Wear and Friction behavior of particulate polyester matrix composite

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***Abstract*— Research in the field of tribology in composite materials is of prime importance for the industry. Polymer composites are well known for offering engineers high strength to weight ratios and design flexibility. The physical properties of a Composite may be tuned to satisfy various functional requirements of a target application, including stiffness and strength, thermal and electrical transport and wear resistance. We discuss the method of measurement of friction and wear with pin on (POD) and also discuss factor affecting the wear and friction property of material. The main aim of this research is to study factor affecting on wear and friction of natural fiber reinforced composites. Here, the parameters studied are peel concentrations, distance, load speed.**

***Keywords*— wear, friction, tribology, composite, natural fiber**

I. INTRODUCTION

The interest in natural fiber-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants, such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana, etc., as well as wood, used from time immemorial as a source of lignocellulosic fibers, are more and more often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibers used for the manufacturing of composites. The natural fiber-containing composites are more environmentally friendly, and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling paneling, partition boards), packaging, consumer products etc. [1].

On The other hand, the natural fibers permits moisture absorption form environment causes weaker bond between polymer and fiber and so mechanical properties may compromise. Making of composite is also challenging task due to various chemical structures of natural fibers and polymer. With the use of special treatments, the fiber modification is possible, which reduce absorption of moisture and give excellence bonding between fibers and polymer matrix [2].The demand of NFPCs in various engineering fields are growing rapidly. Some of the kind NFPCs have replaced conventional materials for using in various automotive applications by many companies such as Cambridge industry (USA), Proton company (Malaysia) and German companies like BMW, Ford, Volkswagen etc. and recognized for that. Apart from automobile industry, the use of NFPCs have been find out in sport, aerospace, building and construction, for example, bicycle frame, panels, decking and window frame [3].

In 21st century, polymer have created good footprint over the usage in everyday life. To improve toughness of epoxy material, synthetic filler materials widely used as reinforcement. One of the suitable alternative to synthetic materials are using natural filler or fiber materials due to their renewability, cost effectiveness, environment friendliness and high abundance [4-7]. Lot of research have been done to study the tribological and mechanical behavior of natural filler or fiber based composites, concentrating mainly on filler or fibers and their volume or weight percent's within the composite [8-10]. Here, the study is concentrated on the tribological aspects by using the natural filler material as reinforcement in fabrication of composites.

II. EXPERIMENTAL DETAILS

A. *Material:*

Raw materials used in this experimental work are orange peel as natural fiber, Polyester Resin and Hardener.

1) *Natural Fiber:*

Orange is a citrus fruit mainly originated in Southeast Asia used as a natural fiber. It is the most commonly grown tree fruit in the world. Like all citrus fruits, the orange is acidic having pH range 3.35-4.0. Orange peel, the outer cover part of an orange, mainly consists of cellulose, essential oils, proteins and some simple carbohydrates. The orange peels were collected locally and were sun dried for 5 days. Sun drying was necessary to remove the moisture from the peels. The fibers were then grinded into fine powder.

2) *Polyester Resin:*

The type of Polyester resin used in the present investigation is AROPOL 7241 T-15 which is chemically belongs to ester family. AROPOL 7241 T-15 resin is a thixotropic, promoted, corrosion resistant isophthalic polyester resin. The resin has excellent corrosion resistance, high strength and high heat deflection temp.

