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MECHANICAL PERFORMANCE OF GREEN COCONUT FIBER/HDPE COMPOSITES BY USING FLEXURAL STRENGTH

T. BALARAMI REDDY

Lecturer, Department of Mechanical Engineering, Bule Hora University, Ethiopia

ABSTRACT

Many of our morden technologies demand materials with unusual combination of properties such as high strength to weight ratio, high stiffness, high corrosion resistance, high fatigue strength, high dimensional stability etc., these can't be met by conventional metal alloys.

Composites consists of two phases namely fiber and matrix. Fibers are dis-continuous phase used to carry the load and matrix is continuous phase used to bind and transmit the load to the fibers. Fibers are produced with various materials such as metals, Glass, carbon and aramid etc.

The present work includes the processing, characterization of green coconut fiber reinforced HDPE composites. An investigation is carried out to evaluate the Mechanical properties such as Flexural strength by adopting Taghuchi's Design of Experiments (DoE) L_9 orthogonal array concept.

This investigation was set to analyze and develop a mathematical model using response surface methodology (RSM) for the observed responses i.e, Flexural strength (FS). The developed models were checked for their adequacy and significance of all the terms included in the models.

KEYWORDS: Green Coconut Fiber, Wood, Bio-Composites, HDPE, Flexural Strength Test

INTRODUCTION

This thesis outlines some of the recent reports published in literature on mechanical behavior of natural fiber based polymer composites with special emphasis on green coconut coir fiber reinforced polymer composites.

The mechanical properties of a natural fiber-reinforced composite depend on many parameters, such as fiber strength, modulus, fiber length and orientation, in addition to the fiber-matrix interfacial bond strength. A strong fiber-matrix interface bond is critical for high mechanical properties of composites. A good interfacial bond is required for effective stress transfer from the matrix to the fiber whereby maximum utilization of the fiber strength in the composite is achieved. Modification to the fiber also improves resistance to moisture induced degradation of the interface and the composite properties. In addition, factors like processing conditions/techniques have significant influence on the mechanical properties of fiber reinforced composites. Mechanical properties of natural fibers, especially flax, hemp, jute and sisal, are very good and may compete with glass fiber in specific strength and modulus. A number of investigations have been conducted on several types of natural fibers such as kenaf, hemp, flax, bamboo, and jute to study the effect of these fibers on the mechanical properties of composite materials. Mansur and Aziz [1] studied bamboo-mesh reinforced cement composites, and found that this reinforcing material could enhance the ductility and toughness of the cement matrix, and increase significantly its tensile, Flexural and impact strengths. On the other hand, jute fabric-reinforced polyester composites were tested for the evaluation of mechanical properties and compared with wood composite, and it was found that the jute fiber composite has better strengths than wood composites. A pulp fiber reinforced thermoplastic composite was investigated and found to have a combination of stiffness increased by a factor of 5.2 and strength increased by a factor of 2.3 relative to the virgin polymer. Information on the usage of banana fibers in reinforcing polymers is limited in the literature. In dynamic mechanical analysis, Laly et al. [2] have investigated banana fiber reinforced polyester composites and found that the optimum content of banana fiber is 40%. Mechanical properties of banana–fiber–cement composites were investigated physically and mechanically by Corbiere-Nicollier et al. [3]. It was reported that Kraft pulped banana fiber composite has good flexural strength. In addition, short banana fiber reinforced polyester composite was studied by Pothan et al. [4] the study concentrated on the effect of fiber length and fiber content. The maximum tensile strength was observed at 30 mm fiber length while maximum impact strength was observed at 40 mm fiber length. Incorporation of 40% untreated fibers provides a 20% increase in the tensile strength and a 34% increase in impact strength. Joseph et al. [5] tested banana fiber and glass fiber with varying fiber length and fiber content as well. Luo and Netravali [6] studied the tensile and flexural properties of the green composites with different pineapple fiber content and compared with the virgin resin. Sisal fiber is fairly coarse and inflexible. It has good strength, durability, ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in Sea water. Sisal ropes and twines are widely used for marine, agricultural, shipping, and general industrial use. Belmar's et al. [7] found that sisal, henequen, and palm fiber have very similar physical, chemical, and tensile properties. Cazaurang et al. [8] carried out a systematic study on the properties of henequen fiber and pointed out that these fibers have mechanical properties suitable for reinforcing thermoplastic resins. Ahmed et al. [9] carried out research work on filament wound cotton fiber reinforced for reinforcing high-density polyethylene (HDPE) resin. Khalid et al. [10] also studied the use of cotton fiber reinforced epoxy composites along with glass fiber reinforced polymers.

