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Optimal process parameters settings affecting the impact strength response of biocomposite materials

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ABSTRACT

This paper utilized Taguchi robust design of experiment to obtain the optimum response and optimum setting of control factors affecting the impact strength response of ukam plant fiber reinforced CNSL biocomposite. Fiber Orientation (A), Fiber volume fraction (B) and Aspect ratio(C) are the considered process parameters used in the study. Charpy Impact test was carried out considering Standard L9 orthogonal array for the nine experimental runs and the optimization was done based on a larger is better Signal Noise ratio. Fiber volume fraction had the most significant effect on impact strength response evaluated. The optimum impact strength was captured as 11.12963KJ/m^2.

Introduction

Ukam plant fiber has been used as cordage crop to produce twine, rope, sack cloth, building material, absorbent and animal feeds. Ukam plant fiber is an example of natural plant fiber sourced at Nsukka area in Enugu state of Nigeria. Natural fibers have recently become attractive to researchers, engineers and scientists as an alternative reinforcement for fiber reinforced polymer (FRP) composites. Due to their low cost, fairly good mechanical properties, high specific strength, non-abrasive, eco-friendly and biodegradability characteristics, they are exploited as replacement for the conventional fiber, such as glass, aramid and carbon[1]. Cashew nut shell liquid (CNSL) is one of the examples of the class of thermosetting natural resin referred to as bio-resins. This study focused on determination of the optimal setting of control factors affecting impact strength response of ukam plant fiber reinforced CNSL biocomposite. Composites are termed bio composites if either the reinforcement or the matrix phase is from natural sources. Both ukam plant fiber and Cashew nut shell liquid used in this research are from natural sources.

Literature/background of study

Studies carried out with traditional experimental method of utilizing one-factor-at-a-time method has inherent inabilities to determine the effects that are caused by several factors acting in combination, requires more runs of experiments for the same precision in effect simulation, can miss out optimal settings of factors and cannot estimate interactions. [2, 3, 4, 5]. That is the case with research done so far using Ukam plant fiber as reinforcement. Apart from the fact that only few literatures are available on the properties of the fiber, the ones studied were only carried out with one-factor-at-time method.

Okpanachi and Ogakwu [6] investigated the effects of fiber surface treatment on the mechanical properties of Ukam Fiber reinforced polyester composites. Saline, alkaline and acidic treatments were used to perform the surface modification of Ukam fiber. Twelve samples were produced and tensile, compressive and bending tests were conducted to determine the properties of the specimen based on untreated, saline, alkaline and acid treatments conditions. Results obtained showed that surface treatment especially sodium hydroxide treatment gave improvements on properties up to 79%. A conclusion was reached by stating that surface treatments have significant impact on the mechanical properties of Ukam Fibers.

Ugoamadi [7] studied the factors that improve the impact responses of Ukam plant fiber reinforced composite. One-factor-at-a-time method of experimental design was utilized to study the effect of fiber conditions, Application of additives, fiber length, fiber orientation and fiber volume fraction on impact response of Ukam plant reinforced polymer composite. Samples were also produced

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for E-glass fibers for comparison with Ukam plant fiber. 1zod test of Hammer velocity = 3.46m/s and Hammer weight = 0.905kg was carried out. Results showed that impact strength of Ukam plant fiber is comparable to E-glass fiber. The optimum impact strength of Ukam Fiber was captured at fiber volume fraction of 40%.

Olusegun *et al* [8] accessed the mechanical properties of Natural Fiber reinforced composites for engineering applications. Mechanical properties of Ukam, banana, sisal, coconut, hemp and E-glass fiber reinforced polymer composites. Samples were fabricated by hand lay up techniques at the ratio of 30:70 fiber and matrix ratio by weight. Alkaline treatment of fibers was done and impact tensile, compressive, and bending strengths of each of the composites were determined. Tensile strength of Ukam plant fiber was capture at 16.25Mpa. The properties of Ukam plant fiber followed next to sisal and E-glass.

From the literatures available, it is obvious that the research carried out so far on the properties of ukam plant fiber reinforced polymer composite is not much and most of those research were not done with any specific experimental design matrix. This study therefore explores the use of Taguchi Robust design of experiment to predict the optimal setting of control factors affecting the impact strength response of Ukam plant fiber reinforced CNSL composite

Methodology

The three factors and three levels utilized to study the impact response of the bio- composite under study is shown in Table1 considering Taguchi Robust design of experiment.

