International Journal of Scientific & Engineering Research, Volume 4, Issue 8, August 2013
ISSN 2229-5518

Investigations on Mechanical Properties of Pineapple Fiber Reinforced Polymer Composite Material

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Abstract — Natural fibers as reinforcement in polymer have gained great importance in recent years due to their good mechanical properties and eco-friendly nature. They have been gaining importance and replacing artificial fibers in many of the applications. Among the wide range of natural fibers that are available pineapple fiber was selected as the natural fiber under study for the analysis due to comparatively better mechanical properties, ease of availability and low cost. The test for tear strength, tensile strength and curing time were performed on three samples and the results obtained for the three samples were analysed.

Index Terms — Tear test, Cure time, Pineapple fiber, Natural rubber

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1 INTRODUCTION

Polymer blends are being used extensively in numerous applications; this statement is also true with rubber blends, especially in tire manufacture. Apart from blends of common rubbers, specialty rubber is also being utilized, depending on service demands. Fiber reinforced rubber composites are of tremendous importance both in end-use applications and the area of research and development. These composites exhibit the combined behavior of the soft, elastic rubber matrix and the stiff, strong fibrous reinforcement.

The development of fiber reinforced rubber composites has made available polymers that are harder than aluminum and stiffer than steel. Generally short fiber reinforced rubber composites have become popular in industrial fields because of the processing advantages and increase in strength, stiffness, modulus and damping. The design of a short fiber reinforced rubber composite depends on several factors such as the aspect ratio of the fiber, control of fiber orientation and dispersion and existence of a strong interface between fiber and rubber.

Natural rubber (NR) is known to exhibit numerous outstanding properties such as good oil resistance, low gas permeability, improved wet grip and rolling resistance, coupled with high strength. Natural rubber coming from latex is mostly polymerized isoprene with a small percentage of impurities in it. This will limit the range of properties available to it. Addition of sulphur and vulcanization are used to improve the properties of natural rubber.

Pineapple fiber is extracted from the leaves of the pineapple plant. The selection was made based on few criteria such as availability, ease of extraction, amount of fiber available after extraction from the leaves, mechanical properties in comparison with other available fibers etc.

The project deals with the fabrication process involved, various testing methods conducted and the analysis of a few of the mechanical properties of pineapple fiber reinforced polymer composite materials. A varying amount of fiber with weights of 15g, 30g, and 60g and length 1.0cm are fabricated with natural rubber.

1. EXPERIMENTAL

1.1 Materials and Methods

Zinc Oxide, Sulphur, Stearic Acid and Accelerator F were used as received.

2.1a Reinforcing material: Pineapple Leaf Fiber (PALF) of diameter 10 µm and mean length of 4.5 mm were used as the reinforcement material in the biocomposite

2.1b Matrix polymer: Natural rubber (NR) from latex added with sulphur and subjected to vulcanization was used as the matrix polymer

2.2 Instruments used

Weights of the samples were taken on an electronic balance, curing time of samples were determined using Rheometer, tensile and tear tests were carried out using Universal Testing Machine (INSTRON 4411) and the hardness test was performed using a Durometer (Shore A type)

2.3 Fabrication of biocomposite

2.3a Fiber extraction: The fiber is extracted from the leaves of the pineapple fiber using the fiber extractor machine. The pineapple leaf is introduced into the machine where it is smashed by heavy cast iron impellers which break free the cellulose binding in the pineapple leaf. This results in a fiber with ribbon like structure.

2.4b Fiber preparation: The fiber is taken after extraction and it is dried under the sun to remove the moisture content. The dried fiber is taken and it is then cut into a length of 1.0 cm. The 1 cm fiber is divided into 3 weights of 15gm, 30 gms and 60 gms.

2.4c Mixing of Composite: The natural rubber is first introduced between the rollers and it is allowed to grind and compressed properly. The fiber of specified weights are added by placing it in between the rollers and it is allowed to mix properly.. After the fiber and rubber has been mixed thoroughly, Zinc oxide and Stearic Acid is added and again mixed thoroughly. Then accelerator F is added to the mixture, finally sulphur is added .and the final mix of the sample is taken as a sheet and it is cooled at room temperature

2.4d Preparation of mould: Based on the cure time obtained for different sample, the mould of 10 × 15 ×0.2 cm is prepared in hot hydraulic press, for natural rubber temperature is 150̊ C. Sample is placed between two OHP sheets, and this is embedded between the upper and lower dies of the mould and high pressure is applied. Regular intervals of breathing are provided for escape of air embedded within the fiber. Pressure is applied till the assigned cure time. Then the die is removed and the mould is obtained and is allowed to cool down to room temperature. The mould is cut into different shapes for preparation of test specimen