Objectives of the Research Work

The objectives of the project are outlined below.

- To develop a new class of natural fiber based polymer composites to explore the potential of green coconut fiber.
- To study the effect of fiber length (f_l) and fiber volume fraction (v_f) on mechanical behavior of green coconut fiber reinforced HDPE based composites.
- Evaluation of mechanical properties such as: Flexural strength (FS).
- To develop and analyze mathematical model to predict mechanical properties of green coconut fiber reinforced HDPE composites like Flexural strength (FS) from experimental results using response surface methodology (RSM).

MATERIALS AND METHODS

This chapter describes the details of processing of the composites and the experimental procedures followed for their mechanical characterization. The raw materials used in this work are

- Green coconut coir fiber
- HDPE resin

Green Coconut Coir Fiber

The green coconut fiber or coir is natural fiber taken from coconut husk then cleaned and compressed into bales. Coconut fiber belongs to the category fibers/fibrous materials, Coconut fiber is obtained from the fibrous husk (mesocarp) of the coconut (Cocas nucifera) from the coconut palm, which belongs to the palm family (Palme). Coconut fibers have high lignin content and thus high cellulose content, as a result of which it is resilient, strong and highly durable. The remarkable lightness of the fibers is due to the cavities arising from the dried out sieve cells. Coconut fiber is the only fruit fiber usable in the textile industry. The properties of green coconut fiber are shown in Table 1.

Table 1: Properties of Green and Dry Coconut Fiber

Green Properties	Percentage (%)
Cellulose	33.61
Lignin	36.51
Pentosans	29.27
Ash	0.61

Dry Properties	Percentage (%)
Total water soluble	26.00
Pectin's etc. soluble in boiling water	14.25
Hemi-celluloses	8.50
Lignin	29.23
Cellulose	23.81

Chemical Treatment

The green coconut fiber a lignocelluloses material which has the highest percentage the volume of lignin which makes the fiber very high and stiffer when compare to other natural fiber. This can be attributed to the fact that the lignin helps provide the plant tissue and the individual cells with compressive strength and also stiffness the cell wall of the fiber where it protect the carbohydrate from the chemical and physical damage. The lignin content also influences the structure; properties, flexibility, hydrolysis rate and high lignin content it appear to be finer and also more flexible.

In this investigation, the green coconut fibers are chemically treated with two different types of chemicals namely H_2O_2 and NaoH at varies concentration levels. The purpose of chemical treatment is to remove the moisture content of green coconut fiber and to increase the tensile strength of green coconut fiber.

The green coconut fibers(100g) were pre-treated with 1L alkaline solution which is prepared in different concentrations as 2,3 and 4% of NaoH ,for an hour under constant stirring and for 24hrs at room temperature and then dried in open air for 6 to 7 days. Thereafter fibers are tested for its tensile strength Table 2. Illustrate the tensile strength of green coconut fiber for different chemical treatment process.

Table 2: Tensile Properties of Green Coconut Fiber

Serial No.	Diameter of Coconut Fiber	Type of Fibber	Tensile Strength (TS) in Mpa
1	0.6	Untreated	39.55
2	0.6	H_2O_2	32.70
3	0.6	NaOH 2%	42.09
4	0.6	NaOH 3%	26.09
5	0.6	NaOH 4%	35.13

From the results, it is concluded that maximum tensile strength 42.09 N/mm^2 (Mpa) was noticed, when the fibers are treated with NaoH-2% chemical solution. As the concentration of NaOH solution is increases the tensile strength of the green coconut fiber is decreased.

HIGH-DENSITY POLYETHYLENE (HDPE RESIN)

HDPE is commonly High-density polyethylene (HDPE) or polyethylene high-density (PEHD) is a polyethylene thermoplastic made from petroleum. It takes 1.75 kilograms of petroleum (in terms of energy and raw materials) to make one kilogram of HDPE. Recycled, and has the number "2" as its recycling symbol. In 2007, the global HDPE market reached a volume of more than 30 million tons.

