Development of Vinyl Ester and Reed Composite Material with Weight Fraction of 10% and Reinforcement at Different Orientations

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Abstract—**Composite materials have been used to resolve industrial problems. Considerable attention from the industrial side started in the 1960s with the introduction of polymer-based composite materials. Their advantages such as low weight (density), resistance to corrosion, high strength and low maintenance cost made composite materials an attractive substitute to conventional materials. A new composite material was developed with 10% natural fiber at 0°, 90° and 0/90° orientations resulting in ample improvements in the mechanical properties as compared to previous studies. The sample at 0/90° orientation gives the best results with tensile, tensile strength, tensile elongation and Young's Modulus values of 2458.19N, 4594.5MPA, 4.7% and 23.0 respectively.**

Keywords-composite material; natural fiber; vinyl ester; REED plant

I. INTRODUCTION

Composite materials have been used to resolve industrial problems. Considerable attention from the industrial side started in the '60s with the introduction of polymer-based composite materials. Since then composite materials have been used in the field of engineering. Features like better formability, low cost, renewability and eco-friendliness can be achieved by natural fiber reinforced composites and these composites play an important role in commercial engineering sectors [1]. The maximum strength initially decreases until critical point and then increases with duration of treatment while conducting tensile behavioral study of the natural fiber reinforced polymer matrix base composites. Ultimate and failure stresses decreased with increase in the weight percentage of Cashew-nut shells resin [2]. The natural fiber reinforced composites satisfy the required specifications in tribological applications. The results reflect that these composites can be comparable with conventional fibers, having additionally fiber treatment and fiber orientation [3]. A vacuum assisted resin transfer molding (VARTM) system was developed in [4] for testing the mechanical properties of a composite material. The results reflect that the developed composite material specimen acquired significant enhancement in mechanical properties by adding cotton fabric as a reinforcement agent. Properties (tensile strength, Young's modulus, break elongation and shear modulus) were improved considerably. It was also observed that the developed material was of ductile nature and exhibited improved mechanical properties with closely related developed composite materials.

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Authors in [5] conducted research on cotton fiber as reinforcing agent. Cotton fibber reinforced composite specimens were examined with the help of hand layup process. Samples possessed significant improvement in mechanical properties. In [6], cotton fabric (2/2 plain weave 0/90^o oriented) was used as reinforcement agent with matrix material to develop samples, which were tested to study its effect as reinforcing agent. The result showed the tensile strength improved as much as 11 times, modulus of elasticity (MOE) was increased up to 5.7 times, and break elongation decreased by 0.6%. In [4], the development of one layer, two-layer and four-layer composite material specimen by using VARTM showed that the increasing number of lamination (1L, 2L, and 4L) in developed composite specimen acquired major enhancement in tensile properties.

Reed family natural fiber is a green color long fiber grass which is cultivated naturally at the banks of Indus River and in water storages like fish farms. It has no need of plantation or other fertilizer for its growth and after cutting it grows back quickly. Reed family is plant shown in Figure 1.

Fig. 1. Reed family natural fiber grown on Indus River

The utilization of environment-friendly composites is due to their advantages like good specific strength, less cost, lower pollutant emissions, and fine energy recovery. In this connection researchers developed composites by using unidirectional compressed jute fiber sheets as reinforcement agent with matrix material (unsaturated polyester resin) and it was found that the composites made from raw jute have higher tensile and flexural properties compared to the composites made from jute sliver [7]. Composites can be developed by using epoxy Novolac resin [8]. The composite possesses the desired and preferred properties by coalescing dissimilar constituents in a cautious and judicious way. Generally, they possess higher specific modulus and high specific strength enabling them as valuable material in a huge number of industrialized requests which require such features [9]. The composites possess the desired and preferred properties by coalescing dissimilar constituents in a cautious and judicious way. Generally, they possess higher specific modulus and high specific strength enabling them as a valuable material in a huge number of industrialized requests which requires such features [10-11]. In this study a composite material was developed using natural fiber reinforcement in brass metal to improve its mechanical properties.