Table 1: Processing Factors and Levels Considered in Taguchi Robust Design of Experiment

S/N	Processing Factors	Units	Level		
			1	2	3
1	A: Fiber Orientation	(deg)	0	45	90
2	B: Fiber Volume Fraction	(%)	10	30	50
3	C: Fiber Aspect Ratio (l_f/d_f)	(mm/mm)	8	80	160

Design of Experiment

For an experiment to be performed in an efficient way and studies carried out extensively and efficiently, the experiment has to be designed. Design of experiment is a series of test in which purposeful changes are made to the input variables of a system or process and the effects on response variables are measured [4]. Design of experiment helps draw valid and definite conclusion from measured data with minimum use of resources. Taguchi Robust design involves reducing the variation in a process through robust design of experiments.

Taguchi arrays can be derived or looked up. To select the best orthogonal array, the number of parameters (variables) and the number of levels (states) has to be determined. The suitable Taguchi orthogonal array for the study considering that $T_{i,\,j}$ refers to the number of trials with i = experiment number and j = trial number as shown in Table2 below:

Table 2: L9 Orthogonal Array Showing the Arrangement of Parameters and Levels Utilized

Experiment Runs	A: Fiber Orientation (deg)	B: Fiber Volume Fraction (%)	C: Aspect Ratio	Response		
				Trial 1	Trial 2	Trial 3
1	0	10	8	$T_{1,1}$	$T_{1,2}$	$T_{1,3}$
2	0	30	80	$T_{2,1}$	$T_{2,2}$	$T_{2,3}$
3	0	50	160	$T_{3,1}$	$T_{3,2}$	$T_{3,3}$
4	45	10	80	$T_{4,1}$	$T_{4,2}$	$T_{4,3}$
5	45	30	160	$T_{5,1}$	$T_{5,2}$	$T_{5,3}$
6	45	50	8	$T_{6,1}$	$T_{6,2}$	$T_{6,3}$
7	90	10	160	$T_{7,1}$	$T_{7,2}$	$T_{7,3}$
8	90	30	8	$T_{8,1}$	$T_{8,2}$	$T_{8,3}$
9	90	50	80	$T_{9,1}$	$T_{9,2}$	$T_{9,3}$

Analyzing Experiment Data

Measured performance characteristics from each trial are used to analyze the relative effect of the different parameters. The signal to noise ratio, SN number is used to determine the effect each variable has on the output. Optimization requires maximizing the performance characteristics, so the signal to noise ratio, SN number utilized in this research is based on larger is better SN ratios

The signal to noise ratio based on larger is better equation is:

$$SN_i = -10\log\left[\frac{1}{N_i}\sum_{i=1}^{Ni}\frac{1}{y_i^2}\right] \quad \text{.........1}$$

The mean squared deviation, MSD is given by

$$MSD_i = \frac{1}{N_i}\sum_{i=1}^{Ni}\frac{1}{y_i^2} \quad \text{.........2}$$

$$\therefore SN_i = -10\log MSD_i \quad \text{.........3}$$

The mean response is

$$Mmsi = \bar{y} = \left(\frac{1}{n}\sum_{i-1}^{n} y_i\right) \quad \text{......4}$$

Standard deviation, S

$$S = \sqrt{\sum_{i=1}^{n}\frac{\left(y_i - \bar{y}_i\right)^2}{n-1}} \quad \text{.........5}$$

Where

y_i is the value of the performance characteristics.

Also Degree of Freedom $(DOF)_R$ is

$(DOF)_R = P * (L – 1)$ 6

Where P = number of parameters

L = number of levels

For the three parameters and the three levels utilized in this study,

$(DOF)_R = 3(3 – 1) = 6$

Table 3: Evaluation of Mean, mean squared deviation and SN ratio

Experiment Runs	A	B	C	Response			Mean (Mms)	MSD	SN
				Trial 1	Trial 2	Trial 3			
1	1	1	1	$T_{1,1}$	$T_{1,2}$	$T_{1,3}$	Mms_1	MSD_1	SN_1
2	1	2	2	$T_{2,1}$	$T_{2,2}$	$T_{2,3}$	Mms_2	MSD_2	SN_2
3	1	3	3	$T_{3,1}$	$T_{3,2}$	$T_{3,3}$	Mms_3	MSD_3	SN_3
4	2	1	1	$T_{4,1}$	$T_{4,2}$	$T_{4,3}$	Mms_4	MSD_4	SN_4
5	2	2	3	$T_{5,1}$	$T_{5,2}$	$T_{5,3}$	Mms_5	MSD_5	SN_5
6	2	3	1	$T_{6,1}$	$T_{6,2}$	$T_{6,3}$	Mms_6	MSD_6	SN_6
7	3	1	3	$T_{7,1}$	$T_{7,2}$	$T_{7,3}$	Mms_7	MSD_7	SN_7
8	3	2	1	$T_{8,1}$	$T_{8,2}$	$T_{8,3}$	Mms_8	MSD_8	SN_7
9	3	3	2	$T_{9,1}$	$T_{9,2}$	$T_{9,3}$	Mms_9	MSD_9	SN_9