2.4e Preparation of test specimen: From the obtained mould 3 samples are cut out for tensile testing and 2 samples are cut out for tear testing. For carrying out tensile test the sample is cut out in dumbbell shape and for tear test the sample is cut out into a crescent (wave) shape

Fig 1: Sample shapes (Crescent and Dumbell)

2.5 Samples Prepared

Table 1: Characteristics of samples prepared

Name of Sample	Fiber Length (cm)	Fiber Weight (gms)	Weight of Rubber (gms)
1	1.0	15	100
2	1.0	30	
3	1.0	60	

2.6 Mechanical Testing

Testing of samples for tensile and tear were done on Computerized Universal Testing Machine (INSTRON 4411), cure time testing was done using a Rheometer and hardness test was performed using a Durometer (Shore A type)

2.6a Cure time testing: 10gm of each sample is taken for testing cure time. For natural rubber cure temperature is 150̊C. The 10gm of each sample is placed between two dies in a Rheometer and torque is applied equal and opposite. Torque vs time graph is obtained .curing time is obtained when the value of torque remains stable with respect to time. Optimum cure time at 150 ˚ C were determined by using Monsanto Rheometer (R-100).the optimum cure time corresponds to the time to achieve 90per cent (t90) of the cure calculated from the formula Optimum cure = [0.9(Lf – Li)+ Li], Where Lf is max torque and Li is min torque

2.6b Tensile strength test: Tensile properties are some of the most widely tested properties of natural fiber reinforced composites. Recently, investigation for the PALF reinforced composite's tensile properties have covered the effect of mixing condition for melt mixing, condition for solution mixing, fiber length, fiber loading, chemical treatment, fiber orientation, water absorption and weathering effect. Tensile test is carried on a universal testing machine INSTRON 4411. Each test specimen, dumbbell shaped, is fixed on UTM INSTRON 4411 using pneumatic holders. The extensometers are attached to the test specimen for measuring the strain. After the specimen is fixed, load is applied hydraulically till rupture occurs. Tensile stress vs tensile strain graph is obtained on the screen. The values of tensile strength and percentage of elongation are obtained from computer.

2.6c Tear Test: Each test specimen, crescent shaped, is fixed on the UTM INSTRON 4411 using pneumatic holders. The specimen must be hold in such a way that the angle should be exactly at the middle of upper and lower holder. The load is applied and corresponding load vs extension graph is obtained on the screen. The value of breaking load and tear strength is obtained on the screen.

2.6d Hardness Test: As per ASTM D – 240-81 test method, the hardness of the test specimen was measured using a Shore A type Durometer, which employed a calibrated spring to provide an indenting force. Since the hardness reading decreased with time after firm contact between indentor and the test specimen, the reading was taken immediately after the establishment of firm contact.

3 RESULTS AND DISCUSSION

The importance of static mechanical analysis as a tool in the study of behavior of polymer biocomposites is of great importance. Static mechanical properties depend on the nature of polymer matrix, distribution and orientation of reinforcing fibers and nature of fiber – matrix interfaces.

3.1a Cure time: The cure time graphs obtained for fiber length 1 cm with 15gm, 30gm and 60gm fibers are as below.

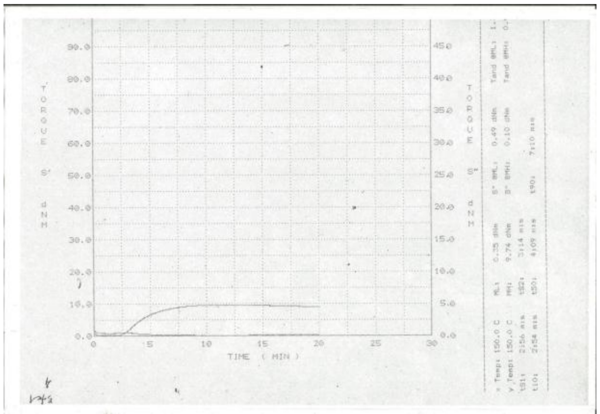

Fig2: Cure time graph for sample 1(1cm, 15gm fiber)

