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Wear Resistance Performance of Treated MASF Polyester Composite

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Abstract: *In the current study, the effects of treating the* Musa acuminata *stem fiber (MASF) on the tribological performance of polyester composite were studied against polished stainless steel counterface using a computerized pin on disc (POD) machine under dry contact condition. Wear and friction characteristics of alkaline treated, silane treated and untreated MASF (MASF-AT, MASF-ST and MASF-UT) reinforced polyester composites were evaluated at different sliding sliding speed (1.5, 2.0, and 2.5 m/s), applied normal loads (15, 20, 25, and 30 N), and applied loads (30–100 N) and for a constant sliding time of 10 min under dry condition. SEM observations were performed on the worn surfaces of the composites to examine the damage features. Wear resistance, and friction coefficient results were presented against the operating parameters. The results revealed that test parameters significantly influenced the wear resistance performance of the composites. Both treated MASF-AT and MASF-ST enhanced the wear resistance and performance of polyester composites reinforced MASF showed more wear resistance about 23% - 34% compared to MASF-UT. But the friction coefficient decreased about 16% - 25 %. This was due to the better interfacial bonding between polyester-MASF offered by the treated fibres. The SEM observation made on MASF-UT worn surface showed debonding and bending of fibres, and fragmentation and deformation on the resinous regions. Furthemore, polyester composite reinforced MASF-AT and MASF-ST showed less damages compared to MASF-UT, where no sign of fibres debonding was observed..*

Keywords: Musa acuminata *stem fiber,Treating, Wear resistance, Friction coefficient, Polyester composite, Alkaline treated, Silane treated*

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I. INTRODUCTION

Recently, tribological performance of synthetic fibres such as glass, carbon and Kevlar reinforced polyester composites has been extensively studied (Bakri.,2011; Braga. R.A., 2014; Prakasha et al., 2016). Nowadays, natural fibres are becoming an alternative reinforcement for polyester due to their excellent advantages, i.e. renewable, environmental friendly, low cost, flexibility of usage, lightweight, natural recyclable and biodegradable (Navin et al., 2006; El-Tayeb et al., 2008). There are numerous applications such as housing construction materials, furniture and pad brake of automotives parts. From mechanical point of view, it has been proven that natural fibres enhanced the mechanical properties of neat polymers. Nevertheless, less work is found on the effects of natural fibres on the tribo-performance of polymeric composites (El-Sayed et al., 1995). In general, the tribo-performance of polymeric composites is influenced by many factors such as test technique and operating parameters. On the other hand, reinforcing the polymers with fibres could significantly improve the tribo-performance of neat polymers (Harsha et al., 2003). In the natural fibre/polymer composites, the interfacial adhesion of the fibres to the matrix plays an important role in control the mechanical properties of some polymeric composites .

The influence of untreated sugarcane fibres on the abrasive wear characteristics of polyester composites was done (El-Tayeb et al., 2008) . He found that the worn surfaces of the composites were highly damaged and different types of wear mechanisms took place during the abrasion tests, i.e. plastic deformation, micro cutting in the matrix, pitting, ploughing, and fragmentation of wear debris and tearing the fibre. On the other hand, it has been found that the treated jute fibres offered better abrasive wear resistance to the polypropylene (PP) compared to the untreated ones. In that work, the coupling agent used to increase the jute fibre adhesion with PP has been leading to enhanced abrasive wear resistance of the composites. From the above, it is observed that there are very few studies on the effects of treated and untreated MASF on the wear resistance performance of polyester composites. Consequently, prediction of the wear resistance characteristics of such composites is a difficult task. Thus, there is a necessity for a better understanding of the effects of the treated and untreated fibre reinforcement on the tribological properties of MASF reinforced polyester composite..