Polyethylene is used more than any other thermoplastic polymer. There is a wide variety of grades and formulations available that have an equally wide range of properties. In general, the outstanding characteristics of polyethylene are toughness, ease of processing, chemical resistance, abrasion resistance, impact resistance, low coefficient of friction and near-zero moisture absorption. HDPE is more rigid and harder than lower density materials. It has a higher tensile strength four times that of low density polyethylene and it is three times better in compressive strength. The extremely high molecular weight of HDPE combined with its very low coefficient of friction provides an excellent abrasion resistant product preventing gouging, scraping.

HDPE have high impact resistant compared to other thermoplastics and maintains excellent machinability and self-lubricating characteristics. Other than that, HDPE possess good chemical resistance of corrosives as stress cracking resistance (with the exception of strong oxidizing swelling at moderate temperature. Moisture and water (including salt water) have no affect on HDPE. It can be used in fresh and salt water immersion applications. HDPE has variety of applications in our life from food cutting board that we have in our kitchen to ration shielding in radiation risk zone. Its corrosion resistant capability made it a perfect protective covering for walls and various equipments that operate in environment with high level of moisture. By combining HDPE with natural fiber (green coconut fiber) we hope to develop a highly biodegradable material or at least increase the degradation rate of HDPE while increasing its mechanical properties. This could lead to several other benefits such as low cost, highly renewable (abundant resources of green coconut fiber) and minimizes safety and health concerns as green coconut fiber is not harmful to human and environment.

The choice of HDPE to be the matrix cloud is the answer to counter the weakness of natural fiber. HDPE has very low moisture absorption level and cloud solve the fast degradation problems of natural fiber, thus improving the natural fiber's performance in wet environment. HDPE also possess good tensile strength compared to other thermoplastics polymer and it is recyclable, which fulfills the objective of this project.

Design of Experiments via Taguchi Method

A Design of Experiment (DOE) is a structured, organized method for determining the relationship between factors affecting a process and the output of that process.

The Taguchi method involves reducing the variation in a process through robust design of experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer. The Taguchi method was developed by Dr. Genichi Taguchi of Japan who maintained that variation. Therefore, poor quality in a process affects not only the manufacturer but also society. He developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning.

The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied; it allows for the collection of the necessary data to determine which factors most affect product quality with a minimum amount of experimentation, thus saving time and resources. Analysis of variance on the collected data from the Taguchi design of experiments can be used to select new parameter values to optimize the performance characteristic. The general steps involved in the Taguchi Method are as follows.

- Define the process objective, or more specifically, a target value for a performance measure of the process. This may be a flow rate, temperature, etc. The target of a process may also be a minimum or maximum;
- Determine the design parameters affecting the process. Parameters are variables within the process that affect the performance measure such as temperatures, pressures, etc. that can be easily controlled. The number of levels that the parameters should be varied at must be specified.
- Create orthogonal arrays for the parameter design indicating the number of and conditions for each experiment. The selection of orthogonal arrays will be discussed in considerably more detail.
- Conduct the experiments indicated in the completed array to collect data on the effect on the performance measure.
- Complete data analysis to determine the effect of the different parameters on the performance measure.

The most important stage in the design of experiment lies in the selection of the control factors. Therefore, a large number of factors are included so that non-significant variables can be identified at earliest opportunity. Exhaustive literature review on mechanical behavior of polymer composites reveals that parameters viz., fiber length and fiber volume fraction etc largely influence the mechanical behavior of polymer composites. The impact of two such parameters are studied using L9 (3^2) orthogonal design.

The control parameters used and their levels chosen are given in Table 3.

Table 3: Control Parameters and their Levels

Fiber volume fraction (v_f) %	**Level 1**	**Level 2**	**Level 3**
	30	40	50
Fiber length (f_l) in mm	3	6	9

Taguchi's orthogonal array of L_9 (3^2) is most suitable for this experiment. This needs 9 runs (experiments) and has 8 degrees of freedom's (DOFs).

COMPOSITE FABRICATION

The matrix material used for the fabrication of green coconut fiber (tested fiber is used) reinforced composites is HDPE. The green coconut fibers are collected from the coconut trees. The green coconut fibers are chemically treated with NaOH solution at various concentration levels. The purpose of chemical treatment is to remove the moisture content of green coconut fiber and to increase the tensile strength of the green coconut fiber.

