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Analysis of Areca Plant Stem Fiber Reinforced Polyester Thermoset Composite Mechanical Properties

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Abstract— **In the present work, mechanical properties of laminates fabricated by Hand lay-up technique using areca plant stem fiber of density 3.4 N/mm2 and general purpose polyester resin was investigated. Areca plant stem fiber polyester composite samples were fabricated with different areca plant stem fiber volume fractions (I-0.05, II-0.10, III-0.15, IV-0.20, V-0.25 and VI-0.30). The materials properties; ultimate tensile strength, young's modulus of elasticity, elastic strain, and impact strength of the materials were determined through standard tests on standard test samples. It was observed that the various mechanical properties (excluding the impact strength) were improved with increase in areca plant stem fiber volume and that the areca plant stem fiber- polyester composite is characterized by high toughness. It was concluded that the optimum areca plant stem fiber volume fraction for the composite is 0.25.**

Index Terms— **Laminates, Areca Plant Stem Fiber Polyester Composite, Toughness**

I. INTRODUCTION

Composite materials are materials that combine two or more materials (a selected filler or reinforcing elements and compatible matrix binder) that have quite different properties that when combined offer properties which are more desirable than the properties of the individual materials. The different materials work together to give the composite unique properties, but within the composite you can easily see the different materials; they do not dissolve or blend into each other. The key characteristics of composites are the

- Specific strength (the strength to weight ratio σ/ρ)
- Specific stiffness or specific modulus (the stiffness-to-weight ratio E/ρ)
- Tailored material (since composites are composed of 2 or more "phases", they can be formulated to meet the needs of a specific application with considerable ease) Fiber-reinforced composites are being increasingly used as alternatives for conventional materials primarily because of their high specific strength, specific stiffness and tailor able properties. In addition the viscoelastic character of composites render them suitable for high performance structural applications like aerospace, marine, automobile, satellites, sports goods, robots, and thermal insulation structures like cryostats for low temperature technology, hydrogen technology tanks, in superconductivity and also in biomedicine for body compatible implants ((Mangalgiri, 1999), (Lynn, 1990), (Fabain et al, 2002) and (Wrobel et al, 2007)).

The above properties are strongly dependent on the factors such as the matrix and fiber material and their volume fractions, the fiber orientation, the applied stress levels and strain rates, as well as the loading conditions and the nature of fiber polymer interface ((Habak, 1991), (Hsio et al, 1999) and (Aramide et al, 2009)). Interface is said to be the heart of the composite. The local response of fiber matrix interface within the composite plays an important role in determining the gross mechanical performance (Zhou, 1993). It provides a means of stress transfer from fiber to fiber through the matrix.

In recent times, there has been a remarkable growth in the large-scale production of fiber and/or filler reinforced epoxy matrix composites. Because of their high strength-to-weight and stiffness-to-weight ratios, they are extensively used for a wide variety of structural applications as in aerospace, automotive and chemical industries (ASM, 1992). On account of their good combination of properties, fiber reinforced polymer composites (FRPCs) are used for producing a number of mechanical components such as gears, cams, wheels, brakes, clutches, bearings and seals. Most of these are subjected to tribological loading conditions. The FRPCs exhibit relatively low densities and they can also be tailored for our design requirements by altering the stacking sequences to provide high strength and stiffness in the direction of high loading (Pascoe, 1973).

The aim of this research is to explore and analyze the possibilities of reinforcing a polyester thermoset composite with natural plant stem areca fiber and to establish the optimum volume fraction as an independent design variable.

II. MATERIALS AND METHODS

The materials and equipment used for this project work are: Polyester resin, Methyl Ethyl Ketone Peroxide (catalyst), Cobalt 2% in solution as accelerator, areca plant stem fiber, Poly Vinyl Acetone as mould release agent, and Ethanol: This is used to clean off the left over of polyester material from the beaker and other apparatus. Weighing balance: This is used to measure the polyester resin, areca plant stem fiber, accelerator and catalyst.

The silicone rubber mould is cleaned and its surface is coated with hard wax to serve as a mould release agent. A weighed gel coat of unsaturated polyester resin containing curing additives (catalyst and accelerator) is then brushed evenly over the mould surface. This is to ensure the formation of a pure resin outer surface to the moulding. After the gel coat has become stiff, successive alternate layers of weighed areca plant stem fiber reinforcement (chopped strands in this

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case) and resin is applied. The areca plant stem fiber are fully wetted and impregnated with resin by rollers. A final sealing layer of resin is then applied. When the laminate was fully hardened, it was stripped from the mould and trimmed to size using hand file.