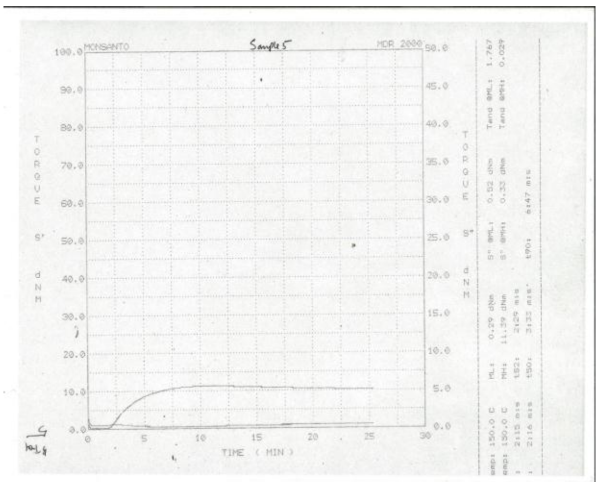

Fig3: Cure time graph for sample 2(1cm, 30gm fiber)

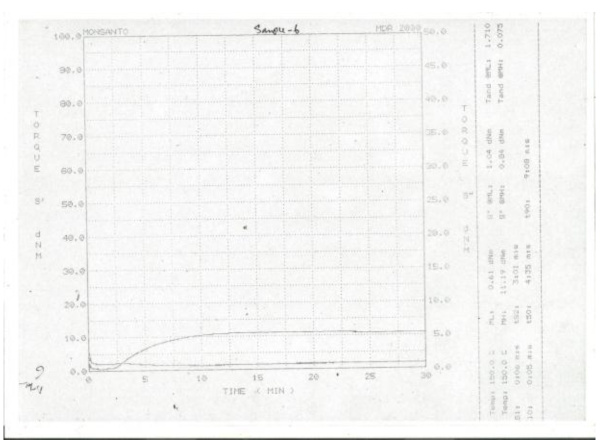

Fig4: Cure time graph for sample 3(1cm, 60gm fiber)

3.1b Tensile strength test: The graphs obtained for fiber length 1 cm with 15gm, 30gm and 60gm fibers are as below.

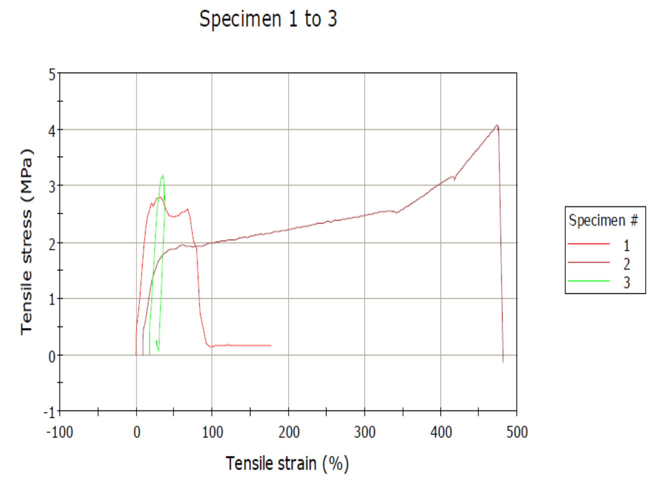

Fig 5: Tensile Test Graph Sample 1(1cm, 15gm Fiber)

Table 2: Tensile Test Results of Sample 1(1cm, 15gm Fiber)

Sample ID	4
Rate 1	500.00000 mm/min

	Specimen label	Thickness (mm)	Width (mm)
1	1	2.540	3.000
2	2	2.450	3.000
3	3	2.570	3.000
Mean		2.520	3.000
Standard Deviation		0.062	0.000

	Tensile strength (MPa)	Elongation at Break (%)	Modulus @ 100% (MPa)
1	2.801	31.597	0.157
2	4.072	464.026	2.012
3	3.185	17.503	-----
Mean	3.353	171.042	1.085
Standard Deviation	0.652	253.829	1.312

	Modulus @ 200 %) (MPa)	Modulus @ 300 %) (MPa)
1	-----	-----
2	2.253	2.501
3	-----	-----
Mean	2.253	2.501
Standard Deviation	-----	-----

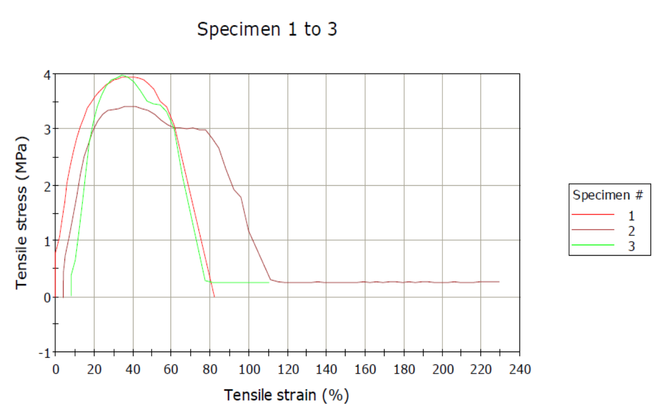

Fig 6: Tensile Test Graph Sample 1(1cm, 30gm Fiber)

