Influence of Fiber Length on the Tribological Behaviour of Short PALF Reinforced Bisphenol-A Composite

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Abstract—In recent years, natural fiber reinforced composites have received increasing attention in light of the growing environmental awareness. The use of natural fibers as reinforcement in polymeric composites for technical application has been a research subject of scientist. Among several natural fibers, Pineapple leaf fibre (PALF) is one that has good potential as reinforcement in polymer composite. PALF was extracted from raw pineapple leaf; it was then chemically treated and dried in hot air oven to hinder the water content. In the present work the composite specimens are prepared by using Bisphenol-A (BPA) as a matrix and the short PALF fiber with length < 15mm and 30% volume fraction as reinforcement. The composites were prepared by hand lay-up technique. The objective of the present work is to investigate the Tribological behavior of Short PALF reinforced Bisphenol-A composite. The composites reinforced with the fiber length of 2mm, 4mm, 6mm, 8mm, 10mm, 12mm & 14mm was subjected wear test. The wear behavior of the composites was performed using pin on disc machine at varying loads of 5N, 10N & 15N and at constant sliding distance, velocity and speed. The result shows that, the wear rate increases with increase in load for the composite specimen which has less interfacial bond strength. From this experimental study, it was observed that the fiber length greatly influences the wear properties of reinforced composites.

Keywords— PALF, BPA, Fiber length, Natural fibers, Alkaline treatment, Specific wear rate, Co-efficient of friction.

I. INTRODUCTION

Composite materials are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter or less expensive when compared to traditional materials.

Natural fibers are plant based which are lignocelluloses in nature and composed of cellulose, hemicelluloses, lignin, pectin and waxy substances. Cellulose gives the strength, stiffness and structural stability for the fibre, and is the major framework components of the fibre. Pineapple Leaf Fibre (PALF) is one such fiber source known from a long time obtained from the leaves of pineapple. Pineapple leaves from the plantations are being wasted as they are cut after the fruits are harvested before being either composted or burnt. Additionally, burning of these beneficial agricultural wastes causes environmental pollution. Over the past decade, cellulosic fillers have been of greater interest, since they give improved mechanical properties to composite material compared to those containing non-fibrous fillers.

Bisphenol-A (BPA) resin is a thermoset resin with good thermal and environmental stability, high strength and wears resistance. This combination of properties permits the application of BPA in polymer-based heavy duty sliding bearings. For these purposes, BPA usually is compounded with reinforcements like glass or carbon fibers and ceramic .mineral oxides and inorganic fillers. The use of fibers in polymeric composites helps to improve tensile and compressive strengths, tribological characteristics, toughness (including abrasion), dimensional stability, thermal stability, and other properties.

II. MATERIALS AND METHODOLOGY

Pineapple Leaf Fibre (PALF) is one such fiber source known from a long time obtained from the leaves of pineapple plant (Ananascomosus) from the family of Bromeliaceous.
Bisphenol-A (BPA) is an organic compound which belongs to the group of diphenyl methane derivatives and Bisphenol. The chemical formula is $(CH_3)_2C\ (C_6H_4OH)_2$. BPA is used to make certain plastics and epoxy resins; it has been in commercial use since 1957.

A. **Materials**

PALF extracted from leaf of pineapple plant by biological method supplied from Chandra prakash.co, Jaipur, Rajasthan .Bisphenol-A resin was supplied from Balaji fabrications, Mysore, Karnataka.

B. **Chemical treatment**

Extracted fibers subjected to Alkali treatment or mercerization using sodium hydroxide (NAOH) is the most commonly used treatment for bleaching and cleaning the surface of natural fibers to produce high-quality fibers. Modifying natural fibers with alkali has greatly improved the mechanical properties of the resultant composites. Firstly 5% NAOH solution was prepared using sodium hydroxide pellets and distilled water. Pineapple leaf fibers were then dipped in the solution for 1hour. After 1 hour fibers were washed with 1% HCl solution to neutralize the fibers. Then it is washed with distilled water. It was then kept in hot air oven for 3hours at 65-70°c. Then fibers were chopped to different fiber length.