The calculation of signal to ratio of each experimental runs is analyzed as follows:

$$SN_1 = -10\log\left[\frac{1}{3}\left(\frac{1}{T_{1,1}^2} + \frac{1}{T_{1,2}^2} + \frac{1}{T_{1,3}^2}\right)\right] \quad \text{.........7}$$

$$SN_2 = -10\log\left[\frac{1}{3}\left(\frac{1}{T_{2,1}^2} + \frac{1}{T_{2,2}^2} + \frac{1}{T_{2,3}^2}\right)\right] \quad \text{.........8}$$

$$SN_3 = -10\log\left[\frac{1}{3}\left(\frac{1}{T_{3,1}^2} + \frac{1}{T_{3,2}^2} + \frac{1}{T_{3,3}^2}\right)\right] \quad \text{.........9}$$

$$SN_4 = -10\log\left[\frac{1}{3}\left(\frac{1}{T_{4,1}^2}+\frac{1}{T_{4,2}^2}+\frac{1}{T_{4,3}^2}\right)\right] \quad \text{.........10}$$

$$SN_5 = -10\log\left[\frac{1}{3}\left(\frac{1}{T_{5,1}^2}+\frac{1}{T_{5,2}^2}+\frac{1}{T_{5,3}^2}\right)\right] \quad \text{.........11}$$

$$SN_6 = -10\log\left[\frac{1}{3}\left(\frac{1}{T_{6,1}^2}+\frac{1}{T_{6,2}^2}+\frac{1}{T_{6,3}^2}\right)\right] \quad \text{........ 12}$$

$$SN_7 = -10\log\left[\frac{1}{3}\left(\frac{1}{T_{7,1}^2}+\frac{1}{T_{7,2}^2}+\frac{1}{T_{7,3}^2}\right)\right] \quad \text{.........13}$$

$$SN_8 = -10\log\left[\frac{1}{3}\left(\frac{1}{T_{8,1}^2}+\frac{1}{T_{8,2}^2}+\frac{1}{T_{8,3}^2}\right)\right] \quad \text{.........14}$$

$$SN_9 = -10\log\left[\frac{1}{3}\left(\frac{1}{T_{9,1}^2}+\frac{1}{T_{9,2}^2}+\frac{1}{T_{9,3}^2}\right)\right] \quad \text{.........15}$$

Now

$$Mms1 = \frac{T_{1,1}+T_{1,2}+T_{1,3}}{3} \quad \text{..........16}$$

$$Mms2 = \frac{T_{2,1}+T_{2,2}+T_{2,3}}{3} \quad \text{..........17}$$

$$Mms3 = \frac{T_{3,1}+T_{3,2}+T_{3,3}}{3} \quad \text{.........18}$$

$$Mms4 = \frac{T_{4,1}+T_{4,2}+T_{4,3}}{3} \quad \text{.........19}$$

$$Mms5 = \frac{T_{5,1}+T_{5,2}+T_{5,3}}{3} \quad \text{.........20}$$

$$Mms6 = \frac{T_{6,1}+T_{6,2}+T_{6,3}}{3} \quad \text{.........21}$$

$$Mms7 = \frac{T_{7,1}+T_{7,2}+T_{7,3}}{3} \quad \text{.........22}$$

$$Mms8 = \frac{T_{8,1}+T_{8,2}+T_{8,3}}{3} \quad \text{.........23}$$

$$Mms9 = \frac{T_{9,1}+T_{9,2}+T_{9,3}}{3} \quad \text{.........24}$$

Evaluation of Average Signal to Noise Ratios, Means Characteristics Response and Optimum Response

Average signal to noise ratio and means quality characteristics tables are shown in Tables 4 and 5.