II. MATERIALS AND METHODS

Brass was used as base metal with dimensions 177.8mm length, 50.8mm width. After machining process, the base metal was cut into a mold cavity with dimensions of 152.4mm length, 25.4mm width and 8mm depth at a distance of 12.7mm from all four edges with the help of vertical milling machine. Furthermore, for setting natural fibers in the base metal, 5mm thick slots were made at 0^o, 90^o and 0/90^o orientations as shown in Figure 2. After mold developing, vinyl ester resin as a matrix material was transferred in the mold for sampling with total weight 200g for pure VE specimen and 10% natural fiber as a reinforcing agent. After curing the specimens were de-molded properly and prepared for testing.

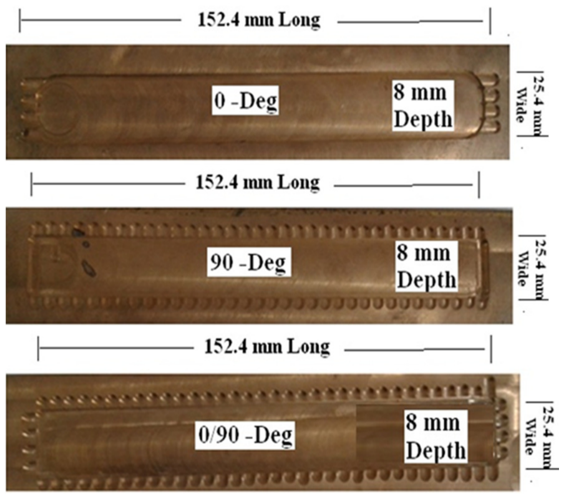


Fig. 2. Mold's design

III. RESULTS

A. Pure Vinyl Ester

The pure vinyl ester resins were tested on an SSTM 20 KN tensile testing machine for mechanical properties. Tensile properties of pure vinyl ester resin samples were tested before adding reed fibers. Table I shows the values of tensile characteristics of the matrix material. It was observed that at maximum tensile load of 2116.6N, the material shows maximum tensile strength of 3955.7MPa, modulus of elasticity has observed as 22.2MPa, and tensile elongation was 3.3%.

B. 10% Reinforced Vinyl Ester

In this setup, the tested samples were reinforced by 10% reed natural fiber (PAL) at 0^o, 90^o and 0/90^o orientations. Tables II-IV show the obtained tensile characteristics for 0^o, 90^o and 0/90^o orientations respectively. In Table II, the result reflects composite specimens reinforced with 10% reed family natural fiber (PAL) at 0^0 orientation. Standard parameters at maximum tensile load of 2394.1N were: maximum tensile strength of 4474.6MPa, modulus of elasticity 22.6MPa, and 4.2% tensile elongation. Similarly, composite specimens reinforced with 10% reed natural fiber (PAL) at 90^o results are shown in Table III. It was observed that at tensile load of 1925.8N, the tensile strength was 3599.4MPa, MOE was 19.1MPa, and tensile elongation was 4.4%. In the same way the composite specimens reinforced with 10% reed family natural fiber (PAL) at 0/90^{0}orientation can be seen in Table IV. It was observed that at tensile load of 2458.2N, the tensile strength obtained was 4594.5MPa, MOE was 23.0MPa, and tensile elongation was 4.7%.

TABLE I. CHARACTERISTICS OF PURE VINYL ESTER COMPOSITES

Pure Vinyl ester	Strip 1	Strip 2	Strip 3	Mean
Yield (N)	1798.54	1800.29	1798.78	1799.2
Yield strength (MPa)	2670.83	2672.58	2671.07	2671.5
Tensile (N)	2115.93	2117.68	2116.17	2116.6
Tensile strength (MPa)	3955.00	3956.75	3955.24	3955.7
MOE (MPa)	21.33	23.83	21.52	22.2
Break elongation (%)	3.46	2.87	3.43	3.3
Yield elongation (%)	2.56	2.30	2.54	2.5
Tensile elongation (%)	3.46	2.87	3.43	3.3
Linear strain	0.03	0.03	0.03	0.03
Lateral strain	0.03	0.02	0.03	0.02
Poisson's ratio	0.74	0.80	0.74	0.76
Energy of material (U) (J)	216.92	194.49	194.74	202.05

