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HYGROTHERMAL RESPONSE OF PLANT FIBRE REINFORCED COMPOSITES

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ABSTRACT

The effect of soaking time and temperature response for coconut and raffia fibre reinforced composite on their mechanical properties have been studied. Tensile and compression test for treated and untreated were performed using a universal testing machine (Monsanto Tensometer). The conditioned samples in each case show better tensile and compressive strength compared to the untreated samples. Raffia fibre reinforced polyester showed a better mechanical and moisture absorption properties at various operating temperature in the study.

Keywords: fibre, raffia, tensile strength, composite, reinforced polyester.

1. INTRODUCTION

The great desires for novel materials for fabrication, aerospace and transportation industry has gained the attention of researchers in recent time. Higher demand for materials overall performance has led to the increasing research efforts towards eco-friendly composites because of their mechanical properties, such as high stiffness, high strength and light weight. These qualities make composite materials more superior compared to many conventional engineering materials [1, 2]. Composites are generally categorized as Ceramic Matrix Composites (CMC), Metal Matrix Composite (MMC), Polymer Matrix Composites (PMC), Inter-Metallic Composites (IMC) and Carbon-Carbon Composites. However, Polymer matrix can be classified as; short fibre and continuous fibre composites. Continuous composites are mainly reinforced with high performance fibres such as carbon and Kevlar; they are mainly used for aircraft applications. On the other hand, short fibre composites are commonly reinforced with chopped fibres such as glasses, graphite and plant fibres.

The numerous applications of composites are dependent mainly on the mechanical property. Stiffness of continuous fibres is predictable by using such scheme as rule of mixture, however due to fibre dispersion, fibre volume fraction, aspect ratio and quality of fibre interface, short fibre stiffness cannot be predicted [3-7]. Good dispersion of the fibre in the polymer matrix enhances the performance of short fibre composites [8]. The increasingly cost of hydrocarbon base-plastic and the need for more eco-friendly materials in recent time makes plant fibres more desirable candidates as reinforcing materials in composites. Plant fibres can give an aspect ratio (L/D) of about 200 for good performance after melt processing [9]. They are abundant and relatively cheap [10-14]. Hygrothermal sensitive of GRP composite properties using computer integrated finite element methods to predict the displacement of GRP at the nodes at elevated temperature has been studied [15], it showed that GRP composite has ultimate strength of 133 MPa at 20^0C-120^0C. Similarly, optimization methods of golden section search and quadratic interpolation to optimize the polynomial model developed by [16] for glass fibre reinforced polyester composites commonly used in structural and mechanical parts revealed that GRP composites have optimum strength of 7-61 MPa at temperature range of 20^0C-120^0C. Compatibility between two phases of matrix and fibre poses great challenge because of the hydrophilic nature of natural fibres and hydrophobicity of polyester resin. This study focuses on the analysis of the effect of hydothermal response of plant fibre reinforced polyester resin composites.

2. EXPERIMENT

2.1. Materials and equipment

The materials used for the study were basically coconut fibre, raffia fibre polyester resin, cobalt (accelerator), MEKP catalyst, binders; gel coat resins release agent and mould. Paint brushes, rollers and electric cutting machine were used as simple tools for the study.

2.2. Methods

2.2.1. Fibre extraction

The coconut husk was detached from the nut and soaked in water for some days to accelerate fermentation and subsequently washed thoroughly to eradicate contaminants. However, the white fibrous stem of raffia stem was soaked in water for fermentation for three weeks and thereafter washed thoroughly to remove non-fibre constituents.

2.2.2. Surface modification

Surface treatment enhances mechanical properties; the fibres were immersed in 12.5g/dm^3 sodium hydroxide solution for 24 hours and double washed with distilled water to remove the alkali and afterward air dried.

2.2.3. Fibre loading formation

The fibre loads were formed using strand mat approach. Fibres were cut (50mm) in length and randomly distributed on the surface of the formica covered with PVA binder. And thereafter, pressed with a roller to ensure adequate binding of the fibres. Figure-1 shows the two samples of the fibre load formed.

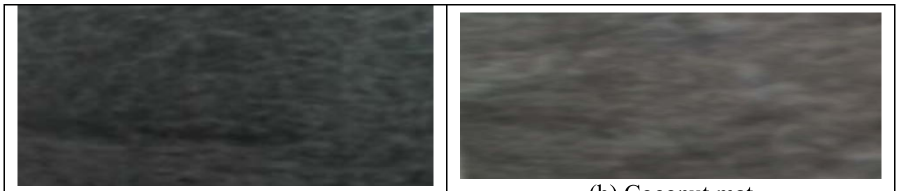

(a) Raffia mat (b) Coconut mat

Figure-1(a)-(b). Formed fibre load samples.