Several samples of varying fiber content, ranging from I (5% fiber content) to VI (30% fiber content) were prepared using the above described method.

2.1. Tensile Testing

The tensile tests were performed on INSTRON 1195 at a fixed crosshead speed of 10mm min-1. Samples were prepared according to ASTM D412 and tensile strength of standard and conditioned samples was calculated.

2.2. Impact Test

Two samples for each set I, II, III, IV, V and VI cast using the same method described above. A mould of uniform rectangular cross section was used to prepare Izod samples of uniform thickness.

The impact tests were performed on various sample determine the impact strengths by the "V-notch method using the Honsfield Balance Impact Testing Machine. Prior to mounting on the machine, the test sample is notched to a depth of 2 mm with v-shaped hand file. The notched test sample was then mounted on the impact-testing machine, which is the operated to apply a (constant) impact force on the test sample. The impact strength (the amount of impact energy the specimen absorbed before yielding) was then read off the calibrated scale on the impact testing machine.

III. Results and Discussion

The results obtained from the tests conducted on various samples was recorded in Table 1 while Figure 1 relates the effect of areca plant stem fiber volume fraction on the modulus of elasticity of the system; Figure 2 shows the effect of areca plant stem fiber volume fraction on the ultimate tensile strength of the system; Figure 3. depicts effect of areca plant stem fiber volume fraction on elastic strain of the system; Figure 4 elucidates effect of areca plant stem fiber volume fraction on the average absorbed energy of the system; Figure 5 shows ultimate tensile strength – strain curve of the system.

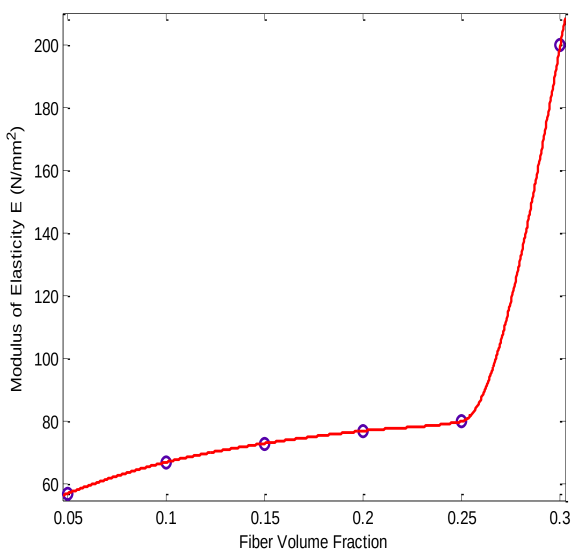

Figure 1. Effect of areca plant stem fiber volume fraction on the modulus of elasticity of the system

Table 1. Analysis table for effect of areca plant stem fiber volume fraction on the modulus of elasticity of the system

X_i	$f(X_i)$	$df(X_i)/dX$	$d^2f(X_i)/dX^2$	$integralf(X_i)$
0.05	57	240	-1200	0
0.075	62.5625	202.5	-1800	1.49648
0.1	67	150	-1440	3.11875
0.125	70..3375	118.5	-1080	4.83711
0.15	73	96	-822.857	6.63
0.175	75.1714	78.8571	-548.571	8.48304
0.2	77	68.5714	-274.286	10.3857
0.225	78.1969	43.5889	970.035	12.327
0.25	80	117.073	135834	14.3006
0.275	118.419	2678.23	69058.5	16.6475
0.3	200	3570	2282.93	20.5812

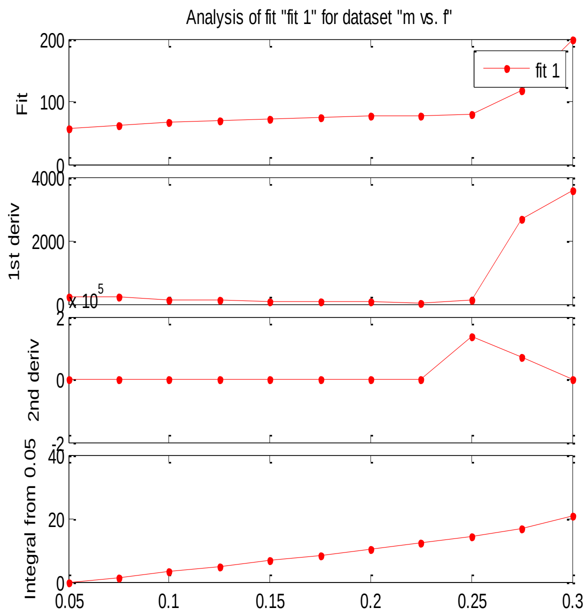

Figure 1a. Analysis fit for effect of areca plant stem fiber volume fraction on the modulus of elasticity of the system