$$SN_{A1} = \frac{(SN_1+SN_2+SN_3)}{3} \quad \text{.........25}$$

$$SN_{A2} = \frac{(SN_4 + SN_5 + SN_6)}{3} \quad \text{.........26}$$

$$SN_{A3} = \frac{(SN_7 + SN_8 + SN_9)}{3} \quad \text{.........27}$$

$$SN_{B1} = \frac{(SN_1 + SN_4 + SN_7)}{3} \quad \text{.........28}$$

$$SN_{B2} = \frac{(SN_2 + SN_5 + SN_8)}{3} \quad \text{.........29}$$

$$SN_{B3} = \frac{(SN_3 + SN_6 + SN_9)}{3} \quad \text{.........30}$$

$$SN_{C1} = \frac{(SN_1 + SN_6 + SN_8)}{3} \quad \text{.........31}$$

$$SN_{C2} = \frac{(SN_2 + SN_4 + SN_9)}{3} \quad \text{.........32}$$

$$SN_{C3} = \frac{(SN_3 + SN_5 + SN_7)}{3} \quad \text{.........33}$$

Table 4: Average Signal to Noise Ratios Table

Level	A	B	C
1	SN_{A1}	SN_{B1}	SN_{C1}
2	SN_{A2}	SN_{B2}	SN_{C2}
3	SN_{A3}	SN_{B3}	SN_{C3}
Δ	R_A	R_B	R_C
Rank	_	_	_

Table 5: Average Means (Mms) Characteristics Response Table

Level	A	B	C
1	Mms_{A1}	Mms_{B1}	Mms_{C1}
2	Mms_{A2}	Mms_{B2}	Mms_{C2}
3	Mms_{A3}	Mms_{B3}	Mms_{C3}
Δ	R_A	R_B	R_C
Rank	_	_	_

$$Mms_{A1} = \frac{(Mms_1 + Mms_2 + Mms_3)}{3} \quad \text{.........34}$$

$$Mms_{A2} = \frac{(Mms_4 + Mms_5 + Mms_6)}{3} \quad \text{.........35}$$

$$Mms_{A3} = \frac{(Mms_7 + Mms_8 + Mms_9)}{3} \quad \text{.........36}$$

$$Mms_{B1} = \frac{(Mms_1 + Mms_4 + Mms_7)}{3} \quad \text{.........37}$$

$$Mms_{B2} = \frac{(Mms_2 + Mms_5 + Mms_8)}{3} \quad \text{.........38}$$

$$Mms_{B3} = \frac{(Mms_3 + Mms_6 + Mms_9)}{3} \quad \text{.........39}$$

$$Mms_{C1} = \frac{(Mms_1 + Mms_6 + Mms_8)}{3} \quad \text{.........40}$$

$$Mms_{C2} = \frac{(Mms_2 + Mms_4 + Mms_9)}{3} \quad \text{………41}$$

$$Mms_{C3} = \frac{(Mms_3 + Mms_5 + Mms_7)}{3} \quad \text{………42}$$

The calculated average signal to noise ratio and means quality characteristics tables are used to determine which factor has the strongest effect. The performance plot against the level helps determine which factors are most significant.

The optimum response is evaluated using the optimum control factor settings from the main effects plots and by employing the response table for mean and signal to noise ratio, according to [9] the expected response model is

$EV = AVR + (A_{opt} – A_{VR}) + (B_{opt} – A_{VR}) +$

$(C_{opt} – A_{VR}) + …(Z^{ith}_{opt} - A_{VR})$ ……. 43

Where:

EV = expected response

AVR = Average response

A_{opt} = Mean value of response at optimum setting of factor A

B_{opt} = Mean value of response at optimum setting of factor B

C_{opt} = Mean value of response at optimum setting of factor C

Raw material preparation / Impact Test

Ukam plant fiber is extracted from the stem of Ukam plant. The plant is sourced from Nsukka area of Enugu State in Nigeria. The sourced Ukam plant was kept outside under the dew for dew retting for a period of two weeks. Retting is a microbial process that breaks the chemical bonds that hold the stem together and allows separation of the fiber from the stem. Moisture is needed for the microbial breakdown to occur and the moisture is obtained from the dew. The dew retting process was monitored to ensure that the best fibers separate from the inner core without much deterioration in quality. After the dew retting process, the stalks were dried and the fibers extracted mechanically from the stem. The fibers were then soaked in a five percent sodium Hydroxide solution for four hours. Sodium hydroxide treatment is an alkaline treatment. The important modification obtained from alkaline treatment is the disruption of Hydrogen bonding in the network structure, thereby increasing surface roughness. The treatment removed certain hemicelluloses, lignin, wax and oils covering the external surface of the fiber wall, depolymerizes cellulose and exposes the short length crystallites [10].