The polyester matrix composite reinforced natural fibers present a great potential application in the automobile industry, especially in the bumper of automobiles, bus and trucks. The future perspective for the use of natural fibers is very good also in other areas. For instance, the textile industry is now with expansion international market. In the last years, use of natural fibers as, coconut, sisal, rami, sugar-cane pulp, jute and pineapple as reinforcement in polymeric material had an accelerated growth. They are source of renewable natural resource. The rear bumper is one part of the vehicle that has a very important role, apart from being aerodynamic and aesthetically pleasing to attract consumers, the bumper also functions as a collision damper from the rear that occurs in the vehicle. Therefore, the material used as the rear bumper often gets damaged during a collision, so it requires a material that has good impact toughness, is light, ductile and corrosion resistant. Natural fibers present low cost, are biodegradable, recycled, no poisonous and can be incinerated. They are being used as reinforcement in polymeric and substitute synthetic fibers partially as asbestos, Kevlar, boron, carbon, nylon and glass. In spite of these good mechanical characteristics, they present a high cost, are abrasive to the processing equipment's, possess high density, generate products with very high recycling cost, besides some of those fibers commit human health.

This study aims to determine the trybological properties (Specific wear rate, wear resistance, and friction coefficient) of traeted Musa acuminata stem fiber reinforced composites with a polyester matrix, for the feasibility of these composites as an alternative solution to the replacement material for vehicle bumpers categorized as Multi-Purpose Vehicle (MPV) which in its application is closely related to safety usage especially in the automotive sectorion.

In the current study, the effects of untreated MASF (T-MASF and UT-MASF) reinforced polyester composites were investigated against smooth stainless steel using computerized pin on disc machine under dry contact condition at different operating parameters, and applied loads (30–100 N) and for a constant sliding time of 10 min under dry condition. Wear and friction characteristics of treated and untreated MASF (T-MASF and UT-MASF) reinforced polyester composites were evaluated at different sliding sliding speed (1.5, 2.0, and 2.5 m/s), applied normal loads (15, 20, 25, and 30 N), SEM observations were performed on the worn surfaces of the composites to examine the damage features

II. EXPERIMENTAL PROCEDURE

1.1 **Preparation of fiber.**

The banana plant Musa acuminata available in Lendang Bajur village, West Lombok district, West Nusa Tenggara state, Indonesia which comes under the family of Musaceae. The Musa acuminata stem fiber (MASF) extracted process is explained in Figure 1. The process includes CI plant stem dipped in water for 1 weeks in order to separate fibers from stem through microbial degradation (Saravanakumar SS et al., 2014) and further by using freshwater, the soaked stem is cleaned and dried in sun light for a week. Combing process was performed with metal teeth brush for extracting the fiber from the stem.

Figure2. The Musa acuminata stem fiber (MASF) extracted process

Furthermore, MASF was given different treatment, namely alkaline treatment and silane treatment. Alkaline treatment is done by dipping MASF in 5 wt.% NaOH solution for 5 hours at room temperature and then washed in running water to remove excess NaOH. Finally, distilled water is used to wash the fiber and the fibers are dried in the direct sunlight for 12 hours. Silane treatment is by soaking MASF in 5 wt.% NaOH. Pre-treated fibers are soaked in a concentration of 3 wt.% on 3-Aminopropyl Trimethoxysilane solution diluted in water and acetone (concentration by 50 % volume) for about 2 hours (Van de Weyenberg et al., 2003) and the fibers are dried in the direct sunlight for a period of 12 hours.

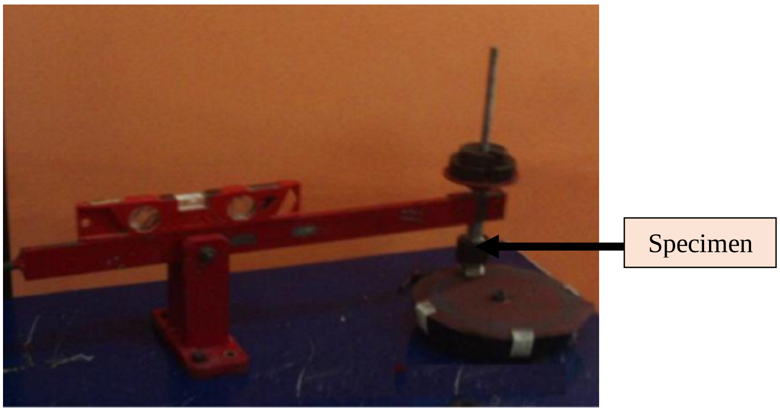
1.2 **Polyester composite material reinforced with MASF preparation.**

Polyester composite material reinforced with MASF was prepared with three different condition of fibers such as untreated fiber, treated with 5 wt.% NaOH and 3 wt.% silane of 20 mm fiber length for all the samples. In laboratory, the chopped MASF and polyester were mixed in the ratio of 30:70. Manual stirring took place to scatter the fibers in the matrix for a sufficient time, whereas hand layup and open mould technique were used to prepare the samples. Mould of glass test tube with dimension of 75 mm length and 10 mm diameter was used. The sample was taken out of the mould after it was cured for 24 h and the entire process was held at a room temperature of around 27 ^{0} C. The samples were signed as MASF-UT, MASF-AT, MASF-ST corresponding to, untreated, alkaline and silane treated MASF reinforced polyester composites.