TABLE II. RESULTS FOR 10% REINFORCED COMPOSITE AT 0^o

10% at 0^o	Strip 1	Strip 2	Strip 3	Mean
Yield strength (MPa)	3021.51	3022.26	3021.75	3021.8
Tensile (N)	2393.75	2394.50	2393.99	2394.1
Break elongation (%)	4.44	3.85	4.21	4.2
Yield elongation (%)	2.86	2.66	2.72	2.7
Yield (N)	2034.68	2035.43	2034.92	2035.0
Linear strain	0.04	0.04	0.04	0.04
Lateral strain	0.03	0.03	0.03	0.03
Poisson's ratio	0.65	0.69	0.65	0.66
Energy of Material (U) (J)	274.28	254.31	254.56	261.05

TABLE III. RESULTS FOR 10% REINFORCED COMPOSITES AT 90^o

10% 90^0	Strip 1	Strip 2	Strip 3	Mean
Yield strength (MPa)	2430.45	2431.20	2430.69	2430.8
Tensile (N)	1925.49	1926.24	1925.73	1925.8
Break elongation (%)	3.99	4.35	4.71	4.4
Yield elongation (%)	2.05	2.81	3.25	2.7
Yield (N)	1636.67	1637.42	1636.91	1637.0
Linear strain	0.04	0.04	0.05	0.043
Lateral strain	0.02	0.03	0.03	0.03
Poisson's ratio	0.51	0.65	0.69	0.62
Energy of Material (U) (J)	157.59	216.24	216.49	196.77

The graphical presentation of the comparison of tensile tests of 10% reed family natural fiber reinforced between 0^0, 90^0 and 0/90^0 orientations is shown in Figure 3. Tensile characteristics of composite specimens reinforced with 10% reed natural fibers (PAL) at 0/90^{o}orientation in matrix material are greater than the specimens developed at 0^o and 90^o. The increments are 13.11%, 9.01% and 16.14% in Tensile (N), 13.12%, 9.01% and 16.15% in tensile strength, while the enhancement seen in MOE was 1.45%, 13.97% and 3.45%. Variation of 28.07%, 33.71% and 45.70% was also observed in tensile elongation (%) at samples reinforced at 0^o, 90^o and 0/90^o orientations respectively against pure vinyl ester specimens.

TABLE IV. RESULTS FOR 10% REINFORCED COMPOSITE AT 0/90^O

10% at 0/90^o	Strip 1	Strip 2	Strip 3	Mean
Yield strength (MPa)	3102.43	3103.18	3102.67	3102.8
Tensile (N)	2457.86	2458.61	2458.10	2458.2
Break elongation (%)	4.78	4.54	4.90	4.7
Yield elongation (%)	2.45	2.93	2.97	2.8
Yield (N)	2089.18	2089.93	2089.42	2089.5
Linear strain	0.05	0.05	0.05	0.05
Lateral strain	0.02	0.03	0.03	0.03
Poisson's ratio	0.51	0.65	0.61	0.59
Energy of Material (U) (J)	241.00	288.05	288.30	272.45