The fibers were further treated with saline solution. Saline is used as coupling agents to allow natural fiber adhere to a polymer matrix thereby stabilizing the composite material. Saline treatment used includes solution of water and methanol. The solution consists of 40% water and 60% methanol. The fibers were finally neutralized with dilute acetic acid and washed with fresh water. The resultant fibers were sun dried for three days before being used as reinforcement in the composite.

The cashew nut shell liquid is a reddish brown viscous liquid extracted from the honey comb structure of the shell of cashew kernel. It is alkylphenolic oil contained in the spongy mesocarp of cashew nut. The main constituents of cashew nut shell liquid are cardonol, anarcardic acid, cardol, 2-methyl cardol and small amount of polymeric material [11,12]. The cashew nut shell liquid used in this research was extracted from cashew nut shell using n-hexane as solvent. The extraction was done at the chemistry department of university of Nigeria, Nsukka.

Impact test is designed to measure the resistance to failure of a material to a sudden applied load and this involves a test piece being struck at sudden blow. Impact tests consist of striking a suitable specimen with a controlled blow and measuring the energy absorbed in bending or breaking the specimen. Impact energy simply refers to the measure of work done to fracture the test specimen. Charpy test and 1zod test are the two common methods of measuring impact energy.

Charpy impact test was used in this research of which the test specimen replicate samples of dimensions 10mm x 10mm x 55mm each were cut and tested according to ASTMD256 standard. The impact testing machine made by Samuel Denison limited Leeds was used with a hammer Velocity of 5.24m/s.

Results And Discussions

Equations (1) to (43) is programmed using Microsoft excel visual basic program to obtain the most significant factors and obtain the optimum response. This result is shown in Figure2.Minitab release 16 software is utilized to obtain the main effects plot for SN ratios, main effects plot for means, residual plots for means and residual plots for SN ratio of the Impact strength response.

Evaluation of Impact Energy per

Unit Area Absorbed by Ukam Plant

Fiber Reinforced CNSL Composite

The impact energy per unit area of the composite material is referred to as impact strength. For composites and plastics, Impact energy per unit area of the specimen is what is expressed for Charpy test. The unit is KJ/m^2 .Now considering the fact that the energy lost due to friction E1=0.1J, hence,

Impact Strength= (E2-E1)/(bxh) ………44

Where b and h are the width and height of the test piece respectively.E_2 refers to the measured energy from the test.

Now b=10mm and h=10mm

The equation (44) is used to obtain the Impact energy per unit area of Table 6

Observations made from figure1showed that the maximum impact strength obtained occurred at the third experimental run while the least is at the first experimental run.

Table 6: Impact Strength Response Data of Ukam Plant fiber Reinforced CNSL Composite

Experiment Runs	A: Fiber Orientation (deg)	B: Fiber Volume Fraction (%)	C: Aspect Ratio	Impact Energy Response (KJ/m^2)		
				Trial 1	Trial 2	Trial 3
1	0	10	8	5.50	4.50	5.50
2	0	30	80	6.50	7.50	6.00
3	0	50	160	11.00	10.50	11.00
4	45	10	80	5.50	6.00	5.00
5	45	30	160	7.00	8.00	7.50
6	45	50	8	9.00	9.50	10.00
7	90	10	160	6.50	7.50	7.00
8	90	30	8	7.50	7.00	7.00
9	90	50	80	10.00	9.50	10.00

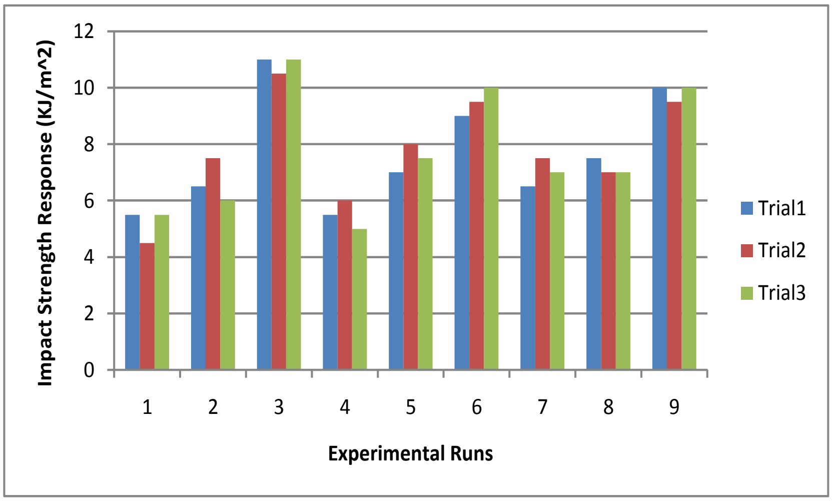


Figure1: Impact Strength response of ukam plant fiber reinforced CNSL composite chart and Experimental runs.