As a result the bonding strength increases. After the chemical treatment, the maximum tensile strength of green coconut fibers are cut in to the lengths of 3, 6 and 9 mm. To prepare the composite slabs, these fibers in pre-determined weight proportion (30, 40 and 50%) are reinforced in random orientation into the HDPE. A block of size (163mm X 12.5mm X 6mm) is thus cast, with Hand injection moulding technique.

Casting

Initially mold is gently cleansed and is set free from moisture and dirt. Weigh the fiber & matrix of different volume fractions i.e. (30, 40 and 50%). After weighing the above raw materials, pour them into the hand injection moulding machine. Maintain the constant temperature (80˚C) in the cylinder. At that temperature the matrix melts. Pressure is applied through the handle to inject the molten material through nozzle in to the die. Release the pressure and remove the specimen from the die and then dipped in to water for curing. The purpose of curing the specimen is for good appearance and to avoid the wrapping.

TESTS PERFORMED

The prepared specimens of suitable dimensions are cut using by lathe machine (according to ASTM standards) for physical characterization. On thus fabricated specimens following test was performed.

Flexural strength characteristics

Flexural strength test is performed on a Grip Components Testing Machine

Flexural Test

Flexural strength:

The strength of material in bending, expressed as the stress on the outer most fibers of a bent test specimen, at the instant of failure. In a conventional test, flexural strength expressed in Mpa.

$$F.S = \frac{3lp}{2bd^2}$$

Where p = the load applied to a sample of test, in Newton

l= specimen length in mm

b = specimen width in mm

d = specimen thickness in mm

Flexural strength was determined using above mentioned equipment as per ASTM D790-03 procedure the test speed was maintained at 2 mm/min, at a temperature 22˚C and humidity 50%. In each case four samples were taken and average value is reported.

Figure 1: Specimen for Flexural Strength

Figure 2: Specimen before Flexural Test

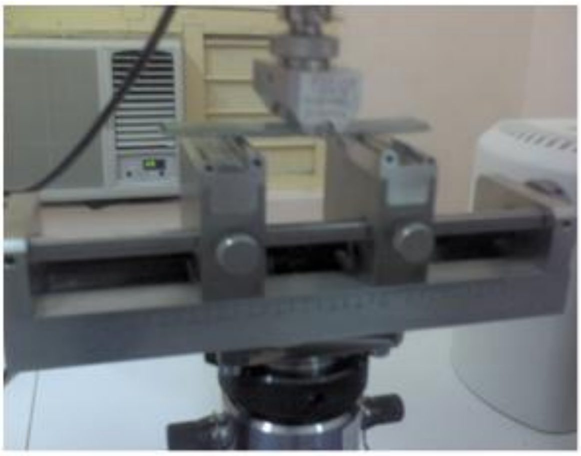

Figure 3: Grip Components for Flexural Test

Figure 4: Specimen after Flexural Test at 10% Deflection

MODELING OF PROCESSING PARAMETERS

In fabrication of composite materials, there will be two or more process variables that are inherently related and it is necessary to explore the nature of their relationship. A model has been proposed relating the process parameters with the output response (Mechanical Properties). This model can be used for prediction, process optimization or control purposes. In general, there will be response or dependent variables (eg. Flexural strength etc...), which depend on some independent variables (eg. Fiber length (f_l) and Fiber volume fraction (v_f) etc).

Response Surface Modeling

Response Surface Methodology (RSM) is the collection of experimental strategies, mathematical methods and statistical inferences that enable an experimenter to make efficient empirical exploration of the system of interest. RSM can be defined as a statistical method that uses quantitative data from appropriate experiments to determine and simultaneously solve multi-variable equations. The work which initially generated interest in the package of techniques was a paper by Box and Wilson. This method is now broadly used in many fields, such as chemistry, biology and manufacturing.

RSM can be used in the following ways:

- To determine the factor levels that will simultaneously satisfy a set of desired specifications.
- To determine the optimum combination of factors that yields a desired response and describes the response near the optimum.
- To determine how a specific response is affected by changes in the level of the factors over the specified levels of interest.

- To achieve a quantitative understanding of the system behavior over the region tested.
- To predict product properties throughout the region, even for a factor combinations not actually run.
- To find the conditions necessary for process stability (insensitive spot).