1.3 **Wear resistance test procedure**

Wear resistance tes used pin-on-disc (POD) tribometer controlled by computer as shawn in Figure 2. Specimens conform to the ASTM standard of G99-95 with the dimension of 10 mm diameter and length 15 mm. Wear resistance specimen was placed against the stainless steel with sliding speed (1.5, 2.0, and 2.5 m/s), applied normal loads (15, 20, 25, and 30 N), and applied loads (30–100 N) and for a constant sliding time of 10 min under dry condition. Direct contact was made between the counter surface of the specimen and the disc by creating roughness on the specimen surface with the use of water proof silicon. The disc and samples were cleaned by the use of acetone before conducting the test.

Figure *2*. The wear resistance tes apparatus



Before the experiments, the sample weight is measured as W_1 and weight of the specimen after the wear test is noted as W_2 with electronic weighing machine assistance with precision weighing 0.001 mg. The weight difference between the weight of the specimen before the wear resistance test and after the wear resistance test is called as weight loss (ΔW). The following equations are used to calculate the weight loss (ΔW), coefficient of friction (μ) and wear rate respectively.

Weight loss (ΔW) = W1 - W2 (1)

Coefficient of friction (μ) = $\frac{f}{N}$ (2)

Wear rate (WR) = $\frac{\Delta W}{\rho L}$ (3)

Wear Resistance = $\frac{1}{WR}$

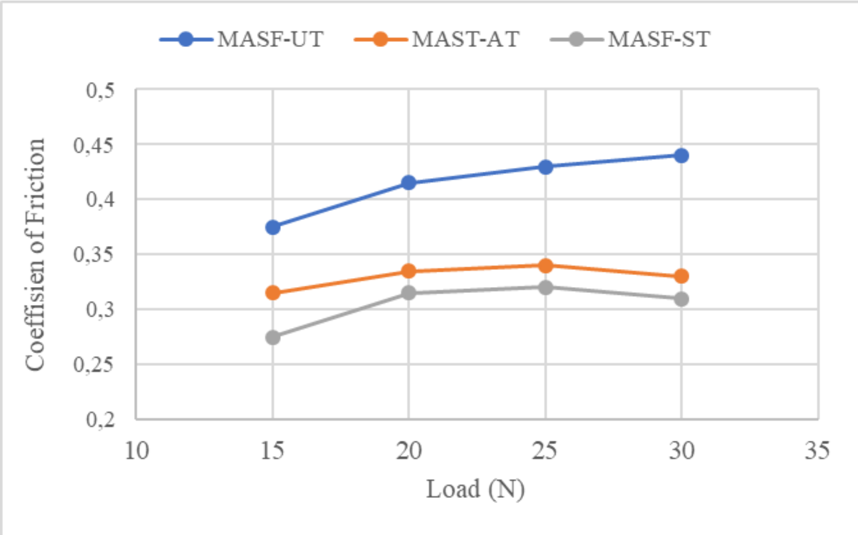
where, μ is coefficient of friction, f = frictional force, N = normal load, ρ = density and L= sliding distance. The test was conducted at room temperature of 29 ^{0} C and relative humidity of 65%. Morphological analysis used scanning electron microscope (Model VEGA 3 TE SCAN) for studying the surface of the wear tested specimen. Thin layer of sputtered gold was coated on the worn surface of all the tested composite specimens to improve electrical conductivity and to obtain better images.

