Effect of Fiber Orientations on Tribological Behaviour of PALF Reinforced Bisphenol-A Composite

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Abstract— Ironically, despite the growing familiarity with composite materials and ever-increasing range of applications, use of natural fibers as reinforcement in polymeric composites for technical application has been a research subject of scientist. Pineapple leaf fibre (PALF) is one of them that have also good potential as reinforcement in polymer composite. In this present work, an experimental study has been conducted to determine the effect of fiber orientation, namely, unidirectional, bidirectional and 45º orientation on specific wear rate and frictional coefficient of PALF reinforced Bisphenol-A (BPA) composite by using a pin-on-disc wear and frictional testing machine. The wear samples are slided against stainless steel disc by varying loads of 5N, 10N & 15 N under constant sliding distance, velocity, speed and dry conditions. It is found that the wear resistance of pure Bisphenol-A resin is improved after PALF reinforcement. Among three types of fiber orientation in composite, bidirectional composite shows least specific wear rate and coefficient of friction.

Keywords— PALF, BPA, Natural fibers, Alkaline treatment, Fiber orientations, Specific wear rate, coefficient of friction.

I. INTRODUCTION

Now a day's polymeric materials are used in almost all the applications because of their specific characteristics such as light weight, self lubricancy and reduced noise. Natural fibers are advantageous over synthetic fibers as they are renewable, eco friendly, low in density, biodegradable and less abrasive. The abundant availability of natural fibers and ease in composite manufacturing has triggered the interest among the researchers to study about their tribological behaviour under reinforcement in polymers. During the tribological applications like bearings, gears, cams etc., the major failure mechanism experienced is due to wear only. The wear takes place during the time of relative movement between tribo materials.

Pineapple Leaf Fibre (PALF) serving as reinforcement fibre in most of the plastic matrix has shown its significant role as it is cheap, exhibiting superior properties when compared to other natural fibre. PALF is multi-cellular and lignocelluloses materials extracted from the leave of plant Ananas cosomus belonging to the Bromeliaceae family by retting (separation of fabric bundles from the cortex). PALF has a ribbon-like structure and is cemented together by lignin material, which contribute to the strength of the fibre.

C.H. Chandra rao et al [1] investigated on wear behavior of coir fiber reinforced epoxy composites. L. Bhoopati et al [2] studied the wear behaviour of Borassus fruit fiber reinforced epoxy composites. S.R.Chauhan [3] studied the friction and wear behaviour of vinylester composites under dry and water lubricated conditions. Mohit Sharma et al [4] studied the influence of fiber orientation on abrasive wear of unidirectionally reinforced carbon fiber–polyetherimide composites. Punyapriya mishra et al [5] studied the abrasive wear behavior of bagasse fiber reinforced polymer composite. Therefore in the present work an attempt has been made to investigate the specific wear rate and coefficient friction of long PALF reinforced Bisphenol-A composite for different fiber arrangements under various loads from 5N to 15N.

II. EXPERIMENT

A. Materials

PALF extracted from the leaf of pineapple plant by biological method supplied from Chandra Prakash. Co, Jaipur, Rajastan. Bisphenol-A resin was supplied from Balaji fabrications, Mysore, Karnataka.

B. Chemical treatment of fiber

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. 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.

C. Preparation of composites and samples

All specimens in this study were manufactured by hand layup technique. The mould that was used is made of poly propylene with dimension (100*70*10 mm^3) is sown in the Figure 2.1. The chemical treated fiber yarns are woven in to unidirectional, bidirectional and 45 º orientational mats. The mould was filed by the mixture of Bisphenol-A resin and hardener (HY 951) of 10:1 ratio at room temperature. The mats (30% volume fraction) were added to mixture of resin and hardener. The load was applied to solidify, when the solidification process for all moulds is completed after 24 hours, the casts are released from the moulds. The composite laminates with different fiber orientation are shown in Figure 2.2. The laminates were cut in to sample of dimensions 8×8×10 mm^3. The samples were attached to sample holder which was of c/s area of 8×8×32 mm^3. Samples attached to sample holder s are shown in Figure 2.3.