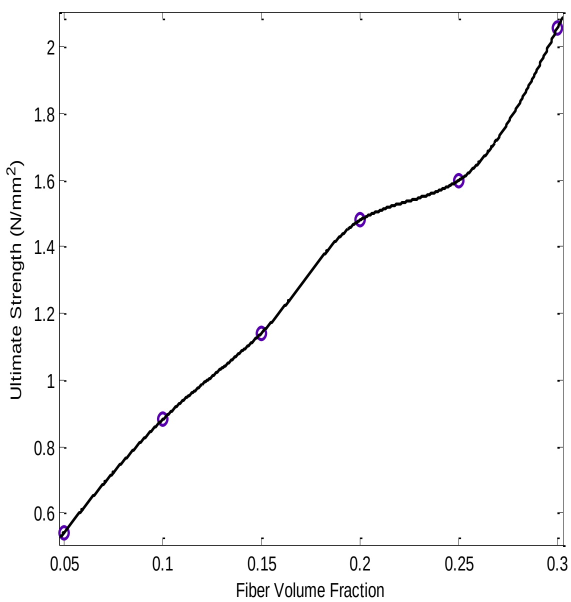

Figure 2. Effect of areca plant stem fiber volume fraction on the ultimate tensile strength of the system

Table 2. Analysis table for effect of areca plant stem fiber volume fraction on the ultimate tensile strength of the system

X_i	$f(X_i)$	$df(X_i)/dX$	$d^2f(X_i)/dX^2$	$integralf(X_i)$
0.05	0.54	7.6	-27.7333	0
0.075	0.720667	6.82667	-34.1333	0.0157986
0.1	0.88	5.89333	-83.2	0.0358556
0.125	1.01	4.85333	1.42109e-014	0.0595347
0.15	1.14	5.89333	202.62	0.0863556
0.175	1.32466	7.83971	-46.9101	0.117062
0.2	1.48	3.54783	-296.441	0.152344
0.225	1.53838	1.76132	5.18141	0.190167
0.25	1.6	3.8069	295.448	0.22929
0.275	1.77504	9.69828	175.862	0.271171
0.3	2.06	12.6	56.2759	0.318958

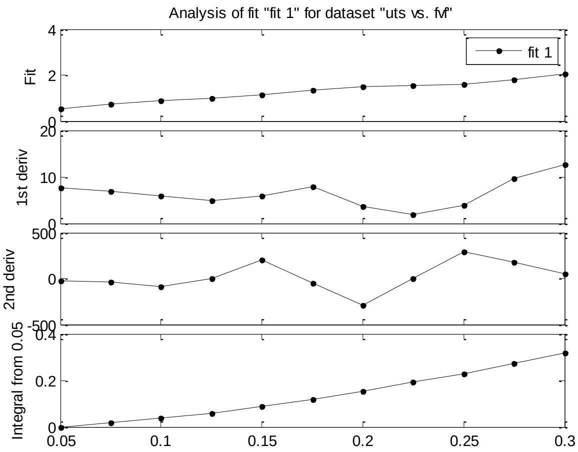

Figure 2a. Analysis fit for effect of areca plant stem fiber volume fraction on the ultimate tensile strength of the system

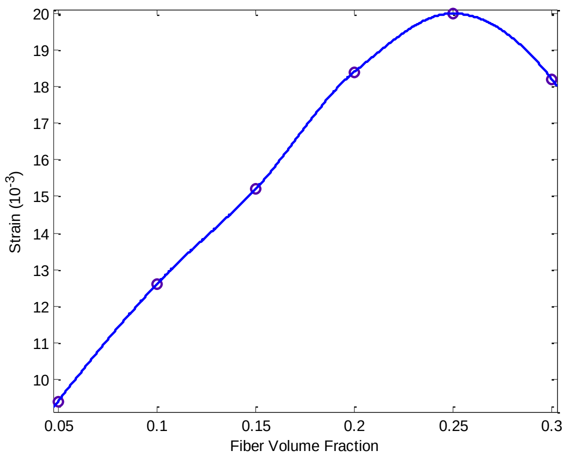

Figure 3. Effect of areca plant stem fiber volume fraction on strain of the system