III. RESULTS AND DISCUSSIONS

3.1. Friction coefficient of polyester composite reinforced MASF

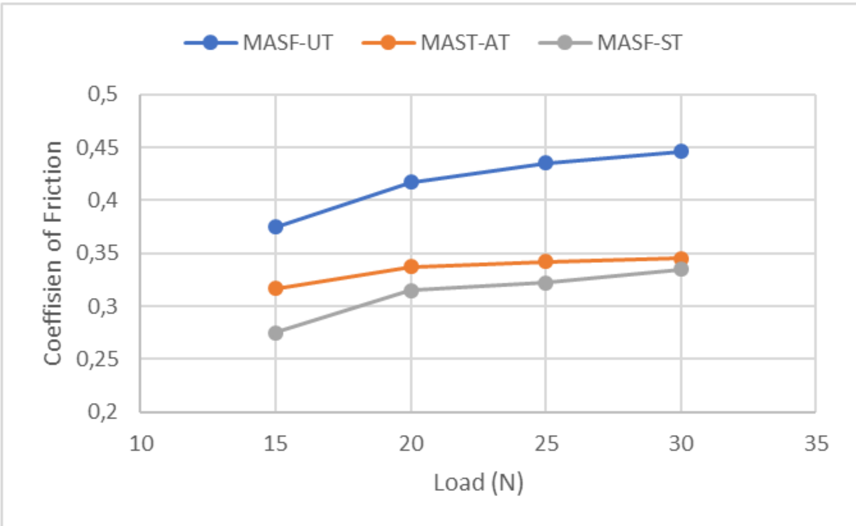
Figure 1 shows the reaction scheme of the syntheses of the derivatives of ibuprofen through the esterification reaction, which resulted in the production of 5 derivatives.

Figure 3. Friction coefficient of polyester composite reinforced MASF, a.at velocity of 1.5 m/s, b. at velocity of 2.0 m/s, c. at velocity of 2.5 m/s



a

Treatment on MASF caused a decrease in the friction coefficient on polyester composite reinforced MASF compared without treatment (MASF-UT). Treatment with silane causes a decrease in friction coefficient which is higher than that of alkaline treatment. The reduction in friction coefficients of polyester composite reinforced MASF about 34% occurs in the treatment of fibers with alkaline at the sliding speed 2.5 m/s and load 30 N as shown in Figure 3c, The lowest friction coefficients reduction occurs in alkaline treatment by 3% at the sliding speed 2.0 m/s and load 15 N, as shown in Figure 3b.