In this study, to create RS model, available **MINITAB14** software was used.

By using the RSM and finding the optimal set of model coefficients, an empirical second-order model is obtained. Then, the analysis of variance (ANOVA) is used for identifying the factors affecting the performance measures of the proposed quadratic model or test for the significance of regression. The name analysis of variance is derived from a partitioning of total variability in an experiment into its component parts ascribable to the controlled factors and error. In modeling, the objectives are to estimate the variability of the parameters and variability among the error effects.

The sum of squares (SS) is the square of the deviation from the grand mean of the response and the mean square (MS) is the ratio of sum of squares to the number of degrees of freedom. F-value is an index used to check the adequacy of the model, which is the ratio of mean squares of the regression to the error terms. The calculated or model F-value should be greater than the table value of F. In order to determine the significance of the individual effects, t-value is used. The larger the absolute value of t-value, the more significant the factor will be. When there is no relationship between the independent variable and the response variable, it can be concluded that it is a type I error. The probability of making a type I error is called alpha (α) and is sometimes referred to as the level of significance. A commonly used α value is 0.05. The p-value provides a way of testing the relationship between the independent variable and the response. With a pre-selected α-level, a p-value smaller than α indicates that the coefficient is significantly different from zero at the α-level.

The co-efficient of determination (R^2) is a measure of the amount of reduction in the variability of the response y obtained by using the regress or variables in the model. Adjusted R^2 is a modified R^2 that has been adjusted for the number of terms in the model. In this discussion including unnecessary terms, R^2 can be artificially high. Unlike R^2, adjusted R^2 may get smaller when added to the model. Because the adjusted R^2 takes into consideration the number of independent variables in the model, it is more appropriate than R^2 for comparing models with different number of independent variables. When R^2 and adjusted R^2 differ dramatically, there is a good chance that non-significant terms have been included in the model.

Table 4: Experimental Results

Experiment No	Fiber Volume Fraction(vf)%	Fiber Length (L) in mm	Flextural Strength at 10% Deflection in Mpa
1	30	3	14.75
2	30	6	12.46
3	30	9	13.81
4	40	3	13.59
5	40	6	13.31
6	40	9	12.99
7	50	3	12.99
8	50	6	13.64
9	50	9	13.42

DEVELOPMENT OF RSM MODEL

The data collected from the experiments was used to build the mathematical model using response surface methodology. The response surface methodology is a collection of mathematical and statistical techniques that are used for modeling, analysis and optimizing the mathematical model in which response of interest is influenced by fiber volume fraction, fiber length and the objective is to develop the mathematical model for flexural strength.

Flexural Strength (FS) for RSM

The second order response surface representing the flexural strength can be expressed as function of control parameters such as fiber volume fraction, fiber length. The relationship between the flexural strength and control parameters has been expressed as follows

The multiple regression coefficient of the second order model was found to be 0.94. This shows that second order model can explain the variation of the extent of 94%.

The response function has been determined in un-coded units as

$$F.S=21.741-0.276*V_f-0.795*f_l+0.00238*(V_f)^2+0.0243(f_l)^2+0.0107*V_f*f_l \quad (1)$$

Diagnostic Checking of the Developed Model

The diagnostic checking of the developed model has been performed using residual analysis. The regression model was used to determine the residuals of each individual experimental run. The difference between the observed values and predicted or fitted values is called residuals. The residuals are calculated and ranked in the ascending order. Examination of the residuals should form an automatic part of any analysis of variance. If the model is adequate, the residuals should be structure less that is, they should contain no obvious patterns. In the present study, a prediction check was made to test the adequacy of the developed models, (i.e.) construction of a plot of predicted versus actual values. The points show some scatter around the 45 degree line. The plot shows how precisely the experimental value are close to the predicted values. The relation between the experimental and the predicted values are shown in Figures 5 from the figures, it can be seen that most of the points are close to the centre line and hence, this empirical model provides reliable prediction. Hence, it can be concluded from these observations that the models developed for surface roughness, cutting force, specific cutting pressure and cutting power for all the three cutting tools are satisfactory.

