Statistical analysis of mechanical properties of Kenaf fiber/ Palmyra sprout/Glass fiber reinforced Epoxy composites using Taguchi method

R. Ravi Kiran [1], B. Anil Kumar Reddy[2], K. Balaji [3] , Sk. Mahaboob Malik Babu [4]

[1]Student; Dept. of Aeronautical Eng.: PVPSIT, Andhra Pradesh, India
[2] Student; Dept. of Aeronautical Eng.: PVPSIT, Andhra Pradesh, India
[3] Student; Dept. of Aeronautical Eng.: PVPSIT, Andhra Pradesh, India
[4] Student; Dept. of Aeronautical Eng.: PVPSIT, Andhra Pradesh, India

---

Abstract - *In the present study, Kenaf fiber/ Palmyra sprout/Glass fiber Epoxy composites fabricated and tested for their mechanical properties. The effect of matrix modification on mechanical properties investigated. Experiments conducted using Taguchi L12 orthogonal array considering the two deign parameters viz. weight fraction of the fiber. The experimental results were analyzed using Taguchi optimization method. Analysis of variance (ANOVA) carried out to obtain the significant values of tensile strength, and impact strength at 95 % confidence level .Multiple regression analysis technique is applied to obtain the mathematical model for tensile, and impact strengths.*

Key Words: Epoxy resin, Kenaf fiber, Palmyra sprout, Glass fiber, S/N Ratio, ANOVA;

1. INTRODUCTION

There has been a developing enthusiasm for using fibers as support to create composite materials. Researchers lean toward thermoplastic polymeric lattices than thermosets because of the low generation cycle, lower expense of preparing and high reparability of thermoplastics. Different natural fibers are generally utilized as support as a part of thermoplastic polypropylene (PP) matrix material to get ready composites. The utilization of regular fiber polypropylene composite materials in basic applications expanding in the most recent years due to their points of interest in bio degradability, recyclability, ease, ecofriendly and low thickness, Because of the adhesion between matrix and fibers, the mechanical properties of natural fiber polypropylene composites affected mainly. Distinctive Chemical alteration strategies used to improve the fiber and matrix adhesion, due to the improvement of adhesion between matrix and fiber the mechanical properties of the composites increased Taguchi method of design of experiments, genetic algorithm, and artificial neural network are some of the important tools used for robust design to produce high quality products quickly and at low cost. Taguchi method based on performing evaluation or experiments to test the sensitivity of a set of response variables to a set of control parameters (or independent variables) by considering experiments in "orthogonal array" with an aim to attain the optimum setting of the control parameters. Orthogonal arrays provide a best set of well-balanced (minimum) experiments [4]. The S/N ratios, which are log functions of desired output, serve as the objective functions for optimization, help in data analysis and the prediction of the optimum results. There are three forms of S/N ratio that are of common interest for optimization of static problems. 1. Smaller-the-better, 2.Larger-the-better and 3.Nominal- the-best. Different factors affect the strength to a different degree. Analysis of variance is a better feel for the relative effect of the different factors obtained by the decomposition of variance [5, 6].A short Palmyra sprout, Kenaf, glass fiber epoxy reinforced composites have been developed by Handlayup technique with varying parameters like fibre loading ((0%, 7.5%, 15% by weight) and fibre condition at constant fibre length of 3mm [7].In this present study, Composites comprising of epoxy fortified with Palmyra sprout, Kenaf, glass fiber arranged by Handlayup with shifting weight divisions of fiber (0%, 7.5%, 15%). The created Palmyra sprout, Kenaf, glass fiber strengthened Epoxy composites tried for their mechanical properties [8].The main objective of this work is to determine the suitability of Palmyra sprout, Kenaf, glass fibers as reinforcement in the Epoxy matrix for making composites. The effect of the fiber content and the interfacial adhesion on the mechanical properties of Palmyra sprout, Kenaf, glass fiber /Epoxy composites prepared by Handlayup process was investigated. Taguchi method of analysis is uses to reduce total number of experiments. The experimental data is analyzed using Taguchi method for optimal conditions of input parameters. ANOVA carried out on experimental data to find the significant effect of the input parameters.