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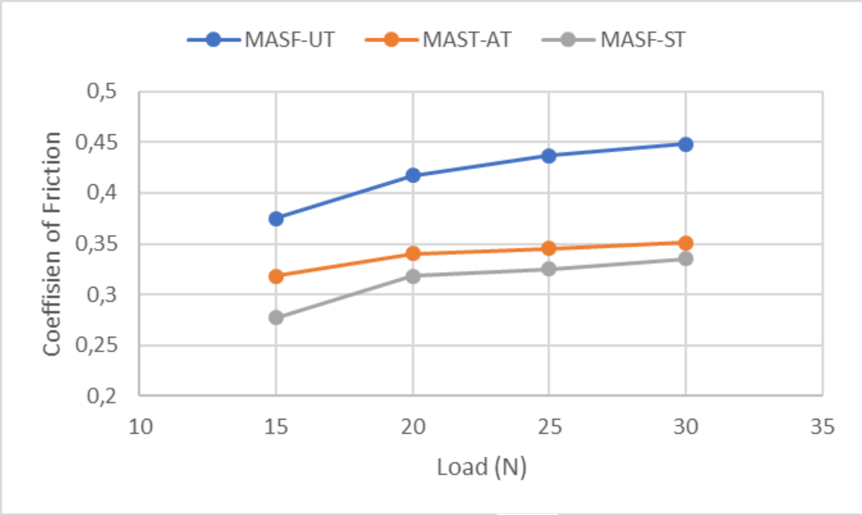
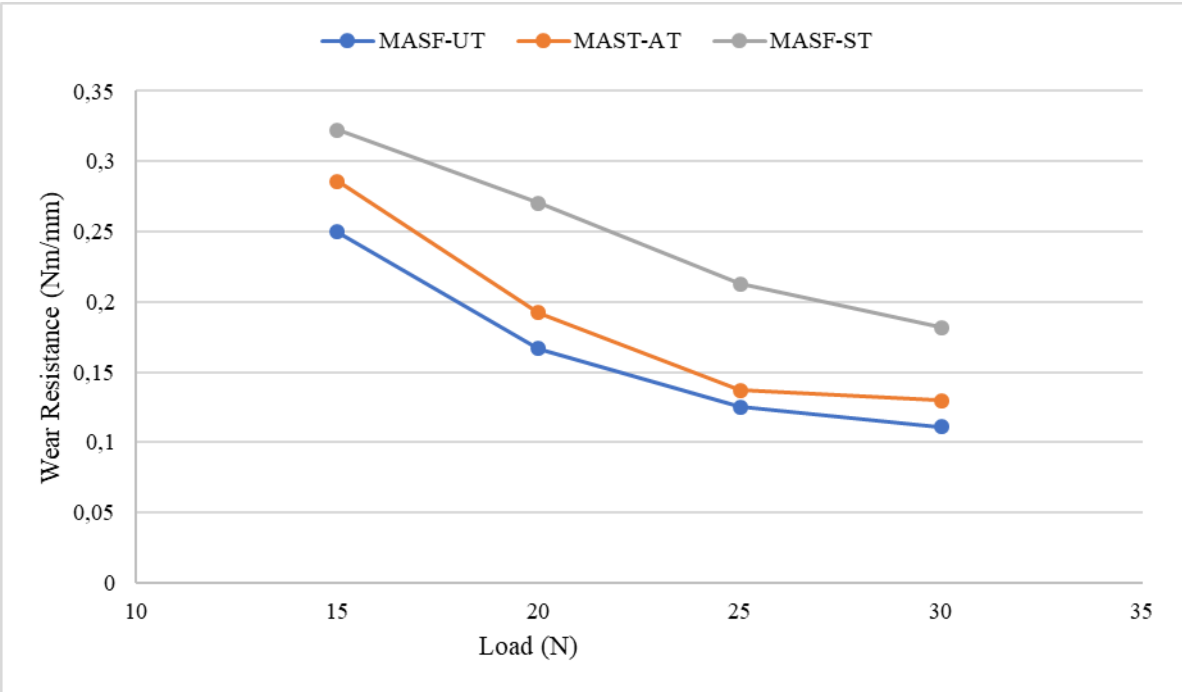


c

3.2. Wear resistance of polyester composite reinforced MASF

In general, MASF treatment causes increased wear resistance on polyester composites compared to no treatment. Treatment with silane caused a higher increase in wear resistance compared to alkaline treatment. Increase in maximum wear resistance on polyester composite reinforced MASF is 34% occurs in fiber treatment with silane at sliding speed 2.5 m/s and load 30 N as depicted in Figure 4c. The lowest increasing is occurs in fiber treatment with alkaline at sliding speed 2.0 m/s and load 15 N as shown in Figure 4b.

Figure 4. Wear resistance of polyester composite reinforced MASF, a.at velocity of 1.5 m/s, b. at velocity of 2.0 m/s, c. at velocity of 2.5 m/s



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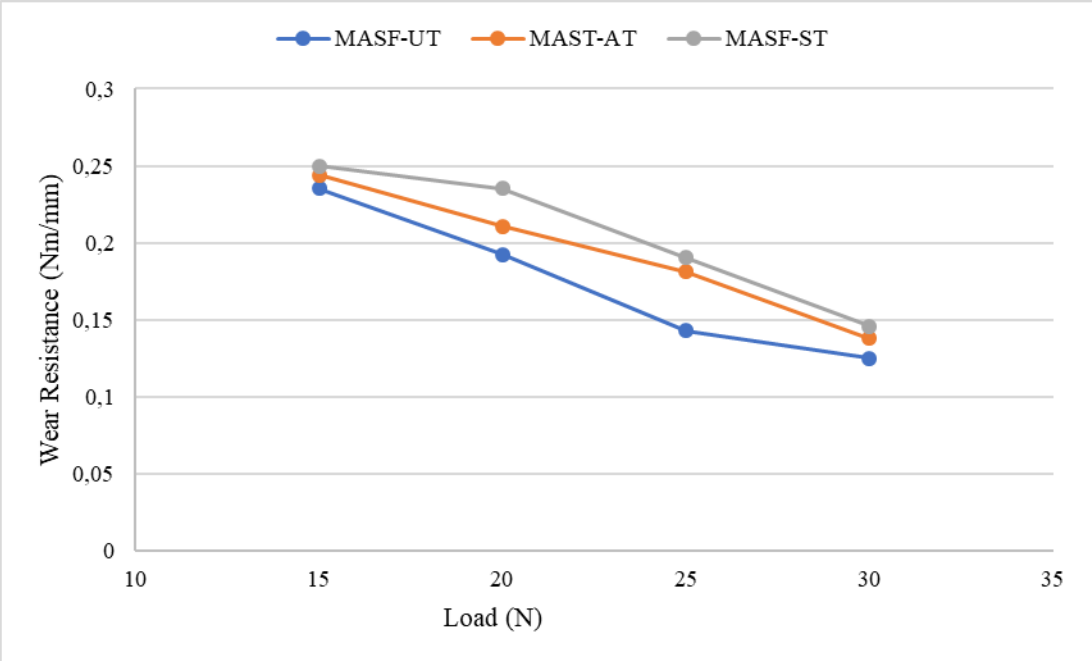