C. **Manufacturing of composite**

A polypropylene (PP) mould having dimensions of 80 X 60 X 10 mm is used for composite fabrication. The mass fraction for the prepared mould is calculated using equation of volume fraction of the fiber and density of fiber. The mould was first cleaned with wax so that the laminate easily comes out of the die after hardening. Then around 15 to 20 ml of promoter and accelerator are added to Bisphenol and the color of the resin changes from pale yellow to dark yellow with the addition of these two agents. The laminates of different fibers lengths of short PALF are prepared using hand layup method. This method of manufacturing is a relatively simple method compared to other methods like vacuum bag molding, resin transfer molding, autoclave molding etc. Fig 2.1 shows the PALF reinforced laminated composites with fiber length of 2, 4, 6, 8, 10, 12 and 14mm respectively.
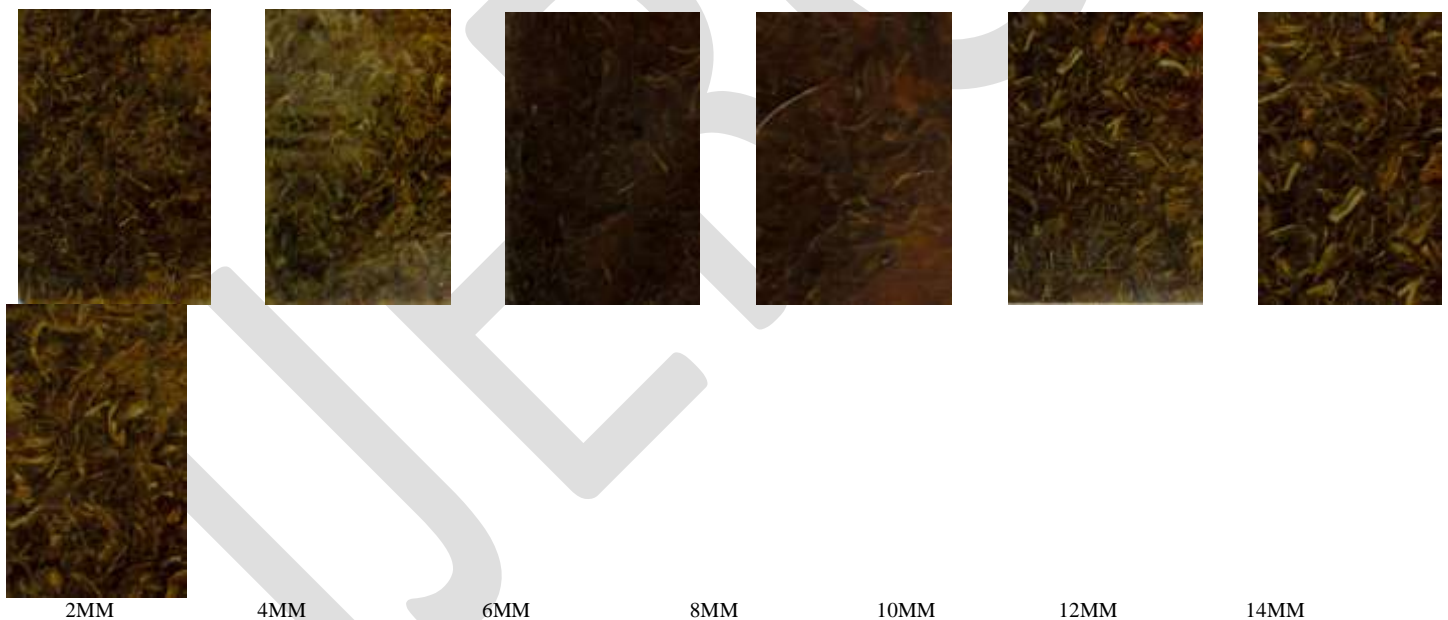

| 2MM | 4MM | 6MM | 8MM | 10MM | 12MM | 14MM |

Figure 2.1: PALF reinforced composites of different fiber length

Figure 2.2: 80 X 60 X 10 mm^3 mould

The mass fraction for the prepared mould and for desired volume fraction of fiber is calculated using equations:

Volume fraction of fiber $(V_F) = v_f / v_c$ (1)

Density of the fiber $(\rho) = m_f / v_f$ (2)

Were v_f = Volume of the fiber, v_c = Volume of the composite, m_f = Mass fraction of the fiber.