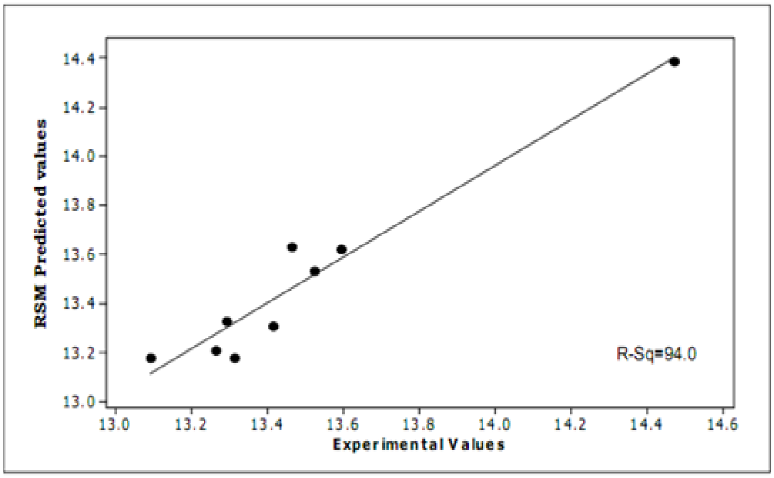

Figure 5: Comparison Plot for Flexural Strength

Summary of Models

The experimental results are modeled using RSM and empirical model has been developed. Table 5 shows the summary of models for the responses.

Table 5: Model Summary Results

Measure of Performance	Model Expression	R^2
Flexural strength	$22.4856+0.3046*V_f-0.8172*f_l-0.0027*(V_f)^2+0.028(f_l)^2+0.00991*V_f*f_l$.	92

The characterization of the composites reveals that the fiber length (f_l) and fiber volume fraction (v_f) is having significant effect on the mechanical properties of composites. The properties of the composites with different fiber lengths (f_l) and fiber volume fraction (v_f) under this investigation are presented in Table 6

Table 6: Model Results for Flexural Strength (FS)

Experiment No	Fiber Volume Fraction(v_f)%	Fiber Length (f_l) in mm	Experiment Values	Predicted by R.S.M.
1	30	3	14.47	14.39
2	30	6	13.46	13.63
3	30	9	13.41	13.31
4	40	3	13.59	13.62
5	40	6	13.31	13.18
6	40	9	13.09	13.18
7	50	3	13.29	13.33
8	50	6	13.26	13.21
9	50	9	13.52	13.53

RESULTS AND DISCUSSIONS

This chapter discusses the mechanical properties of the green coconut fiber reinforced HDPE composites prepared for this present investigation. Details of processing of these composites and the tests conducted on them have been described in the previous chapter. The results of various characterization tests are reported here. This includes evaluation of Flexural strength (FS) has been studied and discussed. The effects of constituent phases of mechanical properties are discussed in detail. The interpretation of the results and the comparison among various composite samples are also presented.

Effect of Fiber Volume Fraction (v_f) on Flexural Strength (FS)

The test results for flexural strength is shown figure 5. The graph is drawn with the help of response surface model observed. In this graph one variable in variation in nature by keeping the other variable constant at the middle level. From the graph shows the comparison of flexural strength of the composites obtained experimentally from the bend tests. It is interesting to note that flexural strength decreases with increase in fiber volume fractions (v_f). In the present investigation the maximum flexural strength of 9.35 Mpa was notice for fiber volume fraction (v_f) of 30% and minimum flexural strength of 1.31 Mpa was noticed for fiber volume fraction (v_f) of 50%.

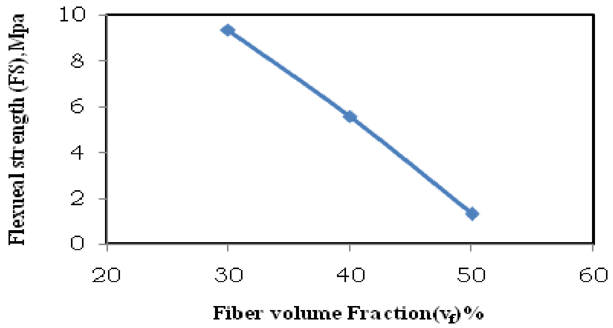

Figure 6: Variation of Flexural Strength with Respect to Fiber Volume Fraction (v_f) %

Effect of Fiber Length (f_l) on Flexural Strength (FS)

Figure 6 shows the variation of Flexural strength with respect to the fiber length (f_l). The graph is drawn with the help of response surface model observed. In this graph one variable in variation in nature by keeping the other variable constant at the middle level. From the graph it is clearly seen that flexural strength of the composite material decrease with increase in the fiber length (f_l) up to 6mm then after it decreases slidely. In the present investigation the maximum flexural strength of 13.63 Mpa was notice for fiber length (f_l) of 3 mm and minimum flexural strength of 13.17 Mpa was noticed for fiber length (f_l) of 9 mm.