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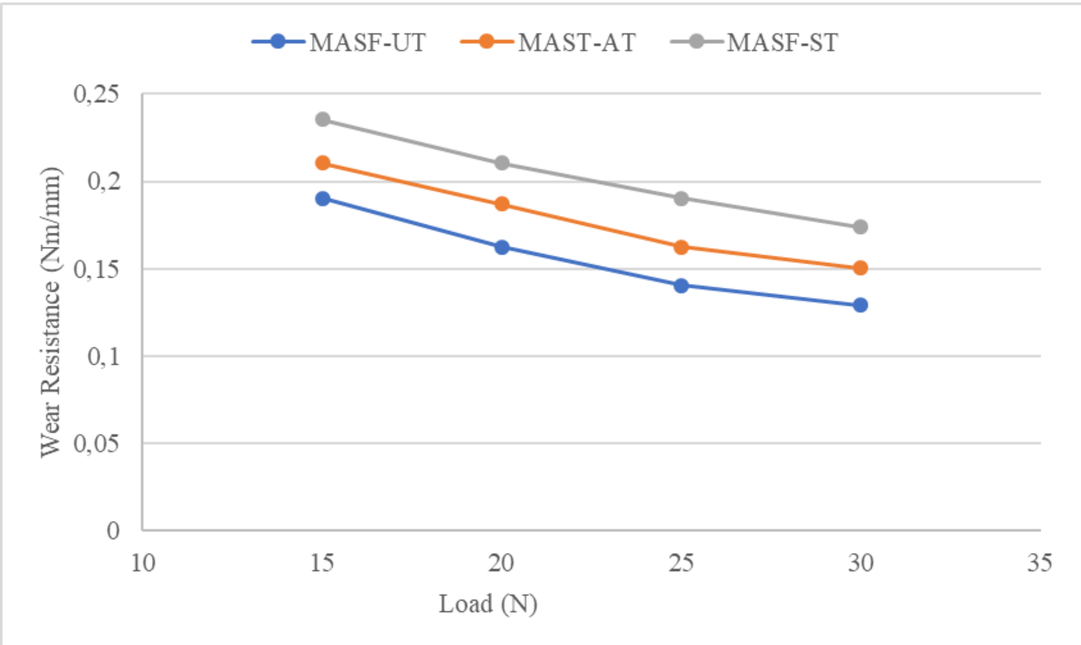