2.2.4. Preparation of composites

Composites were made from the processed fibre. Prior to curing, the matted fibres were accelerated with MEKP and then catalyzed using cobalt as catalyst. Curing was done followed by fibre impregnation within the formica mould as shown in Figure-2. After reasonable and uniform impregnation, the male mould was placed on the female mould containing the impregnated fibre to ensure proper compression. The sample was left in the mould for 24 hours for proper curing time. The sample was then removed after the demoulding and cut into different dimensions for the various tests. The dimensions used for the test were 300×21×5.2 mm^3 and 40×20×20 mm^3 for the tensile and compression tests, respectively.


(a) Gel coat resin (b) Fibre impregnation (c) Mould coupling

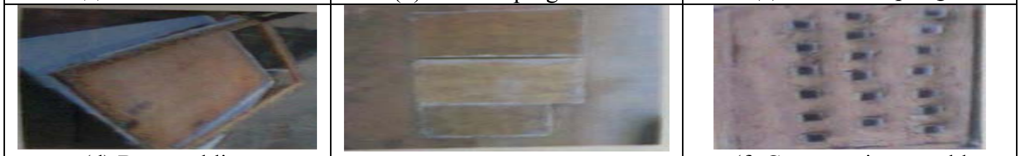

(d) De-moulding (e) Tensile sample (f) Compression mould

Figure-2. Moulds and laminate formation stages.

2.2.5. Mechanical test

Hounsfield (Monsanto) Tensometer model S/N 8889 (Universal testing machine) was used for the mechanical tests (tensile and compression tests. The test reading was taken by sliding the cursor to and fro in unison with the mercury head. The movement of the worm gear which causes the deformation of the specimen is transmitted through a gear train to the recording drum. The rotation of the drum is directly proportional to the deformation of the test piece.

Tensile test parameters:
Cross sectional area = 21mm×5.2mm = 109.2mm^2
Gauge length = $5.65\sqrt{A_0}$ (1)
= $5.65\sqrt{109.2}$
= 59.04m
Where A_0 = cross sectional area
Compression test parameters:

Cross sectional area = 20mm×20mm = 400mm^2
Gauge length = 20mm.

2.2.6. Moisture absorption

The weight gained by the condition specimens in the study were carefully examined by weighing multiple specimens periodically for 4, 8, 12 and 24 hrs at 20, 40, 60, and 100^0C. The percentage weight gain was determined as:

$M = (M_2 - M_1) \times 100\% / M_1$ (2)
M_1 = mass of fiber before soaking
M_2 = mass of fibre after soaking

2.2.7. Volume fraction measurement

The volume fractions of the fibres were evaluated based on Archimedes principle, which states that when a solid is fully or partially immersed in a fluid, it displaces the volume which is equal to the volume of the solid.

$$\text{Solid volume fraction} = \frac{Volume\ of\ solid}{Volume\ of\ fluid}$$

$$\text{Fibre volume fraction} = \frac{Volume\ of\ fibre}{Volume\ of\ composite} = \frac{Vf}{Vc} \quad (3)$$

$$= \frac{Vf}{Vf + \quad Vm} \quad (4)$$

3. RESULTS AND DISCUSSIONS

3.1. Tensile test

Each of the samples was subjected to tensile strength test at a constant fibre fraction $V_f = 0.35$. The results from the tensile test show that stress tends to be fairly proportional to strain. However, as the soaking time increases, the tensile strength increases (reduction in strain), stiffness for the treated composites. The untreated samples demonstrate reduced tensile strength compared to the treated composites under hygrothermal condition as shown in Figures 3 and 4.