International Journal of Scientific & Engineering Research Volume 4, Issue 8, August-2013
ISSN 2229-5518

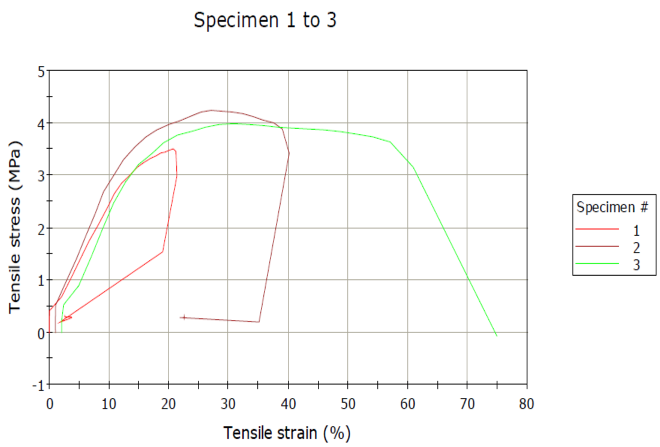

Fig 7: Tensile Test Graph Sample 3(1cm, 60gm Fiber)

Table 4: Tensile Test Results of Sample 3(1cm, 60gm Fiber)

Sample ID	6
Rate 1	500.00000 mm/min

	Specimen label	Thickness (mm)	Width (mm)
1	1	2.670	3.000
2	2	2.620	3.000
3	3	2.700	3.000
Mean		2.663	3.000
Standard Deviation		0.040	0.000

	Tensile strength (MPa)	Elongation at Break (%)	Modulus @ 100% (MPa)
1	3.502	20.698	-----
2	4.218	27.705	-----
3	3.960	31.302	-----
Mean	3.893	26.568	-----
Standard Deviation	0.363	5.393	-----

	Modulus @ 200 %) (MPa)	Modulus @ 300 %) (MPa)
1	-----	-----
2	-----	-----
3	-----	-----
Mean	-----	-----
Standard Deviation	-----	-----

From table 2, 3 and 4, the value of tensile strength is more for sample 3(1cm, 60gm fiber) and less for sample 1 (1cm, 15 gm fiber). The value of tensile strength for sample 3 is 3.893 MPa and for sample 1 is 3.353 MPa.

3.1c Tear Test: The graphs obtained for fiber length 1 cm with 15gm, 30gm and 60gm fibers are as below.

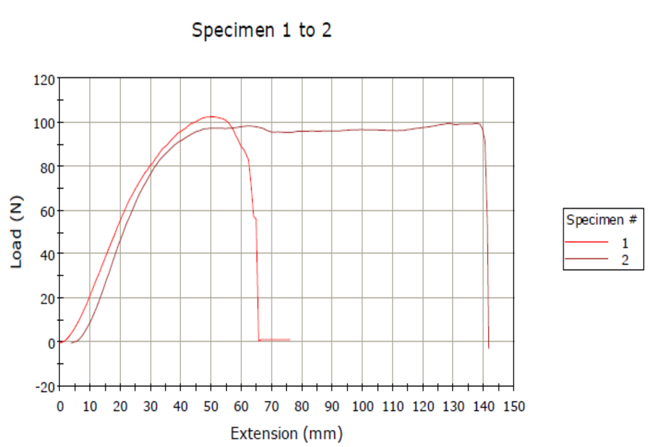

Fig 8: Tear Test Graph Sample 3(1cm, 15gm Fiber)

Table 5: Tear Test Results of Sample 3(1cm, 15gm Fiber)

Method description	Angle Tear
Sample ID	4
Rate 1	500.00000 mm/min

	Specimen label	Thickness (mm)	Width (mm)
1	1	2.540	12.500
2	2	2.470	12.500
Mean		2.505	12.500

	Load at Break (N)	Tear Strength (N/mm)
1	102.410	40.319
2	99.320	40.211
Mean	100.865	40.265