1 Materials

1.1 Kenaf

The kenaf fiber collected from local fields. The collected fibers drenched in water for two weeks. Later cleansing done and the fibers desiccated for a week. The draw out fiber then chopped into short fiber. The organic constitutes of Kenaf fibers are cellulose, hemicelluloses, lignin and pectin's, with a small quantity of extractives. The Kenaf plant belongs to Malvaceae family.

1.2 Palmyra sprouts

The Borassus flabellifer is a tall and erect palm, with large, fan-shaped leaves which are quite unlike the pinnate leaves of other palms. The seeds are sown on top of mounds and watered regularly within 45-60 days before germinating. The embryonic axis grows downward within a long apical tube into the soil and strikes roots. Growing upward from the roots is a bladeless first leaf within which accumulated food material translocate from the endosperm, there by forming the starchy tuber. The collected fibers drenched in water for two weeks. Later cleansing done and the fibers desiccated for a week. The draw out fiber then chopped into short fiber.

1.3 Glass Fibre

Glass fiber (or glass fibre) is a material consisting of numerous extremely fine fibers of glass. Glassmakers throughout history have experimented with glass fibers, but mass manufacture of glass fiber was only made possible with the invention of finer machine tooling. In 1893, Edward Drummond Libbey exhibited a dress at the World's Columbian Exposition incorporating glass fibers with the diameter and texture of silk fibers. Glass fibers can also occur naturally, as Pele's hair.

1.4 Epoxy

Epoxy is either any of the basic components or the cured end products of epoxy resins, as well as a colloquial name for the epoxide functional group. Epoxy resins, also known as polyepoxides, are a class of reactive prepolymers and polymers which contain epoxide groups. Epoxy resins may be reacted (cross-linked) either with themselves through catalytic homopolymerisation, or with a wide range of co-reactants including polyfunctional amines, acids (and acid anhydrides), phenols, alcohols and thiols. These co-reactants are often referred to as hardeners or curatives, and the cross-linking reaction is commonly referred to as curing. Reaction of polyepoxides with themselves or with polyfunctional hardeners forms a thermosetting polymer, often with favorable mechanical properties and high thermal and chemical resistance.

2. Processing

The extracted fibers dried in oven at a temperature of 800 C for 2 hours to expel the moisture. The composite samples were prepared. The weight fraction of the fiber 0, 7.5, 15% mixed with Epoxy. Composites of different weight fractions of fiber fabricated using Handlayup technique. Five specimens composed for each weight fraction of fiber composites.

2.1Design of experiments by Taguchi method:

The design of experiments carried out with the help of Taguchi's L12 orthogonal array to reduce the number of experiments. The L12 orthogonal array contains twelve rows and two columns, with 11 degrees of freedom (df) to treat one parameter with six levels and another parameter with two levels. Each parameter level is set according to the L12 orthogonal array, based on Taguchi method of design. The experimental results further transferred into S/N ratio using MINITAB 17 software. The different levels of variables used in experiment listed in table 1. When response maximized (Larger-the-better), Taguchi uses the following formula for S/N ratio (⍰).

$$(S/N = -10 * \log (\Sigma (1/Y2)/n)$$

After that the experiment results are statically studied by analysis of variance (ANOVA).

Table 1. Levels of variables (control factors) used in experiment.

CONTROL FACTOR	LEVELS			UNITS
Weight fraction of fiber	**1**	**2**	**3**	
PALMYRA SPROUTS (X)	**0**	**7.5**	**15**	**WT%**
KENAF% (Y)	**0**	**7.5**	**15**	**WT%**
GLASS	**0**	**7.5**	**15**	**WT%**

3. Tensile and Impact tests

A Tensometer is used to find the tensile properties of the composite specimens. Dog bone shaped tensile test specimens were made in accordance with ASTM-D 638M to measure the tensile properties. The samples tested at a crosshead speed of 1 mm/min. A Charpy impact test machine used to find the impact properties of the composite specimens. The specimens were prepared in accordance with ASTM D256-97.