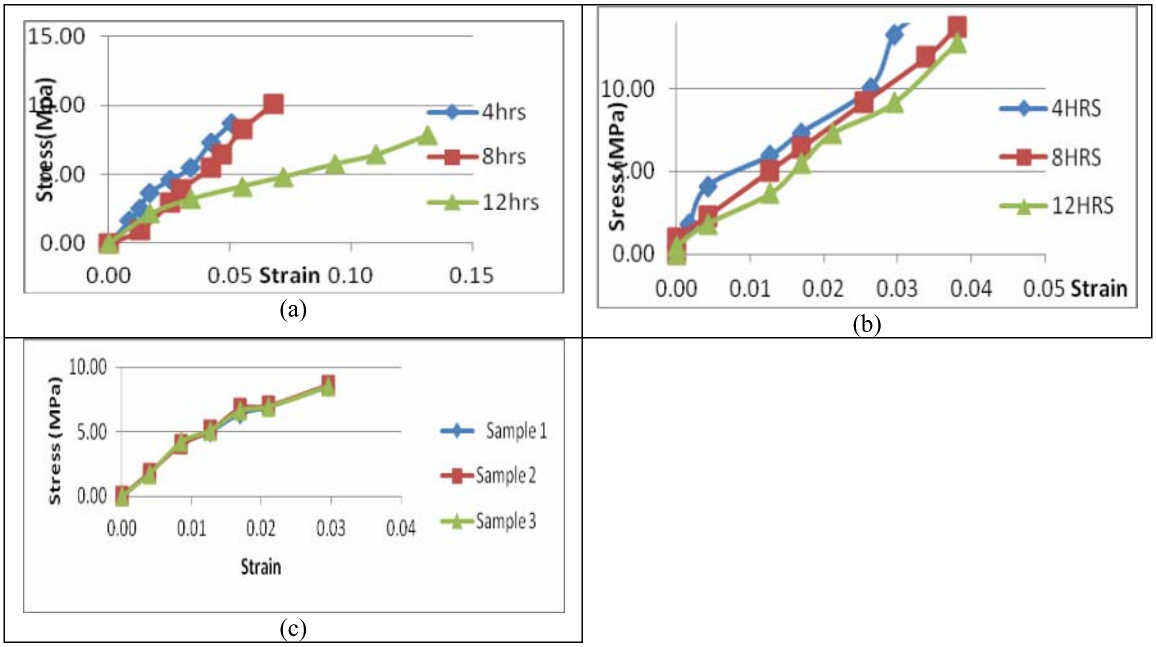


Figure-3(a), (b), (c). Tensile stress - strain response of coconut fibre reinforced polyester composite samples at 20^0C, 40^0C and untreated sample, respectively.