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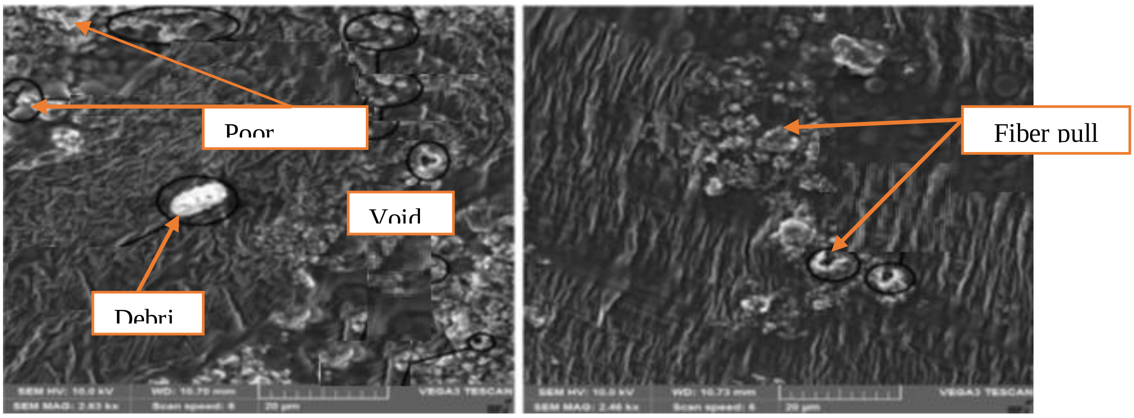
3.3. Worn surface morphology of polyester composite reinforced MASF

Worn surface morphology of polyester composite reinforced MASF, as shawn in Figure 3. They were examined by using SEM for different modes of the wear resistance mechanism occurred in polyester composite reinforced MAS. SEM image clearly depicts peel-off, shearing, delamination, fiber pull outs, epoxy deformation debris, fiber-matrix debonding and matrix crack. Generally, the interfacial debonding of fiber matrix occurs in the polymer matrix composite due to fiber fracture and fiber wear (Osterle W et al., 2006). At higher loads, all composites that have large deformations on the worn surface and some debris. The good formation of the interfacial bond between the matrix and the fibers shows an increase in the wear resistance performance of the MASF-AT and MASF-ST compared to MASF-UT composites.

Figure 5. SEM image of worn surface of of polyester composite reinforced MASF, a. MASF-UT, b MASF-AT, c. MASF-ST.



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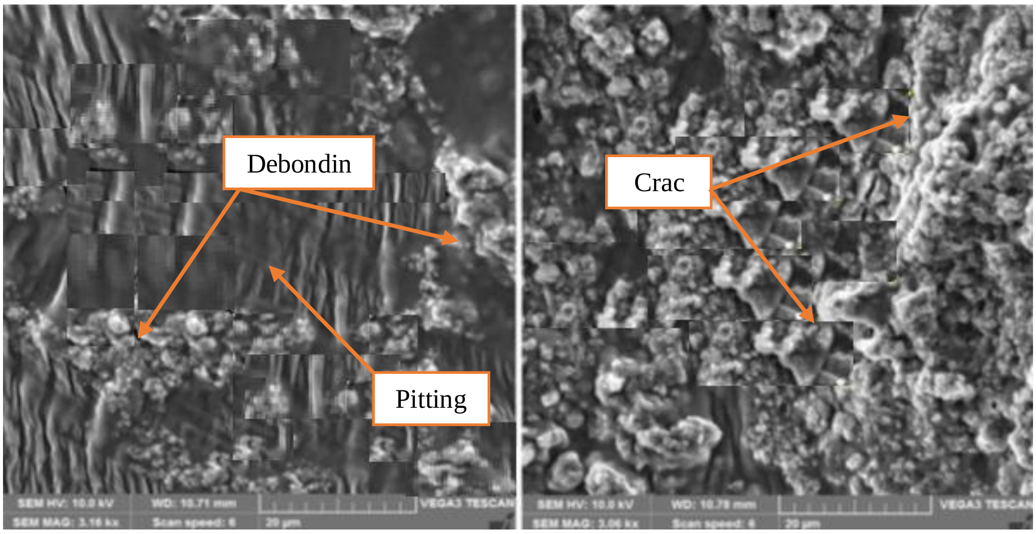