D. Pin-on-disc wear test

Wear tests were carried out by using a pin-on-disc. The samples attached to the sample holder is connected to the 8×8c/s area chuck against rotating wear disc (EN-31(56-60 HRC) of Ø165mm * 8mm thick. The disc was made to rotate at constant speed of 160 rpm, velocity of 1 m/s and sliding distance of 180 m under different applied loads (5N, 10N and 15N). Three samples namely: A, B and C from unidirectional, bidirectional and 45º orientational composite are used for 5N, 10N and 15N loads respectively. After the end of testing the specimens were removed and weighed to determine the weight loss due to wear. The differences in weight measured before and after tests gives wear of the composite specimen. The following relations 1& 2 are used to investigate the, specific wear rate and coefficient of friction respectively, V = volume of material removed by wear in cm^3, P = Normal load in N, L= sliding distance in meter (m), F = Tangential frictional force in N. Figure 2.4 shows sample against disc.

$$K_o = \frac{V}{P.L} \tag{2.1}$$

$$\mu = \frac{F}{P} \tag{2.2}$$

Figure 2.2 100×70×10 mm^3 mould

(a) (b) (c)

Figure 2.2: (a) Unidirectional (b) bidirectional (c) 45º orientational

Figure 2.3 Samples with sample holder

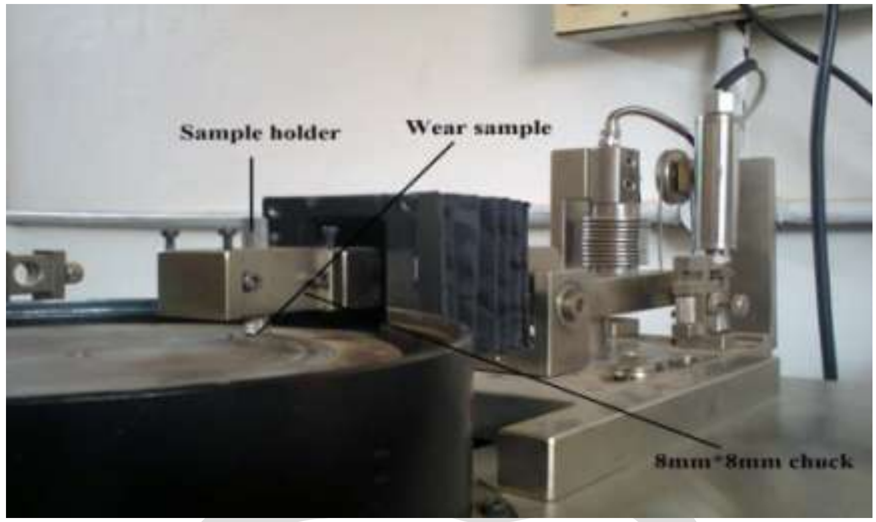

Figure 2.4 Sample against steel disc

III. RESULTS AND DISCUSSION

Table 3.1 shows the wear & frictional properties of composite for different fiber orientations for Constant parameters such as velocity 1m/s, sliding distance 180m and speed 160rpm. 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 is specific wear rate (K_o) and frictional properties are, coefficient of friction (μ) and tangential friction force (F_t), 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. The relation for the specific wear rate is given in the Equation 2.1. Coefficient of friction gives relation between tangential friction force that will be existed between composite sample surface and abrasive disc surface. Specific wear rate and coefficient of friction for different fiber arrangements in composite are listed in Table 3.1. Specific wear rate, coefficient of friction and trend of specific wear rate and coefficient of friction with respect to 5N, 10N and 15N are shown the Figure 3.1, 3.2, 3.3 & 3.4 respectively.