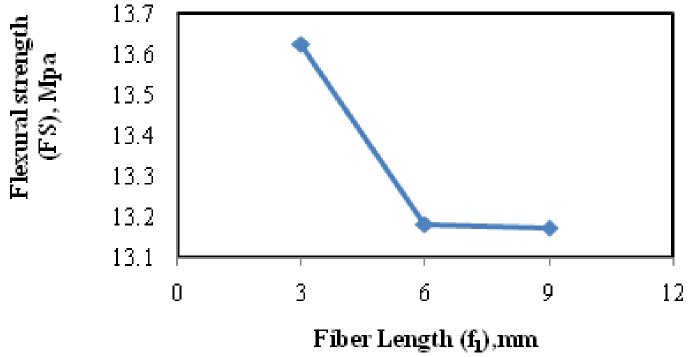

Figure 7: Variation of Flexural Strength with Respect to Fiber Length (fl), mm

Effect of Constituent Phases of Composition on Flexural Strength (FS)

The flexural strength is a predominant property in processing of composite materials. It is more influenced by fiber length (f_l) and fiber volume fraction (v_f). The influence of amount of constituent phases on flexural strength of the green coconut fiber reinforced HDPE composites can be studied by using response table 7 and response graph 2.8.

Table 7: Response Table for Flexural Strength (FS)

Level	Fiber Volume Fraction(V_f)	Fiber Length (F_l) in mm
1	13.78	13.78
2	13.33	13.34
3	13.36	13.34
Delta	0.45	0.44
Rank	1	2

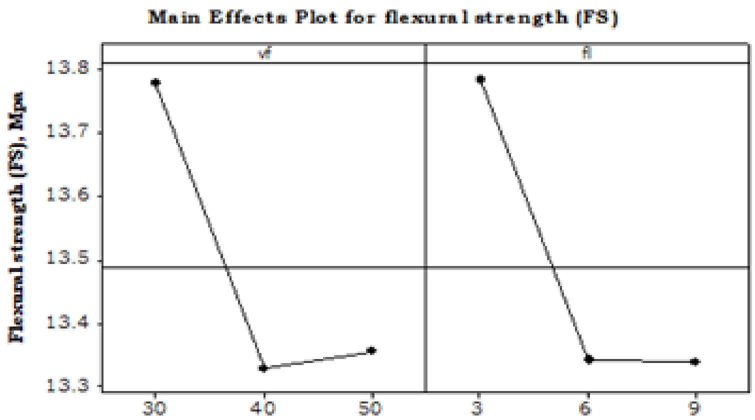

Figure 8: Effect of Control Factors on Flexural Strength (IS)

Figure 8 shows the influence of constituent phases on flexural strength. The observed flexural strength is high at lower fiber volume fraction (v_f) compare to high fiber volume fraction (v_f). The experimental results indicated that flexural strength of the composite is high at lower fiber length (f_l) than compare to the flexural strength of the composite at higher fiber length (f_l).

The results predicted by RSM model were compared with the experimental result values are shows figures 9.

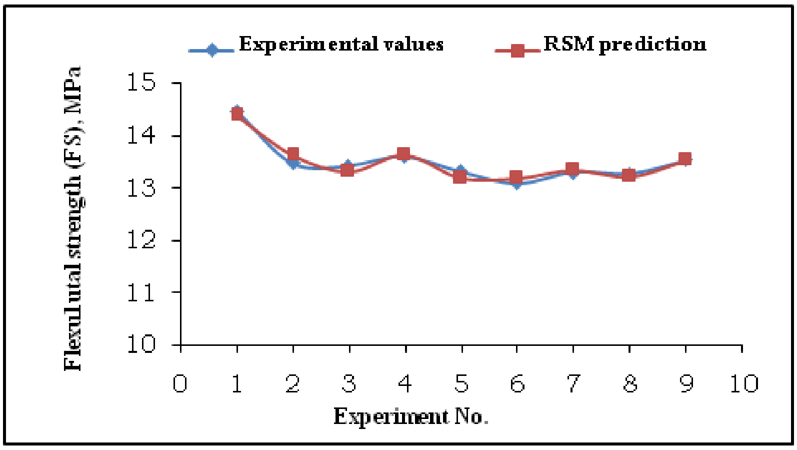

Figure 9: Variation of Flexural Strength with Respect to Experiment No

From the plot it is observed that the comparison between the experimental and prediction of Flexural Strength (FS).