3.1Tensile and impact strength test results

The tensile and impact properties are found out using three different fiber weight percentages (0%, 7.5%, and 15%). For each weight percentage, five specimens tested to achieve the repeatability in results. The variations of tensile strength and impact strength with weight fraction of fibre

Table 2. **Experimental results of tensile strength along with S/N ratio.**

SL. NO	WEIGHT FRACTION OF PALMYRA SPROUTS FIBER	WEIGHT FRACTION OF KENAF FIBER	WEIGHT FRACTION OF GLASS FIBER	TENSILE STRENGTH (MPa)	SNRA1
1	0.0	0.0	0.0	45.58974359	33.17734299
2	0.0	7.5	7.5	46.80512821	33.16212557
3	0.0	15.0	15.0	37.38461538	31.11454463
4	7.5	0.0	7.5	49.30769231	33.15526282
5	7.5	7.5	15.0	46.53846154	33.10264366
6	7.5	15.0	0.0	50.83333333	34.10789313
7	15.0	0.0	15.0	53.58974359	34.51637022
8	15.0	7.5	0.0	53.46153846	34.40404063
9	15.0	15.0	7.5	48.36153846	33.63965697

Table 3. Experimental results of impact strength along with S/N ratio.

Sl. No	WEIGHT FRACTION OF PALMYRA SPROUTS FIBER	WEIGHT FRACTION OF KENAF FIBER	WEIGHT FRACTION OF GLASS FIBER	IMPACT STRENGTH	SNRA1
1	0.0	0.0	0.0	0.326316	-9.73895
2	0.0	7.5	7.5	0.375	-8.52963
3	0.0	15.0	15.0	0.407895	-7.81623
4	7.5	0.0	7.5	0.419737	-7.54604
5	7.5	7.5	15.0	0.452632	-6.89645
6	7.5	15.0	0.0	0.365789	-8.74471
7	15.0	0.0	15.0	0.417105	-7.61043
8	15.0	7.5	0.0	0.363158	-8.81616
9	15.0	15.0	7.5	0.326316	-9.73895

3.2 Taguchi analysis for tensile and impact strength

Analysis of the influence of control factors on the responses are obtained from the response tables of mean S/N ratio and the results are listed in table 4, 5 respectively. Larger value of S/N ratios corresponds to better quality, so optimal combination of design parameters can be obtained as X4Y2 for tensile and impact strength.

Table 4. Response Table for S/N ratio for Tensile strength.

Level	WEIGHT FRACTION OF PALMYRA SPROUTS FIBER	WEIGHT FRACTION OF KENAF FIBER	WEIGHT FRACTION OF GLASS FIBER
1	32.48	33.62	33.90
2	33.46	33.56	33.32
3	34.19	32.95	32.91
Delta	1.70	0.66	0.99
Rank	1	3	2

Table 5. Response Table for S/N ratio for Impact strength.

Level	WEIGHT FRACTION OF PALMYRA SPROUTS FIBER	WEIGHT FRACTION OF KENAF FIBER	WEIGHT FRACTION OF GLASS FIBER
1	-8.695	-8.298	-9.100
2	-7.729	-8.081	-8.605
3	-8.722	-8.767	-7.441
Delta	0.993	0.686	1.659
Rank	2	3	1

3.3 Analysis of variance

The purpose of the statistical analysis of variance is to investigate which design parameter significantly affects strength of the composites. The analysis carried out for the level of significance of 5% (the level of confidence is 95%). Two-way ANOVA allow comparing population means when the populations classified according to two (categorical) factors (weight fraction of the fiber (X), treatment (Y)). Analysis of variance results are listed in table 8, 9 and 10 respectively.