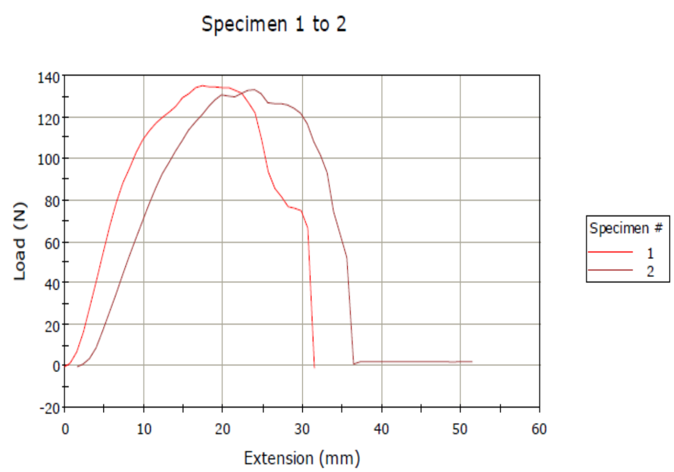

Fig 9: Tear test Graph Sample 3(1cm, 30gm Fiber)

Table 6: Tear Test Results of Sample 3(1cm, 30gm Fiber)

Method description	Angle Tear
Sample ID	5
Rate 1	500.00000 mm/min

	Specimen label	Thickness (mm)	Width (mm)
1	1	2.610	12.500
2	2	2.590	12.500
Mean		2.600	12.500

	Load at Break (N)	Tear Strength (N/mm)
1	134.360	51.479
2	133.150	51.409
Mean	133.755	51.444

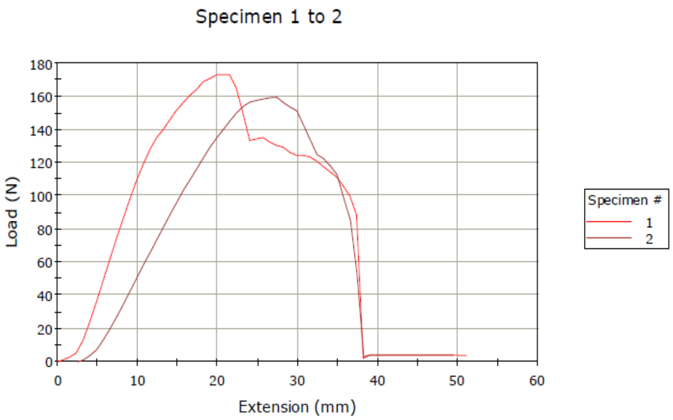

Fig 10: Tear Test Graph Sample 3(1cm, 60gm Fiber)

Table 7: Tear Test Results of Sample 3(1cm, 60gm Fiber)

Method description	Angle Tear
Sample ID	6
Rate 1	500.00000 mm/min

	Specimen label	Thickness (mm)	Width (mm)
1	1	2.850	12.500
2	2	2.790	12.500
Mean		2.820	12.500

	Load at Break (N)	Tear Strength (N/mm)
1	172.880	60.660
2	159.320	57.104
Mean	166.100	58.882

From the graphs it is seen that the value of tear strength is more for sample 3(1cm, 60gm fiber) and less for sample 1 (1cm, 15 gm fiber). The value of tear strength for sample 3 is 58.882 N/mm and for sample 1 is 40.265 N/mm. The load at break for sample 3 is 166.10 N and for sample 1 is 100.865 N.

3.1d Hardness Test: The results of hardness test conducted for sample1(1cm, 15gm Fiber), sample2(1cm, 30gm Fiber) and sample 3(1cm, 60gm Fiber) are as shown.

Table 8: Hardness Test Results Samples 1, 2 & 3

Test Specimen	**Reading 1**	**Reading 2**	**Reading 3**	**Mean**
Sample 1	58	67	70	65
Sample 2	74	66	75	71.67
Sample 3	72	70	71	71

4 CONCLUSION

The addition of natural fiber to rubber was found to reinforce the composite. The natural fiber added in specific quantities was found to increase in strength of the composite. The time taken for a rubber to fully solidify from molten state is cure time. The cure time of rubber is found to increase with the addition of fiber. Maximum cure time is observed in the composite having the largest length and the greater quantity

The tensile strength is the maximum stress a composite can withstand when stretched or pulled. The tensile strength of rubber is found to increase with the addition of fiber. The maximum tensile strength is found to be with the sample having the largest length of fiber and greatest amount of fiber and the least tensile strength is found to be with sample having smaller length and least quantity of fiber.

Tear strength of rubber increases with addition of fiber. The tear strength is found to be maximum for the composite having larger length and larger fiber content

Hardness number is the measure of resistance to deformation of the composite. Hardness number is found to increase with the addition of fiber. .It is found to be greater for the sample having smaller fiber length and greater quantity of fiber.

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