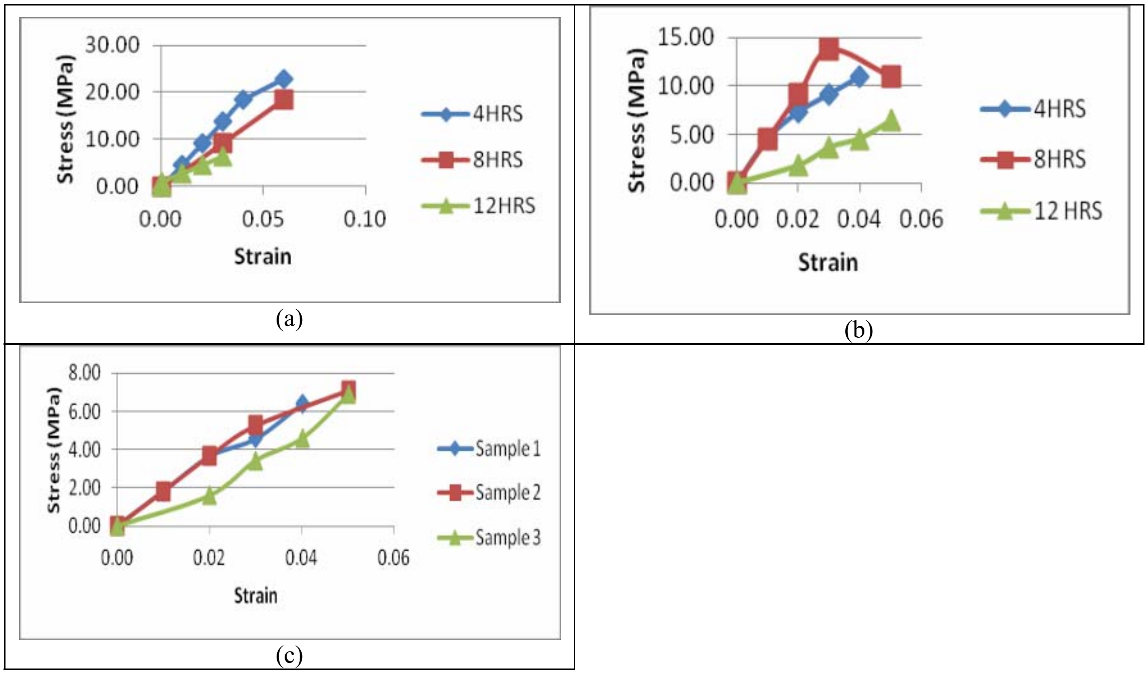
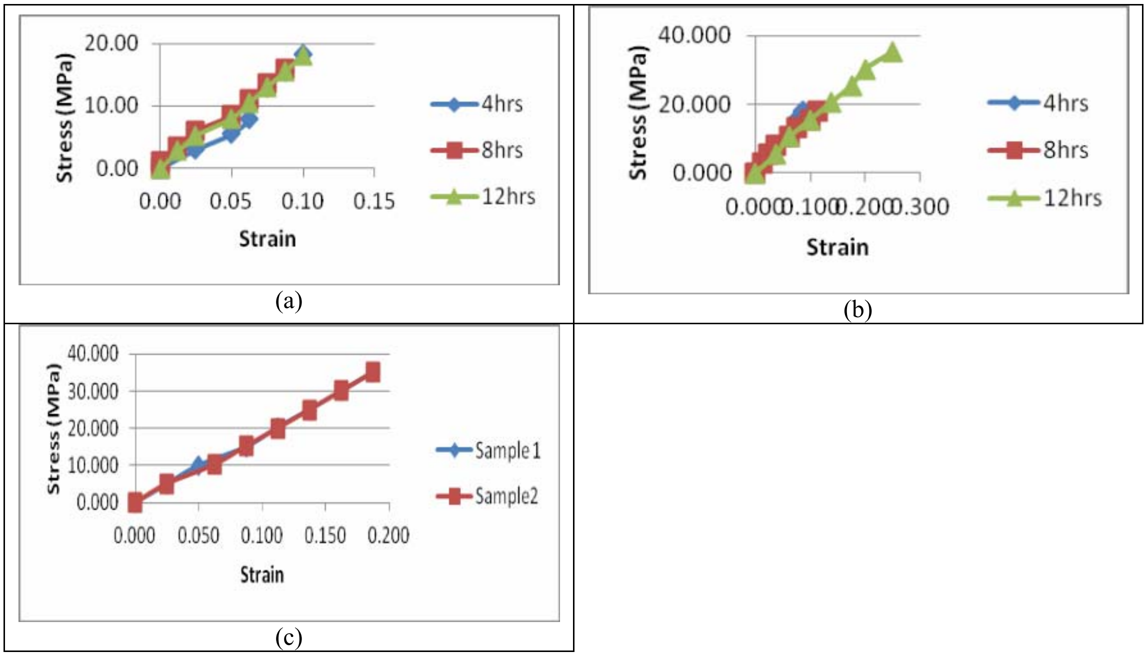


Figure-4(a), (b), (c). Tensile stress - strain response of raffia fibre reinforced polyester composite samples at 20^0C, 40^0C and untreated sample, respectively.