From ANOVA it can conclude that the weight fractions of the fiber (X) and treatment (Y) both are significant for tensile and impact strength. Since corresponding F values is higher than F-crit.

3.4 Mathematical model using multiple regression analysis

Multiple regression analysis is done using the statistical software package MINITAB-17. The fitted line plots for tensile strength, flexural strength and impact strength are shown in Figure 2 (a), (b) and (c) respectively. These graphs show trends of tensile strength, flexural strength and impact strength. As weight fraction of the fiber (X) increases tensile strength is showing a slightly decreasing trend but with treatment, tensile strength is showing

Slightly increasing trend. As weight fraction of the fiber (X) increases flexural and impact strength are showing increasing trend but with treatment, flexural and impact strength are showing slightly increasing trend.

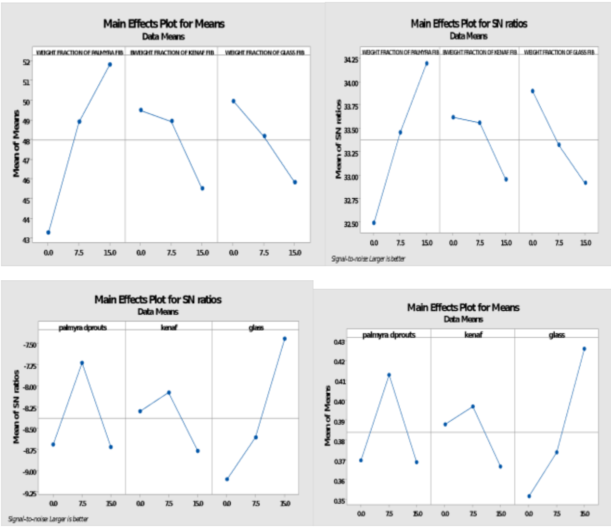


Fig. 1. Main effects plot of S/N ratio for (a) tensile strength; (b) impact strength

Table 6. **ANOVA table for tensile strength**

Source	DF	Seq SS	Contribution	AdjSS	Adj MS	F-Value	P-Value
WEIGHT FRACTION OF PALMYRA FIB	**2**	**4.3739**	**52.79%**	**4.3739**	**2.1870**	**2.67**	**0.272***
BWEIGHT FRACTION OF KENAF FIB	**2**	**0.8049**	**9.72%**	**0.8049**	**0.4025**	**0.49**	**0.670**
WEIGHT FRACTION OF GLASS FIB	**2**	**1.4704**	**17.75%**	**1.4704**	**0.7352**	**0.90**	**0.527**
Error	**2**	**1.6361**	**19.75%**	**1.6361**	**0.8180**		
Total	**8**	**8.2853**	**100.00%**				

**-more significant; * - significant

Table 7. **ANOVA table for impact strength.**

SOURCE	DF SEQ	SS CONTRIBUTION	ADJ SS	ADJ MS	F-VALUE	P-VALUE
Palmyra Spourts	**21.9192**	**24.46%**	**1.9192**	**0.9596**	**2.29**	**0.304**
Kenaf	**20.737**	**9.39%**	**0.737**	**0.3685**	**0.88**	**0.532**
Glass	**24.3516**	**55.47%**	**4.3516**	**2.1758**	**5.19**	**0.161***
Error	**20.8378**	**10.68%**	**0.8378**	**0.4189**		
Total	**87.8456**	**100%**				

**-more significant; * - significant

Table 8.**Error percentage for experimental and predicted values of tensile strength.**

