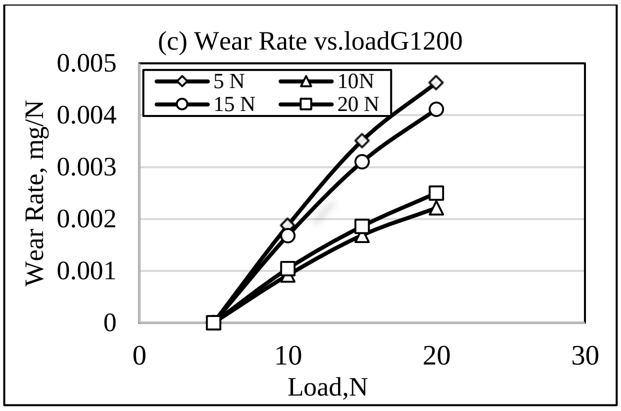


Figure 6. (a-c) shows graphs for Wear rate vs. applied loads.

It is mostly observed from the graphs below that the weight loss and wear rate are higher, and at a particular instant, the wear rate is higher for the normal applied load. After a few iterations of different loads on samples, the wear rate increases, and the material removal rate also reduces. It can also be observed that the specific wear rate after certain iterations is higher for a normal load. It can be justified from the Hogmark article states that the ability of a material depends upon load acting to absorb and deform plastically before deforming, suggesting a modal between wear rate and applied load.

3.1.6 The influence of the Sic grade

The effect of abrasive grit size for prepared coir epoxy composites can be studied by varying the grit size to that of the wear rate of the sample (5mm, 10mm, 15mm) for each grit size (400, 600, 1200). The influence of the wear rate on the applied load for prepared coir epoxy composites is presented in Figure 7 under different grade sizes. In general, there is an increase in the wear rate increases with the applied load of 10N and the selected grades.

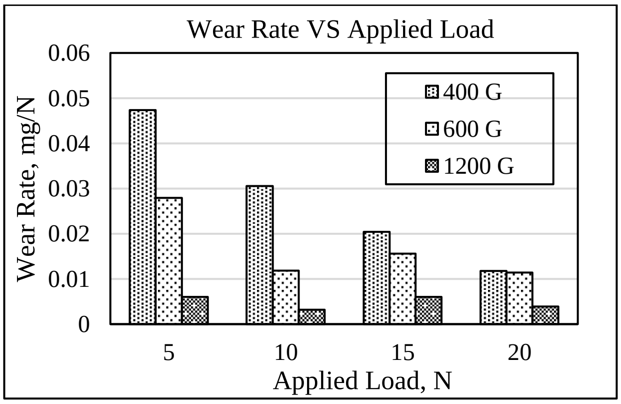
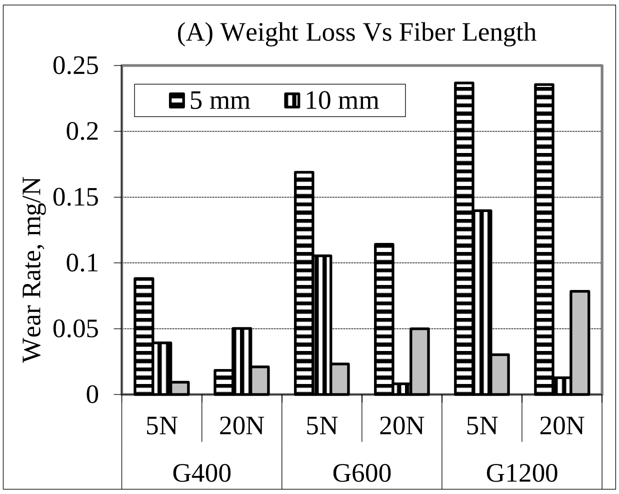


Figure 7. Graph showing coir fibre of wear rate VS applied load.