Specific wear rate (K_o) as a function of load can be seen in the Figure 3.1. It is observed that, the specific wear rate decreased with increase in load and holds good the Equation 2.1, since it is inversely proportional to the normal loads. The bidirectional composite has shown the less specific wear rate compare to specific wear rate of the unidirectional and 45º orientation fiber composite. Specific wear rate of bidirectional fiber composite is 62.28%, 20% and 54%, 65.52%, 37% and 58% and 63.17%, 38% and 53% less than unreinforced Bisphenol-A resin, 45º orientation and unidirectional fiber composite for 5N, 10N and 15N respectively. The reason for the less specific wear rate in case of bidirectional fiber composite is the presence of fibers in either direction (longitudinal and transverse). Due to this, less applied load transmitted through the bidirectional fiber orientation. In addition to this, 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 less specific wear rate. In the case of unidirectional fiber composite, since the fibers were arranged at 90º to the sliding direction, the fibers transmitted most of the applied load and causes 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. In case of 45º orientation fiber composite, since the fibers are oriented at an angle 45º to the sliding direction, specific wear rate is less than unidirectional composite. According to Mohit Sharma et al [4], the specific wear rate of fiber reinforced composite increases with increase in angle of fiber arrangement with respect to sliding direction. In addition to this, he also mentioned that, the presence of micro cracks and voids also increases the specific wear rate. Figure 3.2 shows the variation of coefficient of friction with respect to different normal loads. It can be observed that, the coefficient of friction decreased with increased load. This is due to self lubrication of the samples. Figure 3.3 and 3.4 shows the trend of specific wear rate and coefficient of friction with respect to different fiber orientations in composite.

Table 3.1 wear & frictional properties of composite for different fiber orientations

Sl no	Specimen	Load(N)	Depth of wear (microns)	Frictional force (N)	Specific Wear rate $\times 10^{-3}$ (mm^3/N-m)	Frictional Co-efficient
1	Bisphenol-A	5	175	4.7	12.4444	0.94
		10	236	8.5	8.3911	0.85
		15	277	11.4	6.5659	0.76
2	Unidirectional	5	142	4.5	10.0977	0.9
		10	197	8.1	7.0044	0.81
		15	221	11.2	5.2385	0.74
3	Bidirectional	5	65	3.8	4.6220	0.76
		10	82	7.1	2.9155	0.71
		15	102	10.5	2.4177	0.70
4	45°orientation	5	82	4.1	5.8311	0.82
		10	132	7.7	4.6933	0.77
		15	167	11.0	3.9585	0.73