SL.NO	PALMYRA SPROUTS	KENAF	GLASS	EXPERIMENTAL VALUE	PREDICTED VALUE	ERROR PERCENTAGE
1	**0.0**	**0.0**	**0.0**	**45.58974**	**47.41328**	**-3.99988**
2	**0.0**	**7.5**	**7.5**	**46.80513**	**44.54894**	**4.820381**
3	**0.0**	**15.0**	**15.0**	**37.38462**	**42.95432**	**-14.8984**
4	**7.5**	**0.0**	**7.5**	**49.30769**	**50.35347**	**-2.12092**
5	**7.5**	**7.5**	**15.0**	**46.53846**	**48.44643**	**-4.09976**
6	**7.5**	**15.0**	**0.0**	**50.83333**	**52.87567**	**-4.01771**
7	**15.0**	**0.0**	**15.0**	**53.58974**	**52.15718**	**2.6732**
8	**15.0**	**7.5**	**0.0**	**53.46154**	**56.80299**	**-6.2502**
9	**15.0**	**15.0**	**7.5**	**48.36154**	**53.48668**	**-10.5976**

Tensile strength $=47.31573 \times A^{0.1692} \times B^{-0.0750} \times C^{-0.0824}$ (5)

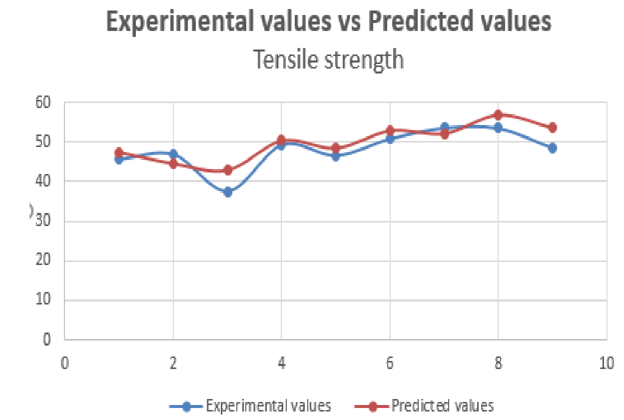
Impact Strength = $0.351 \times A^{a-0.454} \times B^{0.014b} \times C^{-0.039}$ (6)

The predicted values of tensile strength and impact strength calculated from equations (5) and (6), which to be compared with experimental values for which error must be calculated. The predicted error percentage between predicted and measured output values at each experimental condition calculated by using the equation (7).

$$Error\% = \left(\frac{(Experimental\ Value - \Pr edicted\ Value)}{Experimental\ Value} \right) * 100$$

… ……………………equation (7)

Tables 8, 9 shows the comparison of predicted values and experimental values of tensile strength and impact strength respectively along with error (%). The average errors for tensile strength, impact strength equations are -4.27% and -0.29% respectively. From the Regression Analysis we have calculated the mathematical formulae for both tensile and flexural strength. In the Regression coming for Tensile Strength error% (<10) have obtained 77.7778% result, error %(< 12) have obtained 88.8889% result and error %(< 15) have obtained 100 % result. For Impact Strength error% (<10) have obtained 88.8889% result, error %(< 18) have obtained 100% result.



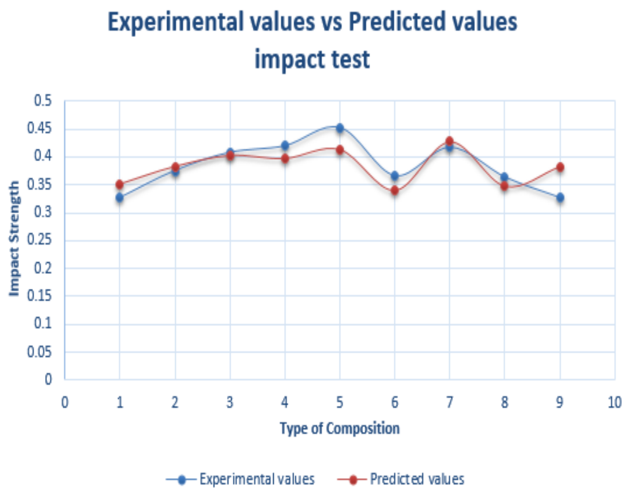


Fig -2 when comparison between the Experimental values and predicted values are approximately equaled to each other.