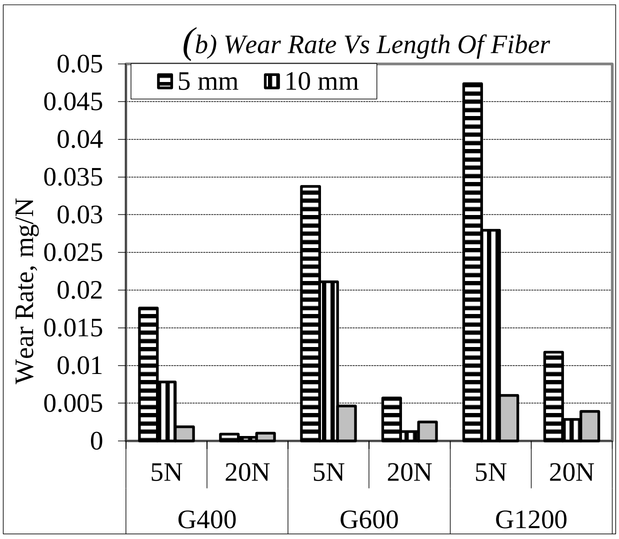
The above graph shows that the wear rate decreases slightly for different grit sizes 400G, 600G, and 1200G at load applied. This may be observed due to the deep penetration of particle sizes, which enhances material removal from the composite sample surface. This shows that wear behaviour during the wear process. At the initial phase, Wear dominates the applied load to the grit paper from Buckley's literature.

3.1.7 The influence of the fibre length

The influence of fibre length of the prepared coir epoxy composites is presented in figures 8 (a, b) under different grade sizes and applied loads. The weight loss vs. different applied loads of 5-20N and grades. Weight loss and wear rate varied for maximum and minimum loads of different fibre lengths. From the below graphs, it could observe that a fibre length of 5mm has drastic variations in wear rate and Wear loss compared to other fibre lengths.



(A) Weight Loss Vs Fiber Length



(b) Wear Rate Vs Length Of Fiber

Figure 8. (a, b) Wear rate and weight loss influence fibre lengths

A fibre length of 15mm had the least wear loss and weight loss for maximum and minimum applied loads. After analyzing all the above graphs, it is observed that the wear rate is high after a certain time duration with a stabilizing trend. This shows that wear behaviour, during the wear process. In the initial phase, Wear dominates the applied load to the grit paper. After a few iterations, the fibre length increment helped decrease the wear rate of the coir fiber-reinforced composite. There is also another possibility that can be considered that the matrix of the composite may be softened by an increase in abrasive time duration, which helps the wear rate to decrease. A research paper can support this from Buckley in 1985 found that Friction and Wear properties depend on surface interactions, properties, and the sizes of the natural fibre composites.

3.2 SEM and optical microscopy observation

Figures from 9 to 11 listed images for different fibre lengths of 5, 10, and 15mm coir fibre and their wear loss on coir fibre reinforced composite. Wear resistance of coir fibre with different fibre lengths to the varying load exhibits a more wear rate, I.e. (about 2 times higher) for 5mm coir fibre than 10 and 15mm fibres. This 5mm fibre type shows minimum wear loss at 40N while optimum wear rate at 10N.

While from SEM micro images, it is observed that broken or sliding powder particles while performing the test are entrapped at the specimen interface, and further passages on these mating surfaces may result in fractured film can be seen through SEM images. This debris hindered on the sample's surface may result in surface damage for the coir fibre composite. Besides all these, as compared to the SEM images, voids and cracks are observed at coir fibre with more applied load wear.There is no evidence to support the obtained images while the surface gets damaged and fractured at normal load on coir fibre. Instead of surface deterioration, cavities, fibre breakage, and debonding are some of the factors observed from SEM images of wear mechanisms.

Here, resin starts melting for the prepared sample to increase temperatures. Results due to frictional heating on the surface are evident. In the sliding mechanism, the entire load is distributed along the fibre as it has no scope to, resultingults in bending without breakage along the fibre composite. It was observed that a few long fibres are peeled off, and further micro-cuts are observed from the SEM images.

In SEM images, the cavities are filled with pulverized coir debris. For coir, fibre had better bonding ability between fibre and resin. This better bonding strengthens the fiber and contributes to high wear resistance for coir fibre composite. Microscope images showing worn surface and resin deformation after different varying parametersAs it is visible from the below images, the most weaken zone is fibre and resin.