CONCLUSIONS

This experimental investigation of mechanical behavior of green coconut fiber reinforced HDPE composites leads to the following conclusions:

- The experiments were carried out in the hand injection technique using Taguchi orthogonal array in the design of experiments and data were collected and reported in previous chapters.
- This work shows that successful fabrication of a green coconut fiber reinforced HDPE composites with different fiber lengths and fiber volume fractions are possible by simple hand injection technique.
- Mechanical properties viz., Flexural strength (FS) of the green coconut fiber reinforced HDPE composite material is greatly influenced by fiber length as well as fiber volume fraction.
- Flexural strength of the composite material decreasing with increasing the fiber volume fraction (v_f).
- Flexural strength of the composite material decreasing with increasing the fiber length (f_l) up to 6 mm, then after decreases slightly.

REFERENCES

1. Mansur M. A and Aziz M. A, “Study of Bamboo-Mesh Reinforced Cement Composites” Int. Cement Composites and Lightweight Concrete”, 5(3), 1983, pp. 165–171.
2. Laly A. Pothana, Zachariah Oommenb, and Thomas S, “Dynamic Mechanical Analysis of Banana Fiber Reinforced Polyester Composites”, Composites Science and Technology, 63(2), 2003, pp. 283-293.
3. Corbière-Nicollier T, Laban B. G, Lundquist L, Leterrier Y,. Månson J. A. E and Jolliet O, “Life Cycle Assessment of Bio fibers Replacing Glass Fibers as Reinforcement in Plastics”, Resources, Conservation and recycling, 33(4), 2001, pp. 267-287.

4. Pothan L. A, Thomas S and Neelakantan, "Short Banana Fiber Reinforced Polyester Composites: Mechanical, Failure and Aging Characteristics", Journal of Reinforced Plastics and Composites, 16(8), 1997, pp. 744-765.

5. Joseph S, Sreekala M. S, Oommen Z, Koshy P, and Thomas S, "A Comparison of the Mechanical Properties of Phenol Formaldehyde Composites Reinforced with Banana Fibers and Glass Fibers", Composites Science and Technology, 62(14), 2002, pp. 1857-1868.

6. Luo S and Netravali A. N, "Interfacial and mechanical properties of environment-friendly 'green' composites made from pineapple fibers and poly (hydyoxybutyrate-co-vale rate) resin", Journal of Materials Science, 34, 1999, pp. 3709-3719.

7. Belmares H, Barrera A and Monjaras M, "New composite materials from natural hard fibers. Part 2: Fatigue studies and a novel fatigue degradation model" Industrial & Engineering Chemistry Product Research and Development, 22, 1983, pp. 643-652.

8. Casaurang M, Herrera P, Gonzalez I and Aguilar V. M, "Physical and mechanical properties of henequen fibers", Journal of Applied Polymer Science, 43, 1991, pp. 749-756.

9. Ahmed E. M, Sahari B, Pedersen P. Non-linear behavior of unidirectional filament wound COTFRP, CFRP, and GFRP composites. In: Proceedings of World Engineering Congress, WEC 99, Mechanical and Manufacturing Engineering, Kuala Lumpur; 1999, p. 537–43.

10. Khalid AA, Sahari B, Khalid YA. Environmental Effects on the Progressive Crushing of Cotton and Glass Fibre/Epoxy Composite Cones. In: Proceedings of the Fourth International Conference on Advances in Materials and Processing Technologies, 98, Kuala Lumpur; 1998, p. 680–89.

11. Fuad MYA, Rahmad S, Azlan MRN. Filler content determination of biobased thermoplastics composites by thermo gravimetric analysis In: Proceedings of the Fourth International Conference on Advances in Materials and Processing Technologies, 98, Kuala Lumpur; 1998, p. 268–75.