3.2. Compression test

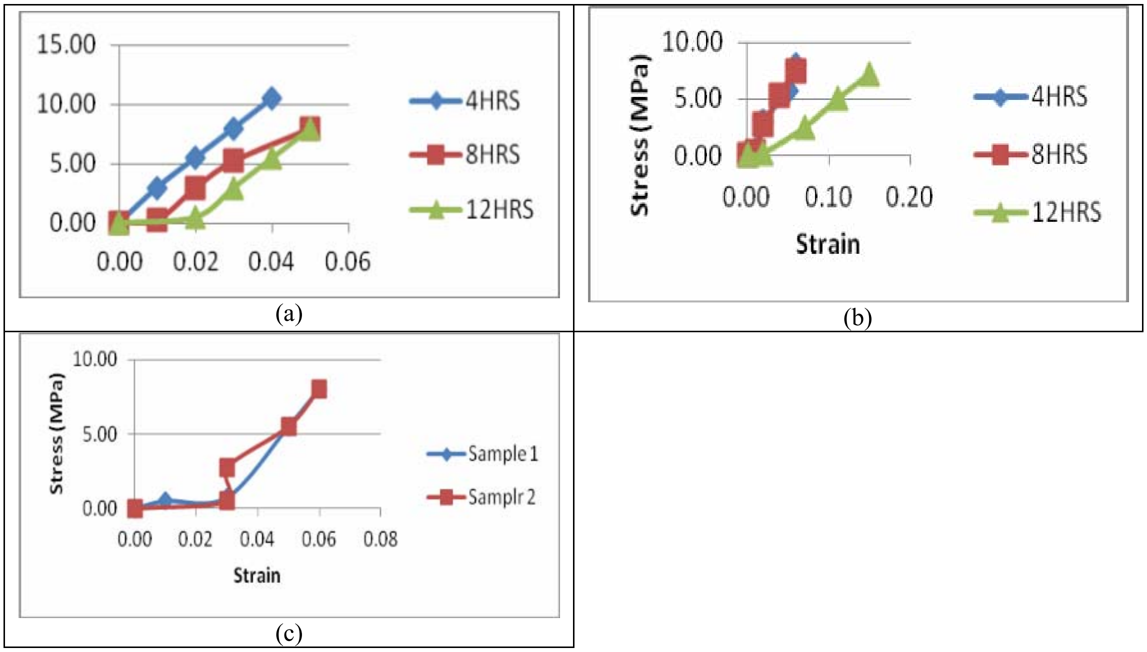
The compressive strength of material is the ultimate stress required to cause deformation under compressive loading. Figures 5 (a), (b) show that lower temperature (20^0C), the rate of failure was higher than at higher temperature for the treated sample as shown in Figure-5(b). Overall, the untreated samples show the highest deformation as shown in Figure-5(c) and 6(c). The maximum yield stress of compression test is much higher compared to tensile test; since the plant fibres are chop strand fibres. Hence higher resistance to compression load than the tensile. Coconut fibre showed a higher compression loading resistance than raffia.



(a) (b)

(c)

Figure-5(a), (b), (c). Compression stress-strain response of coconut fibre reinforced polyester composite sample at 20^0C, 40^0C and untreated sample, respectively.



(a) (b)

(c)

Figure- 6(a), (b), (c). Compression stress-strain response of raffia fibre reinforced polyester composite sample at 20^0C, 40^0C and untreated sample, respectively

3.3. Ultimate tensile strength

Figures 7 and 8 show the ultimate tensile strength of the two fibre composites. Raffia fibre reinforced polyester demonstrates the highest ultimate tensile strength of 22.89 MPa at 20^{0}C compared to coconut fibre reinforced polyester with 14.65 MPa at 40^{0}C after 4 hours, respectively. However, the ultimate strength of both samples decrease as temperature and soaking time increases as a result of debonding at the fibre-matrix interface caused by high moisture absorption, hence a reduction in mechanical properties.

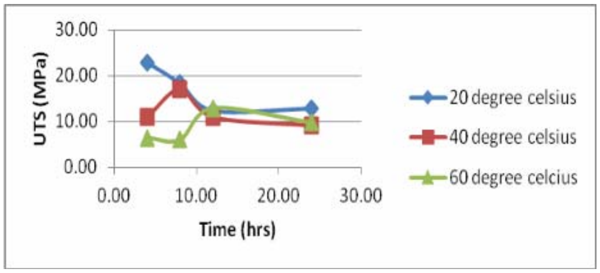


Figure-7. Ultimate tensile strength vs time graph of raffia fibre reinforced polyester composite (treated), Vf = 0.35.

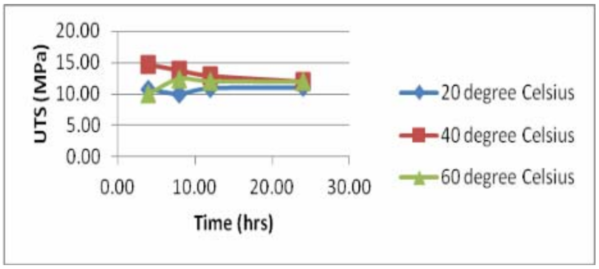


Figure-8. Ultimate tensile strength vs time graph of coconut fibre reinforced polyester composite (treated), Vf = 0.35.

3.4. Moisture absorption

Figures 9 and 10 shows the graph of moisture absorption against time for coconut and raffia fibre reinforced polyester for treated samples at various temperatures. It is evident that as temperature increases the moisture absorption increases. This could be as a result of diffusion due to dryness in the micro-pores, hence the affinity for moisture thus increased. Overall, raffia fibre showed significant moisture absorption at 20^{0}C and 40^{0}C.