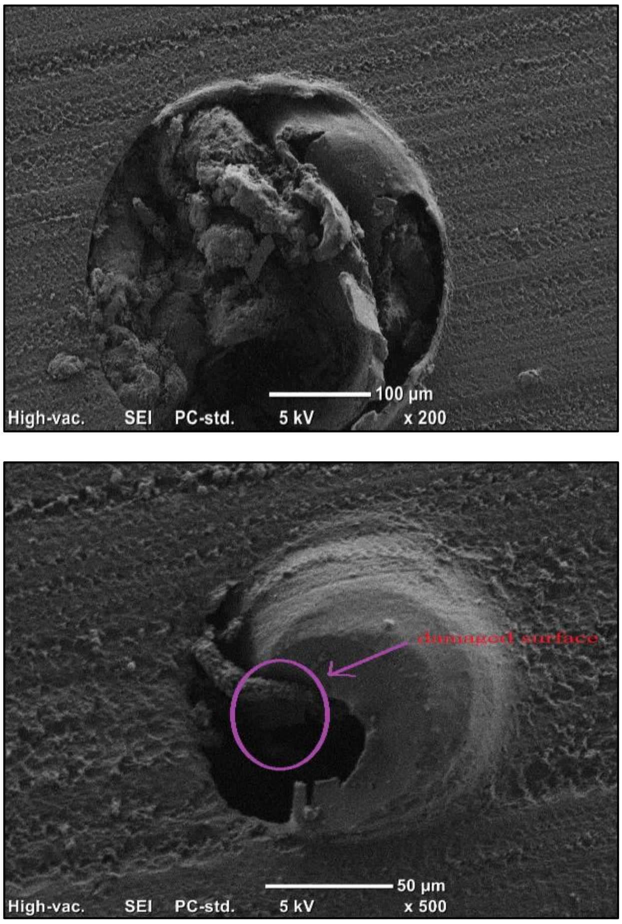
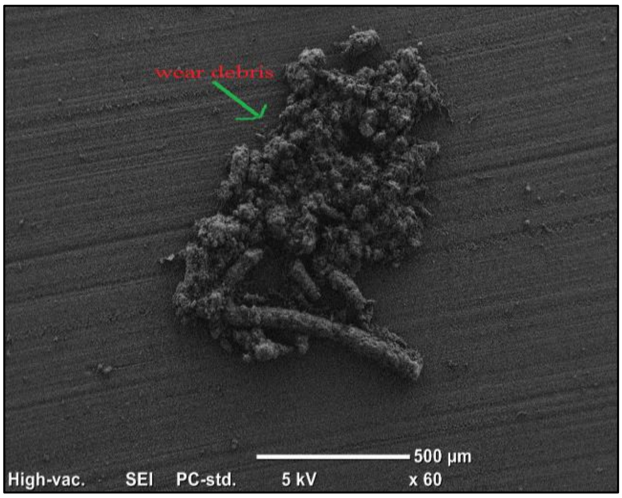


Figure 9. Images showing after the abrasive test for 5mm fibre length.



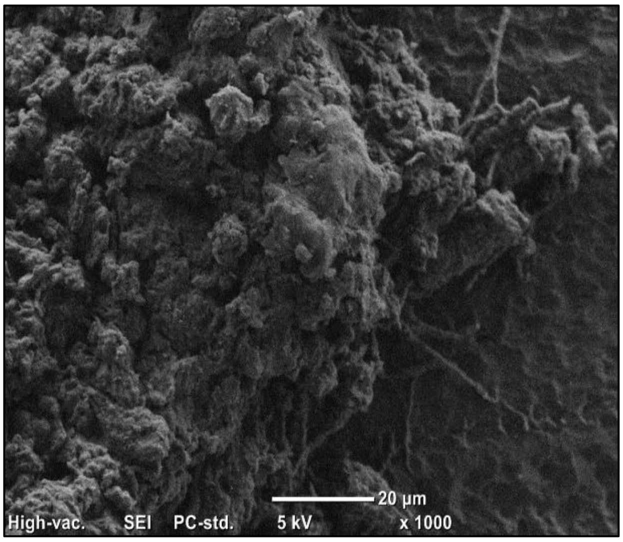


Figure 10. Images showing after the abrasive test for 10mm fibre length.