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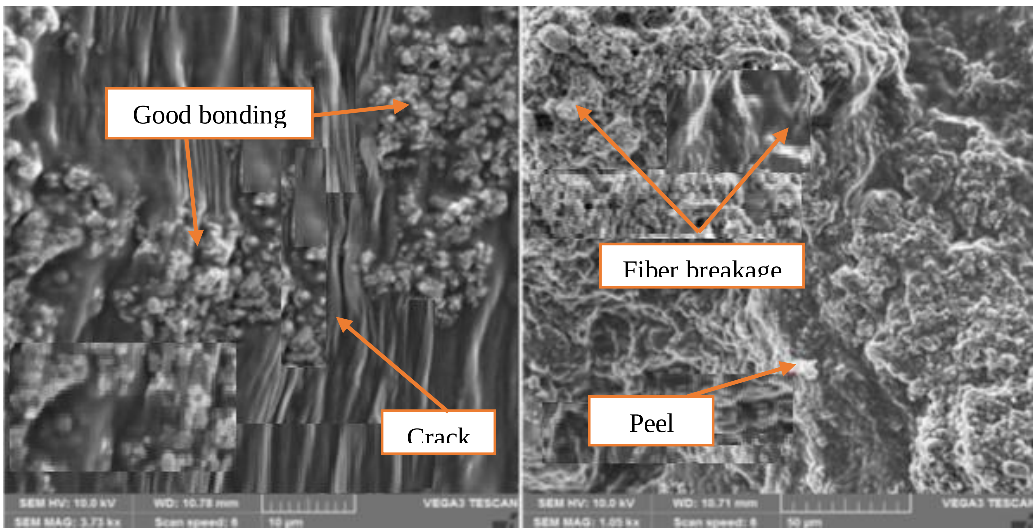

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Figure 5a. illustrates the debonding between MASF and polyester matrix in polyester composites reinforced MASF-UT and moreover, detached MASF and deformed debris of polyester matrix cover worn surface (Jha AK et al., 2010). Additionally, the presence of void that indicates higher weight loss in polyester composites reinforced MASF-UT may be due to fiber pullout. The wear mechanism such partial fiber debonding, wear debris and matrix deformation in polyester composites reinforced MASF-AT are shown in Figure 5b. Better adherence property with polyester matrix has been noted from treated fiber composites than untreated fiber composites and similar kind of result was reported by Liu et al., 2019. Additionally, the bonding between the fiber and the polyester matrix is found to be firm. Fiber alkaline treatment results in better interfacial bonding establishment between fiber and epoxy matrix. From the outer surface of the fiber, the wax and impurities are removed with the help of alkali treatment that result in enhanced interfacial adhesion. Coupling agent creates a chemical bond between fiber and matrix to improve fiber and matrix adhesion and the stress transfer to fiber from matrix because coupling agent leads to improved reinforcing effect. Both wear properties and performance of composites got enhanced by above said treatments. Moreover,fiber and matrix bonded tightly and assists in reducing the rubbing against counter face and reduces loss of weight in composites. In comparison with polyester composites reinforced MASF-UT, the amount of material removed is less because of the better fiber matrix bonding that is evident from the SEM images of the treated fiber composites. The clearly depicts the debonding between fiber and matrix and also has plastic deformation with considerable wear debris at an applied load of 30 N as shawn in Figure 5b.

Good bonding between fiber and matrix is shawn in Figure 5c. It’s sign that in polyester composites reinforced MASF-ST result in least loss of materials during sliding, which indicate high intimate contact through plastic deformation at polyester region. The conclusion, MASF and polyester matrix adhesion improved through silane treatment and good wear resistance was occur from the better.

IV. CONCLUSION

Based on the wear test on effect of treatment polyester composites reinforced MASF results in following conclusions. The wear test parameters (sliding speed, load) and treatment differences decide the wear behavior of the polyester composites reinforced MASF. MASF matrix interfacial bonding is enhanced through the surface fiber treatment, leading to better wear properties. MASF-ST > MASF-AT > MASF-UT was the order of wear resistance performance followed in the composites. Coefficient of friction value got reduced for the polyester composites reinforced MASF-AT and MASF-ST compared to MASF-UT. Reduction minimum by 16%, and 27% respectively for MASF-AT and MASF-ST at sliding speed 1.5mm/s, load 15 N and maximum by 21%, and 25% at sliding speed 2.5 mm/s, load 30 N. Overall the wear resistance of polyester composites reinforced MASF is increasing. The highest increase is 34% in the MASF-ST in the sliding speed 2.5 m/s and load 30 N. SEM investigation of all composites revealed the better bonding of the fiber and the matrix in silane treated composites and formation of thin film of resin on the surface of the composites and reduction in debonding. Thus, it improved the wear resistance performance of silane treated the polyester composites reinforced MASF when compared to the all other composites.

Conflict of interest

There is no conflict to disclose.

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