Table 9 .Error percentage for experimental and predicted values of impact strength.

SL.NO	PALMYRA SPROUTS	KENAF	GLASS	EXPERIMENTAL VALUE	PREDICTED VALUE	ERROR PERCENTAGE
1	0.0	0.0	0.0	0.326316	0.351075	-7.58752
2	0.0	7.5	7.5	0.375	0.38285	-2.09336
3	0.0	15.0	15.0	0.407895	0.402754	1.260243
4	7.5	0.0	7.5	0.419737	0.397424	5.315874
5	7.5	7.5	15.0	0.452632	0.413374	8.673201
6	7.5	15.0	0.0	0.365789	0.339599	7.159995
7	15.0	0.0	15.0	0.417105	0.427324	-2.44985
8	15.0	7.5	0.0	0.363158	0.347102	4.421065
9	15.0	15.0	7.5	0.326316	0.382833	-17.3197

4 CONCLUSIONS

The mechanical properties of Kenaf fiber/ Palmyra sprout/Glass fiber natural fibre composites were prepared by epoxy resin matrix. The composite were prepared with different volume fractions. The following conclusions are made from the results and discussion.

We have obtained from the S-N ratio Palmyra Sprout (A) (15 wt. %), Kenaf (B) (0 wt. %) Glass (C) (0 wt %) and combination (A3B1C1) have maximum strength compared to the other weight fraction combinations for tensile and we have obtained from the s-n ratio Palmyra Sprout (A) (7.5 wt. %), Kenaf (B) (7.5 wt. %) and Glass (C) (15 wt %) combination (A2B2C3) have maximum strength compared to the other weight fraction combinations for impact.

From the Anova Analysis Palmyra sprout have more Impact than the kenaf, glass for tensile and Glass has more impact than Palmyra sprout and Kenaf for impact strength.

From the Regression Analysis we have calculated the mathematical formulae for both tensile and flexural strength. In the Regression coming for Tensile Strength error% (<10) have obtained 77.7778% result, error %(< 12) have obtained 88.8889% result and error %(< 15) have obtained 100 % result. For Impact Strength error% (<10) have obtained 88.8889% result, error %(< 18) have obtained 100% result.

REFERENCES

[1] Adlan Akram Mohamad Mazuki, Hazizan Md Akil, Sahnizam Safiee, Zainal Arifin Mohd Ishak, "Degradation of dynamic mechanical properties of pultruded kenaf fibre reinforced composites after immersion in various solutions" on 12 August 2010.

[2] Annapurna Patra – Dillip kumar Bisoyi, "Investigation of the electrical and mechanical properties of short sisal fibre-reinforced epoxy composite in correlation with structural parameters of the reinforced fibre" on 10 June 2011.

[3] Bisanda. E.T.N. "The effect of Alkali Treatment on the Adhesion Characteristics of Sisal Fibres" in 2000. M. S. Phadke, Quality engineering using robust design, 2ndedition, Pearson, 2009.

[4] Rahul Kumar, Kaushik Kumar, Sumit Bhowmik, Optimization of Mechanical properties of epoxybased wood dust reinforced green composite using Taguchi method, Procedia Materials science 5(2014) 688-696.

[5] Rahul Kumar, Kausik Kumar, Prasanta Sahoo and Sumit Bhowmik, Study of Mechanical Propertiesof Wood Dust Reinforced Epoxy Composite, Procedia Materials Science 6 (2014) 551 – 556.

[6] Gunti Rajesh, A . V. Ratna Prasad: Advanced Materials Manufacturing & Characterization: Advanced Materials Manufacturing & Characterization Vol 3 Issue 2 (2013).

[7] Ravi Kumar N, Ranga Rao CH, Raghava Rao B, Srinivas K, Mechanical Properties of Vakka FiberReinforced Polypropylene Composites, International Journal of Innovative Research in Science, Engieering and Technology, Volume 3, Special Issue 3, (2014) ISSN (Online) : 2319 – 8753.