D. **Pin-on-Disc Wear Test**

Wear tests were carried out on a pin on disc wear test rig at room temperature as shown in Fig 2.3. The square bar specimen of size 8*8*10 mm was prepared from different fiber length PALF sample and glued to a pin(mild steel) of dimension 8*8*32 mm as shown in Fig 2.4. The specimen attached pin is mounted on to the arm of tribometer. The sample is made to rotate on the wear disc of EN-31(56-60 HRC), Ø 165mm* 8mm thick. Then the desired load is applied on to the pin by a pulley arrangement in the range of 5N, 10N, 15N respectively. The disc was made to rotate at constant speed of 160 rpm, velocity 1m/s and sliding distance 180m under different loads 5N, 10N and 15N. The 3 samples namely A, B and C from different fiber length PALF composite are used for different loads respectively. The sample will be weighed before and after the wear test to determine the weighed loss due to wear.
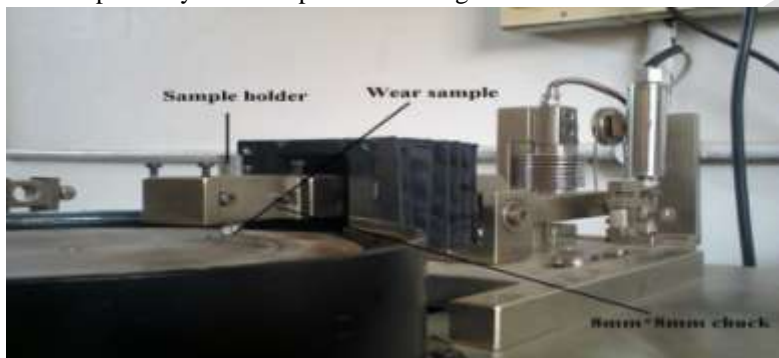

Figure 2.3: Pin on disc machine   Figure 2.4: Wear samples

III.   **Results and Discussion**

Table 3.1 shows wear and frictional properties of composites for different fiber length PALF composites for constant parameters such has velocity 1m/s, sliding distance 180m and speed 160rom. The study on the frictional and wear properties is important for the application of composite where there the composite will be subjected for the friction and wear. Properties which are required to analyze the wear behavior of the composite are specific wear rate (K_o), coefficient of friction (μ) and tangential friction force (F_t). Coefficient of friction gives relation between tangential friction force that will be existed between composite sample surface and abrasive disc surface. Specific wear rate is not the inherent property of the composite, but it gives wear resistance of composite sample being tested in terms of volume of material removed with respect to the applied normal load and sliding distance.

Coefficient of friction gives relation between tangential friction force that will be existed between composite sample surface and abrasive disc surface. It was observed that the Co-efficient of friction decreased with increasing the load. At the beginning the fibers offered resistance to wear. Due to this the frictional coefficient increases and resulting in thermo mechanical loading. Therefore micro cracks were developed on the surface and hence reducing wear resistance. The sliding direction and the random orientation of the fibers were the influencing factors to the friction coefficient values [6]. Coefficient of friction with respect to varying load is plotted in graph Fig 3.1.

When load increases, more material will be removed and this removed material induces self lubrication as it is held in between the contact surface of sample and abrasive disc, which resulted in the existence of less tangential frictional force (F_t) between the mating surfaces of sample and disc, which in turn resulted in less coefficient of friction (μ) and led to less specific wear rate. In the case of 2mm & 14mm PALF composite, fiber delaminates easily when shear force acts between sample and the disc. Therefore fibers transmitted most of the applied load and caused high tangential frictional force and coefficient of friction to exist between mating surfaces of sample and disc, which in turn resulted in high specific wear rate.

The co-efficient of friction for 8mm fiber length PALF composite was decreased by 18.75%, 17.33%, and 14.2% then unreinforced Bisphenol-A for 5N, 10N and 15N respectively. As the length of the fiber increases the adhesion between matrix increases till 8mm, then it decreases. Reason for this is too short fibers, long fiber in composites acts as a flaw hence composite strength decreases [15]. Hence from the experimental results 8mm fiber considered as the optimum fiber length.

Specific wear rate decreased with increase in load. The un-reinforced Bisphenol-A resin showed more specific wear rate when compared to reinforced Bisphenol-A. This is due to presence of reinforcing fibers that lead to increase the average hardness of the composite. Less specific wear rate is observed for 8mm PALF composite. The reason is due to the presence of strong interfacial bond strength between matrix and fibers. Therefore this prevents the delamination and fiber pullouts during the wear process. The specific wear rate for 8mm fiber length PALF composite was decreased by 75.60%, 77.15%, and 61.62% then unreinforced Bisphenol-A for 5N, 10N and 15N respectively. Specific wear rate with respect to varying load is plotted in graph Fig 3.2.