TABLE I
PROPERTIES OF AROPOL 7241 T-15

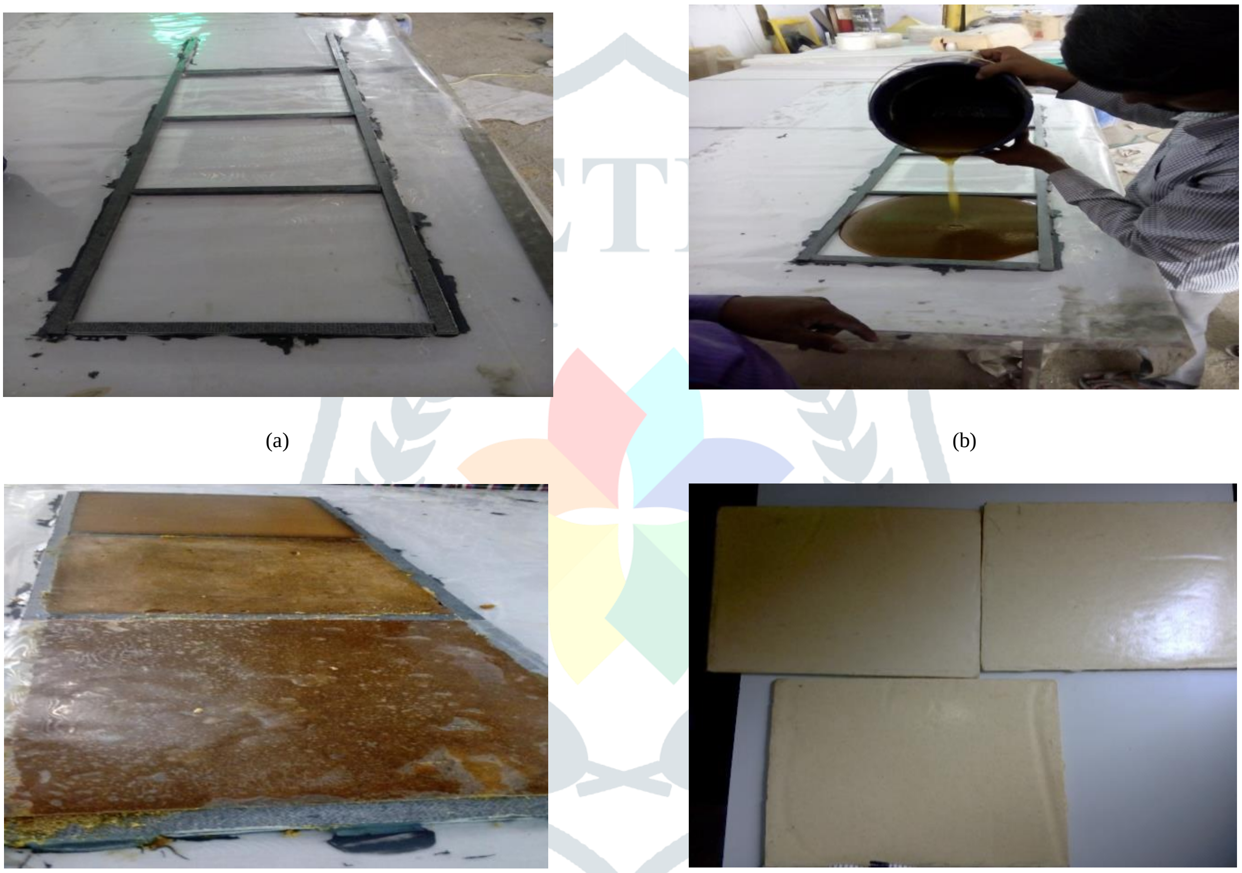
Properties at 25°C (77°F)	Value	Unit
Non-Volatiles Content	54	%
Viscosity, Brookfield, 3@.60 rpm	450	mPas(cps)
Weight per Gallon	9.0	Lb/gallon

TABLE II
LIQUID RESIN PROPERTIES

Cured Casting Property(1) at 25°C (77°F)	Value	Unit	Method
Tensile Strength	10700	psi	ASTM D638
Tensile Modulus	5.4	*10^5psi	ASTM D638
Tensile Elongation	2.4	%	ASTM D638
Flexural Strength	19000	psi	ASTM D790
Flexural Modulus	5.9	*10^5psi	ASTM D790
Heat Deflection Temperature	210	°F	ASTM D648
Barcol Hardness	45	units	ASTM D2538

B. Composite preparation:

A Per-pex sheet mould shown in figure 1 (a) was used for casting the composite sheet. A calculated amount of polyester resin and hardener and accelerator was taken and mixed with particulate with gentle stirring to minimize air entrapment. After keeping the mould on a miler sheet the mixture is then poured into it. This procedure was adopted for preparation of 20, 30 and 35% weight fractions of orange peel.



(a) (b) (c) (d)

Fig. 1 Composite preparation (a) Mould used for making the composite, (b) Pouring mixture in mould, (c) In curing period, (d) Final product.

III. EXPERIMENTAL RESULTS

A. Input parameters:

After literature review found main input parameters are sliding speed, load, sliding distance, temperature for different fiber orientation used for experimentation.

- **Load:** Values of the force in kg at the wearing contact varying from 1kg to 4 kg.
- **Sliding speed:** The relative sliding speed between the contacting surfaces in rpm level value are (500, 1000, 1500) rpm.
- **Sliding distance:** The accumulated sliding distance in meters minimum 1000 m and max 2000 mm.

TABLE III
TAGUCHI DESIGN

Sr.no.	Load (kg)	Speed (rpm)	Sliding Distance (mm)
1	2	500	1000
2	3	500	1500
3	4	500	2000
4	2	1000	1500
5	3	1000	2000
6	4	1000	1000
7	2	1500	2000
8	3	1500	1000
9	4	1500	1500

Experiments are performed on pin on disc (POD) machine where load, speed and sliding distance are input parameters and wear and friction force are output parameters shown on display. Table IV, V, VI and VII shows summery of experimental and analytical data of wear and friction for Neat, 10%, 15% and 20% orange peel composite material respectively.