Table 3. Analysis table for effect of areca plant stem fiber volume fraction on strain of the system

X_i	$f(X_i)$	$df(X_i)/dX$	$d^2f(X_i)/dX^2$	$integralf(X_i)$
0.05	9.4	70	-215.172	0
0.075	11.0789	64.1552	-252.414	0.25629
0.1	12.6	57.3793	-645.517	0.552629
0.125	13.9	49.3103	-2.27374e-013	0.8843
0.15	15.2	57.3793	1382.99	1.24763
0.175	16.892	70.9885	-294.253	1.64807
0.2	18.4	42.6667	-1971.49	2.09069
0.225	19.4667	37.3333	-853.333	2.56431
0.25	20	0	-1520	3.05958
0.275	19.5375	-36.5	-1400	3.5557
0.3	18.2	-70	-1280	4.02917

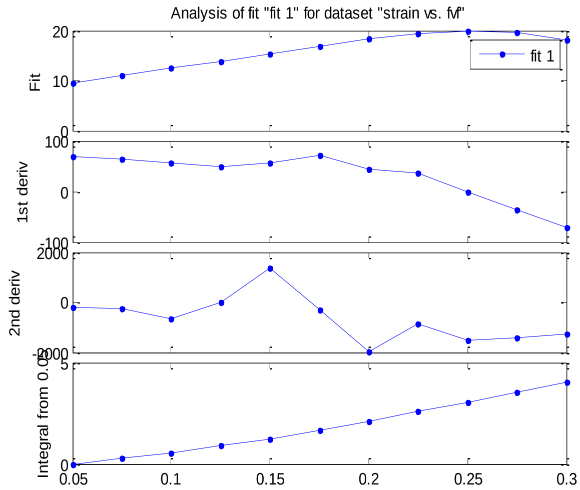

Figure 3a. Analysis fit for effect of areca plant stem fiber volume fraction on strain of the system

From Figures (1 – 1a), (2 – 2a) and (3 – 3a) it can be seen clearly that the modulus of elasticity, ultimate tensile strength, and elastic strain of the system respectively increases with increase in areca plant stem fiber volume fraction. The greater the modulus, the stiffer the material, or the smaller the elastic strain that results from the application of a given stress ((Aramide et al, 2009) and (Callister, 2000)). As seen in Figure (1 – 1a) it reveals that with the increase in areca plant stem fiber volume in the composite samples, it becomes stiffer; considering Figure (3 – 3a), it will be observed that the elastic strain increase with increase in areca plant stem fiber volume fraction attains the maximum value at around 0.25 areca plant stem fiber volume fraction, it there after reduces with further increase in areca plant stem fiber volume fraction. Figures (1 – 1a) and (2 – 2a) only show only little change (reduction) in modulus of elasticity and UTS respectively at 0.25 areca plant stem fiber volume fraction this could be attributed to the fact that areca plant stem fiber are characterized by their high strength, good temperature and corrosion resistance when reinforced, and low price (Drag et al, 2008).

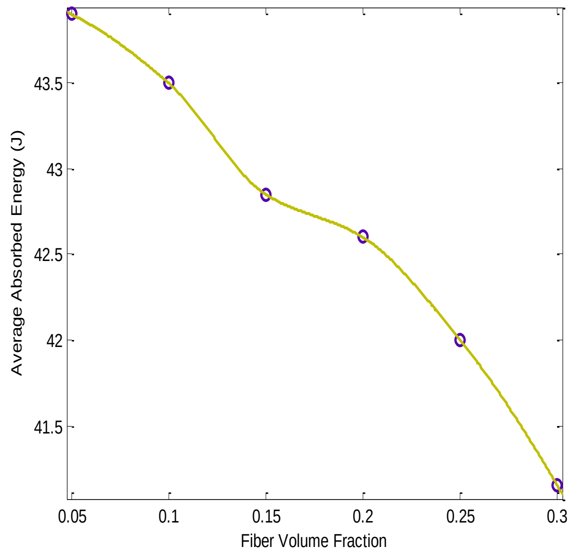

Figure 4. Effect of areca plant stem fiber volume fraction on the average absorbed energy of the system