Table 3.1: Wear and frictional properties of composites for different fiber lengths of PALF composites

Sliding distance =180m, Velocity=1m/s, Time=3min

Fiber length	Load (N)	Wear in microns	Frictional force (N)	CO-EFFICIENT OF FRICTION	SPECIFIC WEAR-RATE (mm^3/Nm)
Bisphenol-resin	5	279	4.5	0.8	19.84E-3
	10	356	7.7	0.75	12.65E-3
	15	385	10.7	0.70	9.12E-3
2mm	5	268	4	0.8	19.05E-3
	10	340	7.5	0.75	12.08E-3
	15	375	10.5	0.70	8.8E-3
4mm	5	212	3.7	0.75	15.075E-3
	10	256	7.2	0.72	9.10E-3
	15	292	10.1	0.67	6.92E-3
6mm	5	210	3.6	0.73	14.9E-3
	10	221	7.0	0.7	7.85E-3
	15	268	10.1	0.67	6.35E-3
8mm	5	68	3.3	0.65	4.85E-3
	10	80	6.2	0.62	3.48E-3
	15	147	9	0.60	2.84E-3
10mm	5	107	3.4	0.67	7.6E-3
	10	213	6.5	0.65	7.57E-3
	15	280	9.3	0.62	6.6E-3
12mm	5	178	3.6	0.72	12.65E-3
	10	213	6.9	0.69	7.57E-3
	15	280	10.1	0.67	6.6E-3
14mm	5	225	3.8	0.76	16.0E-3
	10	272	7.0	0.70	9.67E-3
	15	310	10.3	0.69	7.34E-3

The specific wear rate and co-efficient of friction is calculated experimentally from the equation:

Ko = V / (P.L)   (3)

μ = F/ P   (4)

Were Ko = specific wear rate in mm^3/ N-m, V = volume of material removed By wear in cm3, P = Normal load in N, L= sliding distance in Meter (m), μ = frictional coefficient, F = Tangential frictional force in N.