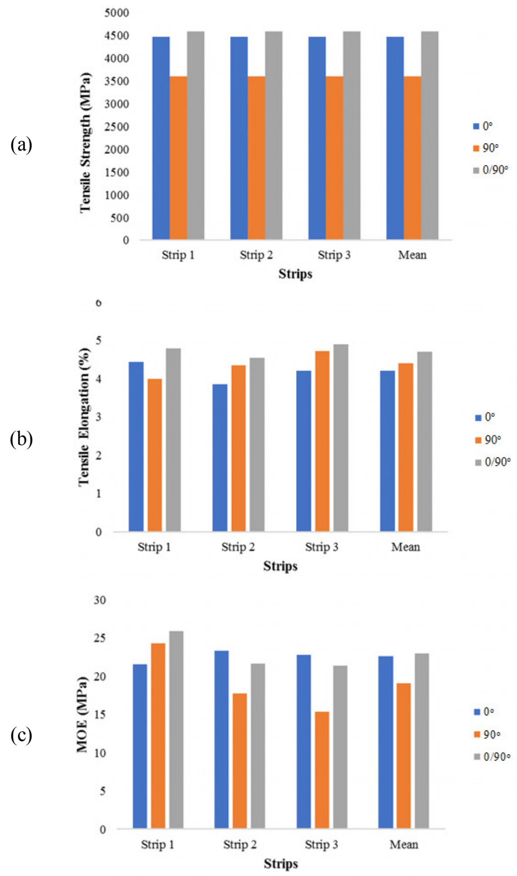


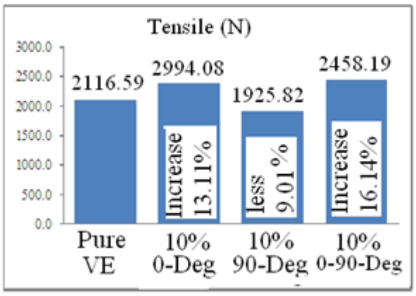
Fig. 3. Comparison of (a) tensile strength, (b) yield strength, and (c) Modulus of elasticity

IV. DISCUSSION

Natural fiber reinforced composite materials play a vital role in today's competitive marketing ranking. A new material was developed with natural reed fibers at different orientations in vinyl ester polymer matrix and was checked through SSTM-20KN. The developed reinforced material is comparative to other natural fibers like abaca, bagasse, bamboo, etc. [12]. After the pure matrix was embedded with 10% reinforcing agent at 0^o, the tensile parameters increased gradually, while specimens at 90^o showed decreasing results. The specimen developed in woven form oriented at 0/90^o was tested at the same machine and gave better results than the other specimens.

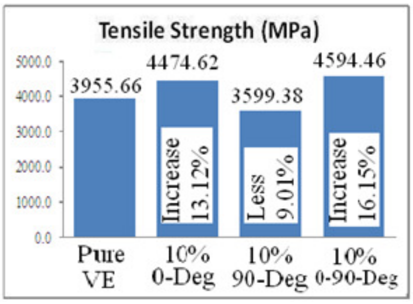
Sample 10%	Pure VE	10% 0-Deg	10% 90-Deg	10% 0-90-Deg
Tensile (N)	2116.59	2394.08	1925.82	2458.19

(a)



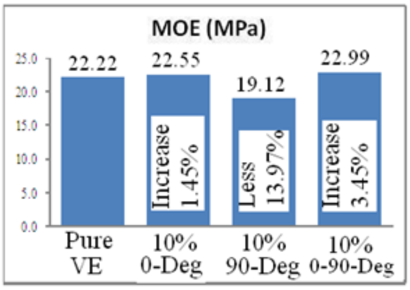
Sample 10%	Pure VE	10% 0-Deg	10% 90-Deg	10% 0-90-Deg
Tensile Strength (MPa)	3955.66	4474.62	3599.38	4594.46

(b)



Sample 10%	Pure VE	10% 0-Deg	10% 90-Deg	10% 0-90-Deg
MOE (MPa)	22.22	22.55	19.12	22.99

(c)



Sample 10%	Pure VE	10% 0-Deg	10% 90-Deg	10% 0-90-Deg
Tensile Elongation (%)	3.25	4.17	4.35	4.74

(d)

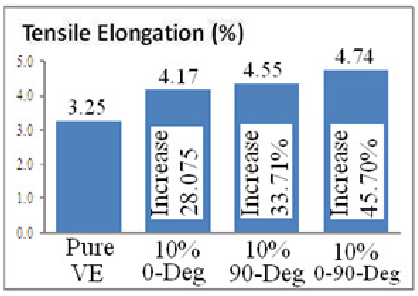


Fig. 4. Comparison of pure VE with 10% reed family natural fiber (PAL) reinforced at 0^o, 90^o and 0/90^o orientations

V. CONCLUSION

The developed composite materials are capable of being utilized as a substitute of expensive materials like metal and ceramic, which have much more weight and require maximum processing technology. In order to provide better alternatives, the natural fiber reinforced composite material was developed and tested at 10% weight fraction with different orientations, 0^o, 90^o and 0/90^o and it was found that at 0/90^o the results of tensile force, tensile strength, MOE, and tensile elongation are better when compared to other natural fibers or petroleum based composite materials like carbon and glass fibers. The results obtained during analysis for tensile load, tensile strength, tensile elongation and MOE were 2458.19 N, 4594 MP, 4.7% and 23.0 respectively.

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