Table 4. Analysis table for effect of areca plant stem fiber volume fraction on the average absorbed energy of the system

X_i	$f(X_i)$	$df(X_i)/dX$	$d^2f(X_i)/dX^2$	$integralf(X_i)$
0.05	43.9	-5.5	-123.81	0
0.075	43.7275	-8.14881	-88.0952	1.09548
0.1	43.5	-9.90476	-478.73	2.18592
0.125	43.1582	-15.2183	53.6508	3.26942
0.15	42.85	-7.22222	260.131	4.34411
0.175	42.724	-3.92974	3.26797	5.41361
0.2	42.6	-7.05882	-253.595	6.48032
0.225	42.3438	-12.7181	-140.203	7.54242
0.25	42	-14.069	-134.483	8.59679
0.275	41.6089	-17.1078	-108.621	9.64206
0.3	41.15	-19.5	-82.7586	10.6767

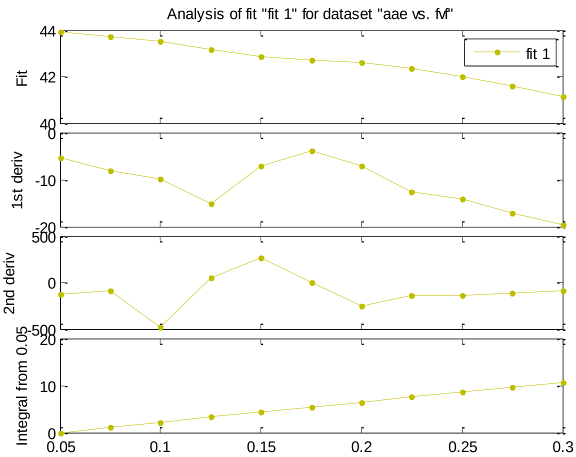

Figure 4a. Analysis fit for effect of areca plant stem fiber volume fraction on the average absorbed energy of the system

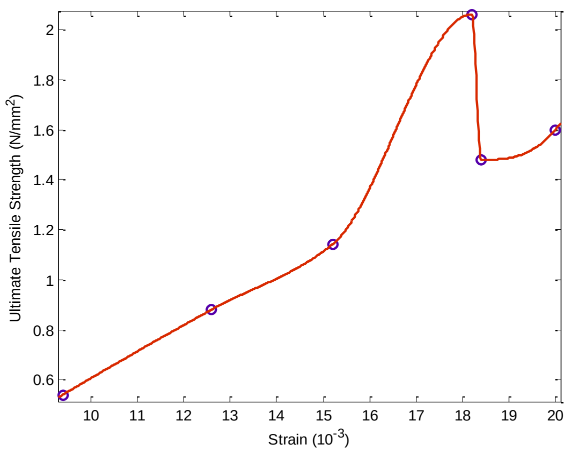

Figure 5. Ultimate Tensile Strength – Strain Curve of the System

Table 5. Analysis table for Ultimate Tensile Strength – Strain Curve of the System

X_i	$f(X_i)$	$df(X_i)/dX$	$d^2f(X_i)/dX^2$	$integralf(X_i)$
9.4	0.54	0.109698	-0.00223082	0
10.46	0.655041	0.107373	-0.00215565	0.633589
11.52	0.76766	0.105128	-0.00208047	1.38783
12.58	0.877941	0.102963	-0.0020053	2.2602
13.64	0.97286	0.083964	0.00574239	3.24298
14.7	1.07424	0.11595	0.0546084	4.32494
15.76	1.27941	0.332681	0.2413	5.55045
16.82	1.70616	0.414556	-0.0868175	7.12513
17.88	2.03537	0.148628	-0.414935	9.13305
18.94	1.48461	0.0256289	0.0949219	10.9434
20	1.6	0.225	0.28125	12.5596

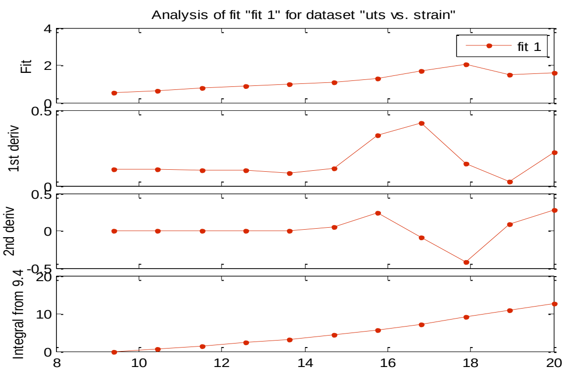

Figure 5a. Analysis fit for Ultimate Tensile Strength – Strain Curve of the System