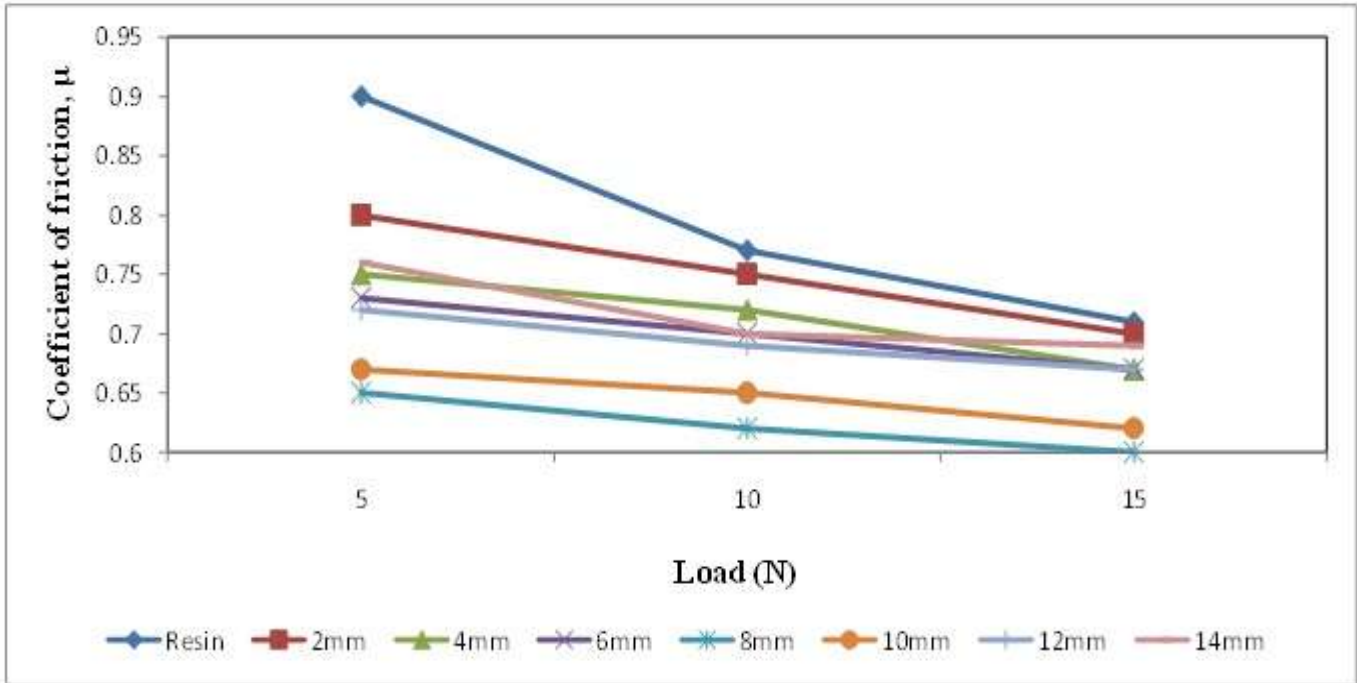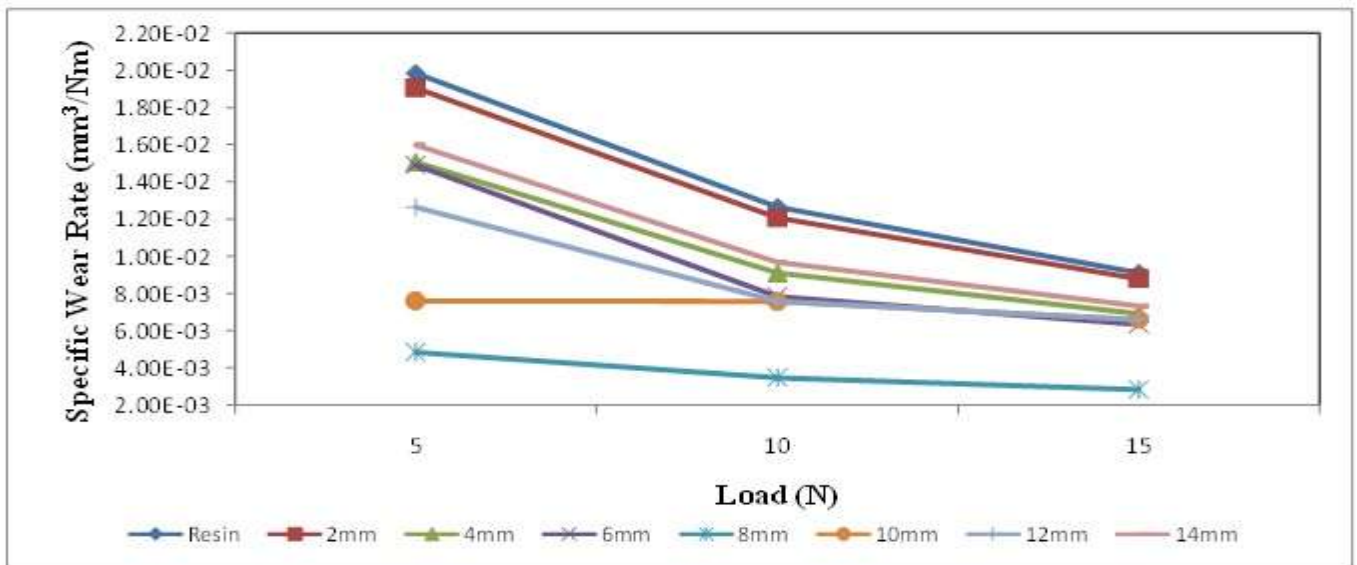Figure 3.1: Coefficient of friction with respect to varying load

Figure 3.2: Specific wear rate with respect to varying load

IV. Conclusion

In the study of wear and frictional properties, the unreinforced resin material and composites with different fiber lengths are subjected to varying load at constant sliding distance, velocity. The PALF composite of fiber length 8mm shows less specific wear

rate and coefficient of friction. The present investigation shows Specific wear rate & coefficient of friction decreased with increase in normal load. As the length of the fiber increases, the strength & adhesion between fibers increases till optimum length of 8mm later it decreases. The presence of too short fibers, long fibers in composites acts as a flaw, hence composite strength decreases. The random distribution of fibers, made the composite material to observe more load and less frictional force at the mating surfaces of samples and abrasive disc. Coefficient of friction for all the different fiber length PALF composites decreased with increase in normal load due to Self lubrication of the testing samples. As the normal load increased, more material was removed and the removed material was held at the mating surfaces of composite and abrasive disc which resulted in self lubrication. From this experimental study, it was observed that the fiber length greatly influences the wear properties of reinforced composites.

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