TABLE IV
SUMMERY OF EXPERIMENTAL AND ANALYTICAL DATA OF WEAR AND FRICTION FOR NEAT POLYESTER

Sr.No	Load (kg)	Speed (rpm)	SD (mm)	Wear (micrometer)	FF (N)	COF
1	2	500	1000	61.42	8.52	0.392
2	2	1000	1500	76.65	16.72	0.65
3	2	1500	2000	145.23	15.26	0.348
4	3	500	1500	140.36	11.83	0.611
5	3	1000	2000	202.56	22.25	0.52
6	3	1500	1000	28.92	15.02	0.212
7	4	500	2000	31.45	5.36	0.198
8	4	1000	1000	200.72	11.43	0.479
9	4	1500	1500	65.82	13.52	0.35

TABLE V
SUMMERY OF EXPERIMENTAL AND ANALYTICAL DATA OF WEAR AND FRICTION FOR 10% WEIGHT FRACTION PIN

Sr.No	Load (kg)	Speed (rpm)	SD (mm)	Wear (micrometer)	FF (N)	COF
1	2	500	1000	107.52	6.89	0.356
2	2	1000	1500	37.25	9.50	0.399
3	2	1500	2000	43.12	11.56	0.45
4	3	500	1500	108.43	12.11	0.411
5	3	1000	2000	70.89	17.46	0.52
6	3	1500	1000	77.45	12.28	0.359
7	4	500	2000	95.26	22.36	0.59
8	4	1000	1000	20.23	20.05	0.287
9	4	1500	1500	98.46	18.09	0.456

TABLE VI
SUMMERY OF EXPERIMENTAL AND ANALYTICAL DATA OF WEAR AND FRICTION FOR 15% WEIGHT FRACTION PIN

Sr.No	Load (kg)	Speed (rpm)	SD (mm)	Wear (micrometer)	FF (N)	COF
1	2	500	1000	62.63	9.89	0.452
2	2	1000	1500	50.25	15.25	0.41
3	2	1500	2000	155.32	21.22	0.55
4	3	500	1500	68.54	9.75	0.489
5	3	1000	2000	88.65	15.65	0.52
6	3	1500	1000	125.48	14.56	0.38
7	4	500	2000	125.63	12.21	0.575
8	4	1000	1000	80.47	15.45	0.485
9	4	1500	1500	47.56	12.36	0.245

TABLE VII
SUMMERY OF EXPERIMENTAL AND ANALYTICAL DATA OF WEAR AND FRICTION FOR 20% WEIGHT FRACTION PIN

Sr.No	Load (kg)	Speed (rpm)	SD (mm)	Wear (micrometer)	FF (N)	COF
1	2	500	1000	44.52	15.75	0.69
2	2	1000	1500	110.29	17.91	0.65
3	2	1500	2000	55.51	20.11	0.312
4	3	500	1500	40.12	11.89	0.511
5	3	1000	2000	118.25	21.56	0.579
6	3	1500	1000	91.81	19.45	0.402
7	4	500	2000	65.34	12.41	0.57
8	4	1000	1000	11.78	11.89	0.458
9	4	1500	1500	195.36	21.65	0.415

B. Effect of operating parameter on Wear:

TABLE VIII
MEAN EFFECT OF OPERATING PARAMETER ON WEAR OF COMPOSITE MATERIAL

		Neat	10%	15%	20%
Load (kg)	2	94.43	62.63	89.4	70.1067
	3	123.94	85.59	94.2233	83.3933
	4	99.33	71.3167	84.5533	90.8267
Speed (rpm)	500	77.74	103.737	85.6	49.9933
	1000	159.97	42.79	73.1233	80.1067
	1500	79.98	73.01	109.453	114.227
Sliding Distance (mm)	1000	97.02	68.4	89.5267	49.37
	1500	94.27	81.38	55.45	115.257
	2000	126.41	69.7567	123.2	79.7

C. Effect of operating parameter on co-efficient of friction:

TABLE IX
MEAN EFFECT OF OPERATING PARAMETER ON FRICTION CO-EFFICIENT OF COMPOSITE MATERIAL

		Neat	10%	15%	20%
Load (kg)	2	0.46333	0.40167	0.47067	0.55067
	3	0.44767	0.43	0.463	0.49733
	4	0.34233	0.44433	0.435	0.481
Speed (rpm)	500	0.40033	0.45233	0.50533	0.59033
	1000	0.54967	0.402	0.47167	0.56233
	1500	0.30333	0.42167	0.39167	0.37633
Sliding Distance (mm)	1000	0.361	0.334	0.439	0.51667
	1500	0.537	0.422	0.38133	0.52533
	2000	0.35533	0.52	0.54833	0.487

IV. CONCLUSION

From the experiment, it concluded that increase, decrease or stabilization of co-efficient of friction and wear, depends on formation of thin polymer film during process. When polymer film formation start during rubbing it will decrease the wear resistance of composite material. At initial stage high frictional heat generated at the interface which leads to more polymer film come out which results in large extent of back transfer patches of polymer film which were intermittently spread over the surface.

Percentage contribution of affecting parameters for friction and wear on Composite material mentioned in table X.

TABLE X
PERCENTAGE CONTRIBUTION OF AFFECTING PARAMETERS FOR FRICTION AND WEAR ON COMPOSITE MATERIAL

% Weight Fraction	Affecting Parameters	% Contribution Rank	
		Wear	Friction Co-Efficient
10%	Load	3	1
	Speed	2	2
	Sliding Distance	1	3
15%	Load	1	3
	Speed	3	1
	Sliding Distance	2	2
20%	Load	3	2
	Speed	2	1
	Sliding Distance	1	3

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