Table 6. Mechanical Properties of the Test Samples

Sample Identity	Fiber Volume Fraction	Strain (10^{-3})	Ultimate Tensile Strength (N/mm2)	Modulus of Elasticity E (N/mm2)	Average Absorbed Energy (J)
I	0.0500	9.4000	0.5400	57.0000	43.9000
II	0.1000	12.6000	0.8800	67.0000	43.5000
III	0.1500	15.2000	1.1400	73.0000	42.8500
IV	0.2000	18.4000	1.4800	77.0000	42.6000
V	0.2500	20.0000	1.6000	80.0000	42.0000
VI	0.3000	18.2000	2.0600	200.0000	41.1500

Figure (4 – 4a) shows that the impact strength of the samples decreases with increase in areca plant stem fiber volume fraction; this is expected because of resistance to impact force.

Observing the Table 6 of data above, it will be seen clearly that there is little change in the absorbed energy; this shows that the areca plant stem fiber contributes little to the impact strength of the composite. Areca plant stem fiber reinforced thermosetting composite and other brittle materials have a very low resistance to crack propagation, as there is no mechanism to cope with the stress concentrations which arise from cracks and flaws. According to fracture mechanics, cracks greater than a critical length will propagate catastrophically under load. Figures (1 – 1a), (2 – 2a), (3 – 3a) and (5 – 5a), point to the fact that the composite resulting from the areca plant stem fiber- polyester is characterize by high toughness (resistance to crack propagation). In this case, a mechanism for crack stopping exists because of the presence of many fiber / matrix interfaces.

IV. Conclusions

From the discussion thus far, it can be concluded that:

- Ultimate tensile strength of the areca plant stem fiber polyester composite increases with increase in the areca plant stem fiber volume fraction
- The Young's modulus of elasticity of the composite increases with the areca plant stem fiber volume fraction
- The elastic strain of the composite increases with the areca plant stem fiber volume fraction up to 0.25, and then subsequently decreases with further increase in areca plant stem fiber volume fraction.
- Absorbed energy (impact strength) of the composite samples on the other hand reduces with increase in areca plant stem fiber volume fraction.

• Generally, areca plant stem fiber- polyester is characterized by high toughness (resistance to crack propagation).

REFERENCES

[1] Aramide, F., O., Oladele, I., O., Folorunso, D., O. (2009). Evaluation of the Effect of Fiber Volume Fraction on the Mechanical Properties of a Polymer Matrix Composite Issue 14, 134-141.

[2] ASM, Hand book.(1992). Materials Park Ohio, USA, ASM International, Volume 18

[3] Callister, W., D. (2000).Materials science and Engineering: An Introduction. John Wiley and sons, Inc., New York

[4] Dag Lukkassen and Annette Meidell, (2008). Advanced Materials and Structures and their Fabrication Processes Book manuscript, Narvik University College, HiN, p68.

[5] Fabian, P., E., Rice, J., A., Munshi, N., A., Humer, K., Weber, H., W. (2002). Novel Radiation-Resistant Insulation Systems for Fusion Magnets. Fusion and Engineering Design; 61(1):795-799

[6] Habak, E. (1991). Mechanical behaviour of woven glass fiber reinforced composites under impact compression load. Composites 22(2):129–134.

[7] Hsiao, H., M., Daniel, I., M., Cordes, R., D. (1999). Strain rate effects on the transverse compressive and Shear behavior of unidirectional composites. Journal of Composite Materials, 33, 1620-1642.

[8] Lynn, J., C. (1990). Polymer composite characterization for automotive structural applications. Journal of Composites Technology and Research;12(4):229–231.

[9] Mangalgiri, P., D. (1999). Composite materials for aerospace applications. Bulletin of Materials Science;22(3): 657–664

[10] Pascoe, M., W. (1973). "Plain and filled plastics materials in bearing: a review." Tribology, Vol. 6 No. 5, pp. 184-190.

[11] Wróbel, G., Wierzbicki, Ł. (2007). Ultrasonic methods in diagnostics of glass-polyester composites. Journal of Achievements in Materials and Manufacturing Engineering, Vol 20 (1-2)

[12] Zhou, L., M. (1993). Micromechanical characterization of fiber/matrix interfaces Composites Science and Technology 48(1-4):227-236.