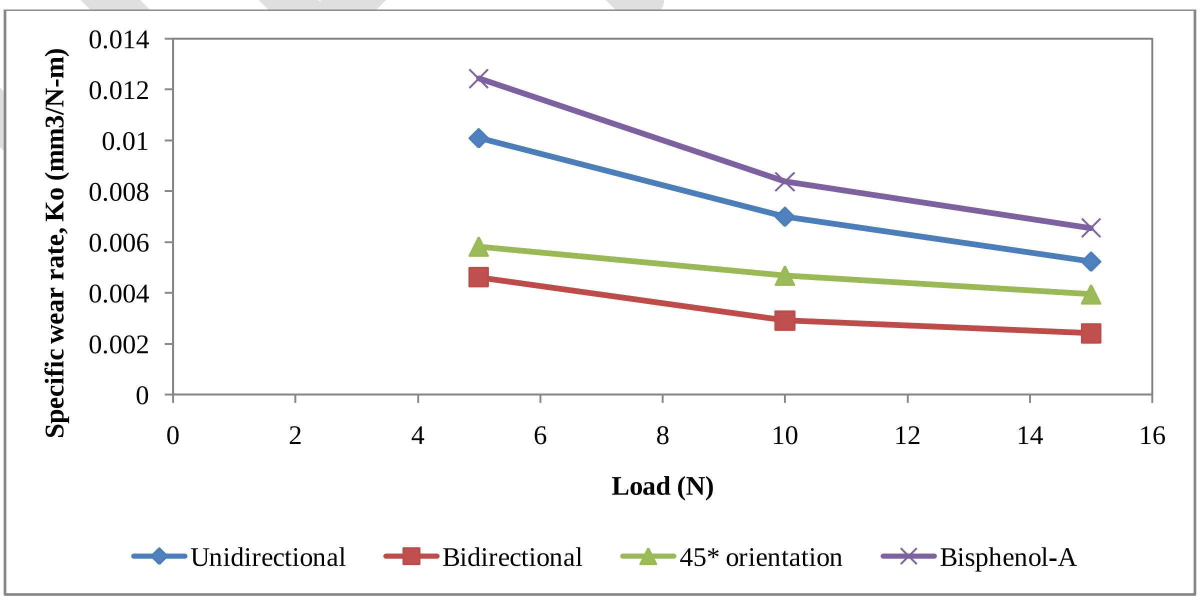

Figure 3.1 Load v/s Specific wear rate

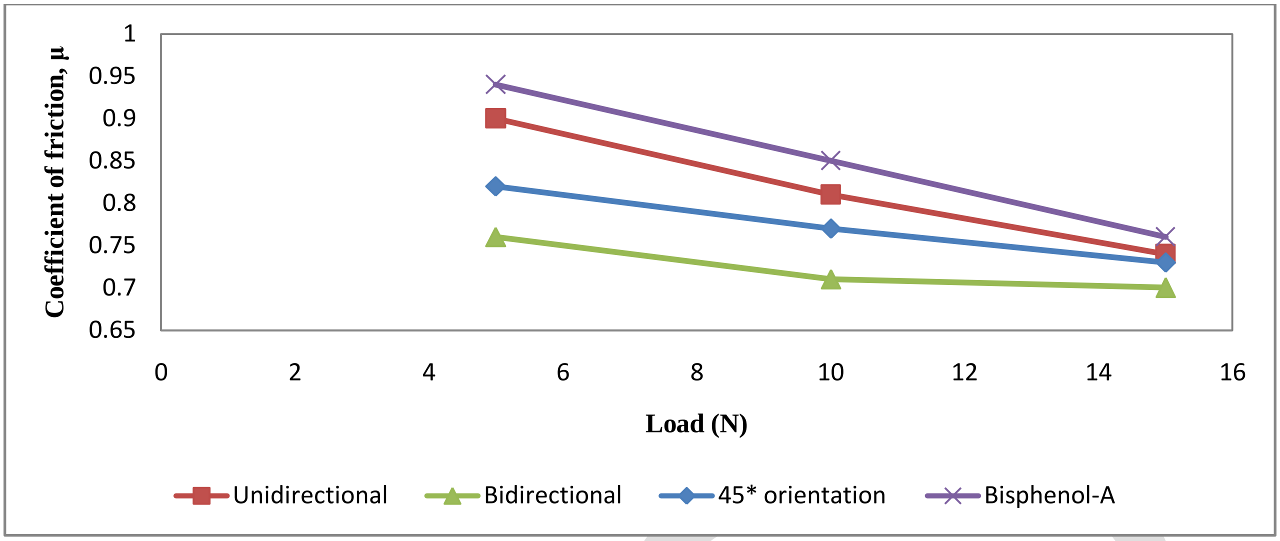

Figure 3.2 Load v/s Coefficient of friction

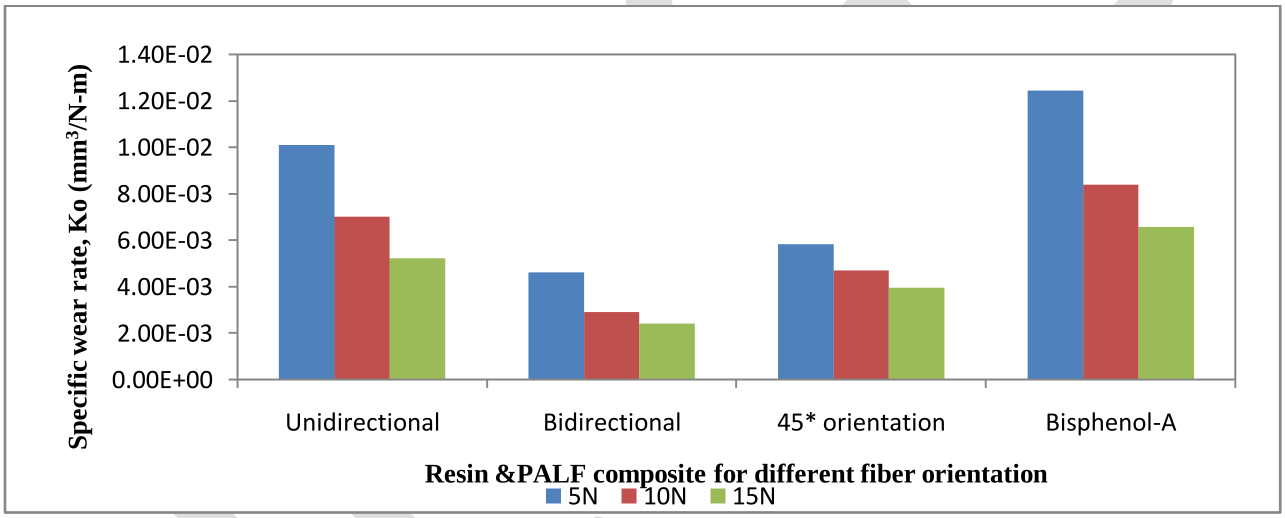

Figure 3.3 Specific wear rate for the resin & PALF composite for different fiber orientation

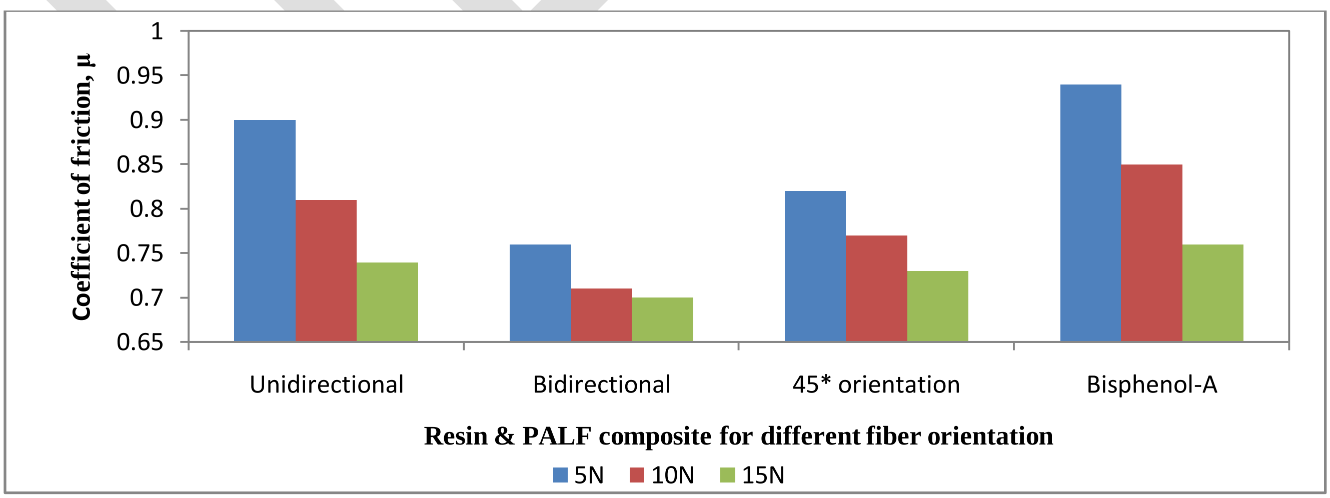

Figure 3.4 Coefficient of friction for the resin & PALF composite for different fiber orientation

IV. CONCLUSION

In the study of wear and frictional properties, the composite with different fiber orientations namely: unidirectional, bidirectional and 45º orientation are subjected to different loading conditions under constant sliding distance, speed & velocity. All three types of composite specimens show less wear rate than unreinforced Bisphenol-A resin. Specific wear rate decreases with increase in normal load. The bidirectional composite shows least specific wear rate, due to the presence of fibers in either direction, made the composite capable of observing more load and shows less frictional force at the mating surfaces of samples and abrasive disc. The Coefficient of friction for all the three types of fiber orientations in composite decreases with increase in normal load, due to self lubrication of the testing samples, as the normal load increased, more material is removed and the removed material is held at the mating surfaces of composite and abrasive disc which is resulted in self lubrication. Hence fiber orientation greatly influence the tribological behaviour of PALF reinforced Bisphenol-A composite.

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