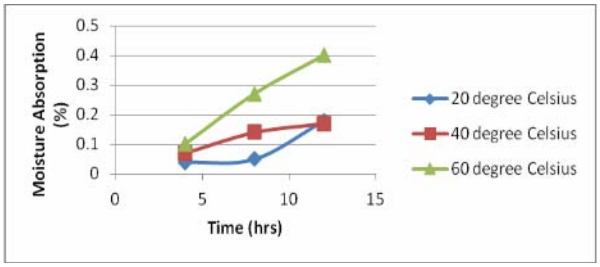


Figure-9. Moisture absorption vs time, of coconut fibre reinforced composite at Vf = 0.35.

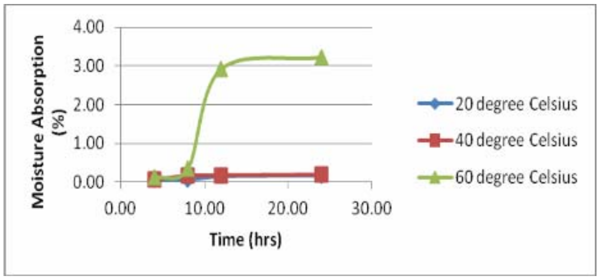


Figure-10. Moisture absorption vs time, of raffia fibre reinforced composite at Vf = 0.35.

4. CONCLUSIONS

The effect of moist and temperature on the mechanical properties of coconut and raffia fibre reinforced polyester composites has been studied and the following conclusions can be drawn from the study;

a) The maximum yield stress of compression test is much greater than the tensile test results due to the chopped strand fibres which possess high resistance to compression load.
b) The mechanical behaviour of coconut and raffia fibres as reinforcement for polyester resins shows that plant fibres possess acceptable mechanical properties similar to the synthetic counterparts.
c) Fibre reinforced polyester developed in the study is environmentally friendly. Moreso, the hand lay -up technique utilized in the study is economically suitable though labour intensive.

REFERENCES

[1] G.M. Newang. 1993. Polymer-Matrix Composites in Materials Science and Technology, VCH, New York. p. 13.

[2] T.W. Clyne and D. Hull. 1996. Introduction to Composites Materials. 2nd Ed. Cambridge University Press, Cambridge.

[3] J.R. White and S.K. De. 1996. Survey of Short - Fibre Polymer Composites. Woodhead Publishing, Cambridge.

[4] M.G. Brader and A.R Hill. 1993. Short-Fibre Composites in Materials Science and Technology, VCH, New York, USA.

[5] G.G. Nando and B.R. Gupta. 1996. Short - Fibre Thermoplastic Elastomer Composites. Woodhead Publishing, Cambridge.

[6] D.N.S Han and S.T Sean. 1993. Composites from Newsprint Fibre and Polyolefin: Their Process ability and Properties, Forest Product Society, Madison.

[7] S.M. Shaler. 1993. Mechanics of the interface in Discontinuous Wood Fibre Composite: Fundamental Concepts, Process and Materials Options, Forest Product Society.

[8] A.D. Foldi. 1992. Short-Fibre Reinforced Rubber: A New Kind of Composites in Composite Applications, VCH, New York, USA.

[9] S.M Lee. 1990. International Encyclopedia of Composites, VCH, New York, USA. 2: 35.

[10] A. RSanadi, D.F Caulfied and R.E Jacobson. 1996. Agro-Fibre/Thermoplastic Composites in Paper and Composites CRC Press, Boca Raton.

[11] R.T. Woodhams and S Law 1993. Intensive Mixing of Wood Fibres with Thermoplastic for Injection Moulded Composites, Forest Product Society.

[12] M.H. Snijder, B.E Wissing and J.F Modder. 1997. Polyolefin and Engineering Plastics Reinforced with Annual Plant Fibre. 4th International Conference on Wood Fibre Plastic Composites, Forest Product Society, Madison. p. 5.

[13] D. Feng and A.R. Sanadi. 1997. Effect of Compatibilizer on the Structure Property Relationship of Kenaf Fibre-Polypropylene Composites. 4th International Conference on Wood Fibre Plastic Composites, Forest Product Society, Madison. 5.

[14] P. Gatenholm and J. Felix. 1993. Methods for Improvement of Properties of Cellulose Polymer Composite: Wood Fibre Composites, Forest Product Society, Madison.

[15] C.C. Hueze. 2006. Hygrothermal sensitivity of GRPC composites properties. Journal of scientific and industrial studies. 14(1): 8-14.

[16] C.C. Ihueze. 2006. Optimum strength of GRP parts in automobile body work. Global Journal of mechanical Engineering. 4(6): 1-7.