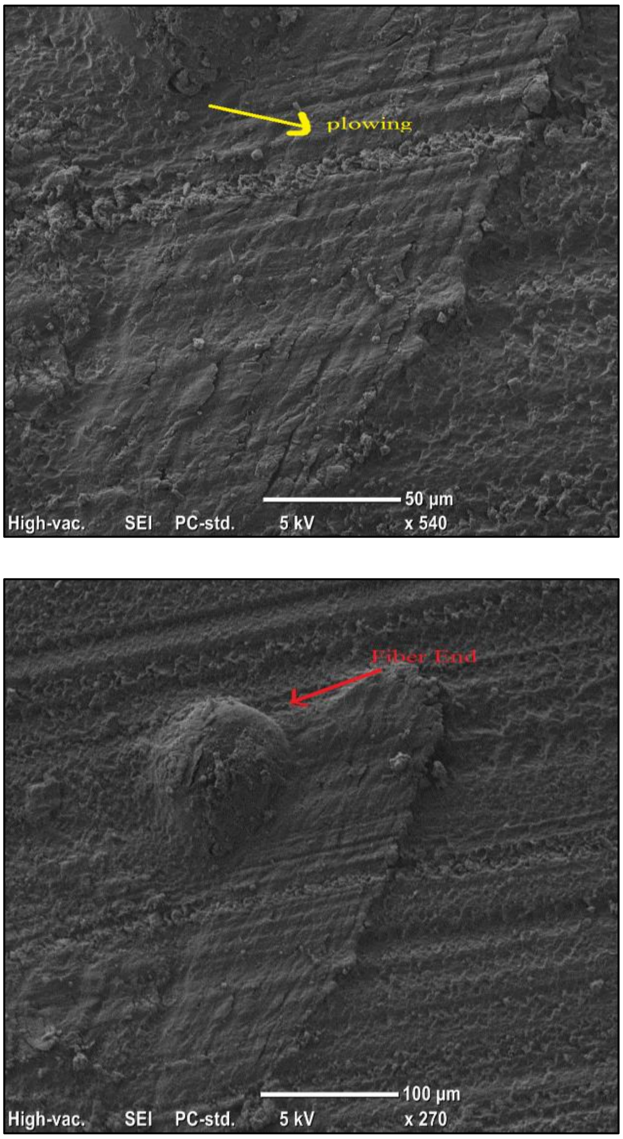


Figure 11. Images showing after the abrasive test for 15mm fibre length.

4. CONCLUSION

The results from the abrasive wear test and SEM are discussed in the preceding chapters, and conclusions for obtained results are as follows.

Coir fiber-reinforced polymer composites influence the wear behavior of composites. Coir fiber composite can be easily fabricated with different fiber lengths, and better tri-biological characteristics are obtained for 15mm fiber length, 20N applied load and 1200 Grit size using coir fibers compared with other fibers.

Fiber lengths applied to normal loads and grit sizes greatly influenced the wear performances. Mostly, the wear rate is consistently high for a 5N load of 400 Grit size and 5mm fiber length of developed composite. Also, sliding velocity and applied normal load had much influence on the tri-biological properties of the coir fiber composite.

The increment in wear rate is due to the varying normal applied load, and grit sizes show the consequent influence on tri biological properties of the developed composite. Mostly applied normal load greatly influenced wear rate, and different influencing factors may also cause wear mechanisms. While performing the abrasive test, deeper penetration of particle size on the surface may cause plowing, which causes a higher increment rate.

Breakage of fiber material is the most significant effect observed for wear mechanisms. Different aspects of wear behavior are observed through SEM, mostly Micro-cracks and wear debris on fiber composites due to the varying applied loads.

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