Optimization of Impact strength response of Ukam Plant fiber Reinforced CNSL Composite

OPTIMIZATION OF IMPACT ENERGY PER UNIT AREA APPLYING TAGUCHI ROBUST DESIGN

KJ/m^2

EXP. RUNS	ORIENTATION (+ - Degree)	VOLUME FRACTION(%)	ASPECT RATIO	TRIAL1	TRIAL2	TRIAL3	MEAN	MSD	SN ratio
1	0	10	8	5.5	4.5	5.5	5.166667	0.038499	14.14545
2	0	30	80	6.5	7.5	6	6.666667	0.023075	16.36863
3	0	50	160	11	10.5	11	10.83333	0.008533	20.68895
4	45	10	80	5.5	6	5	5.5	0.033612	14.73507
5	45	30	160	7	8	7.5	7.5	0.017937	17.46251
6	45	50	8	9	9.5	10	9.5	0.011142	19.53037
7	90	10	160	6.5	7.5	7	7	0.020618	16.85749
8	90	30	8	7.5	7	7	7.166667	0.019531	17.09267
9	90	50	80	10	9.5	10	9.833333	0.01036	19.84636

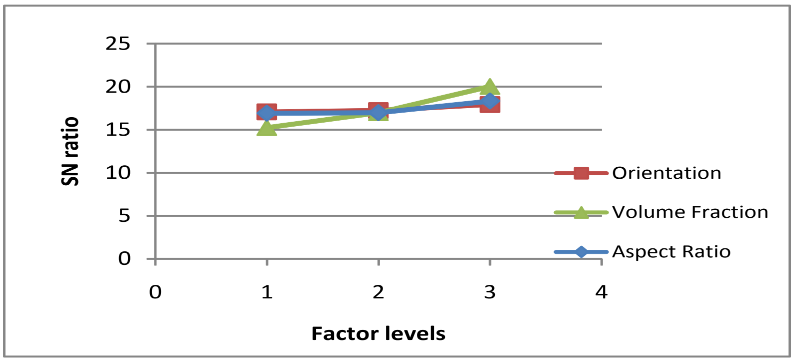
RESPONSE SIGNAL TO NOISE RATIOS

LEVEL	ORIENTATION (+-Degree)	VOLUME FRACTION(%)	ASPECT RATIO
1	17.0676769	15.246006	16.923
2	17.2426487	16.974604	16.983
3	17.9321744	20.021889	18.336
DELTA	0.86449814	4.7758827	1.4135
RANK	3	1	2

MEANS OF QUALITY CHARACTERISTICS

ORIENTATION (+_ Deg)	VOLUME FRACTION(%)	ASPECT RATIO
7.555555	5.888889	7.277778
7.5	7.111111	7.333333
8	10.05556	8.444445
0.5	4.166667	1.166667
3	1	2

Evaluate



Main effects plots for signal-noise ratio

OPTIMUM RESPONSE ANALYSIS

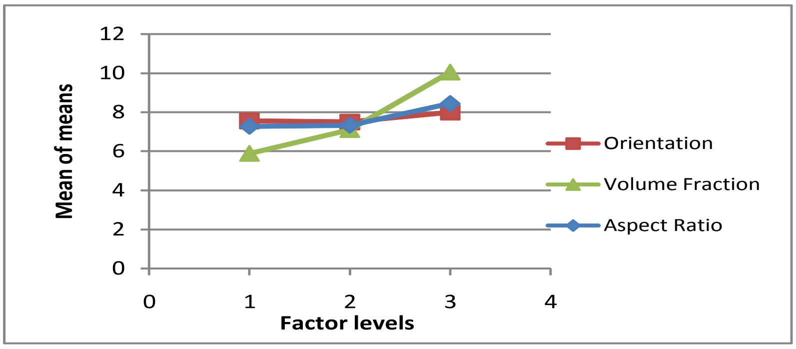
Average Mean = 7.685185

A Optimum = 8

B Optimum = 10.05556

C Optimum = 8.444445

Optimum Response = 11.12963 kJ/m^2



Main effects plots for means

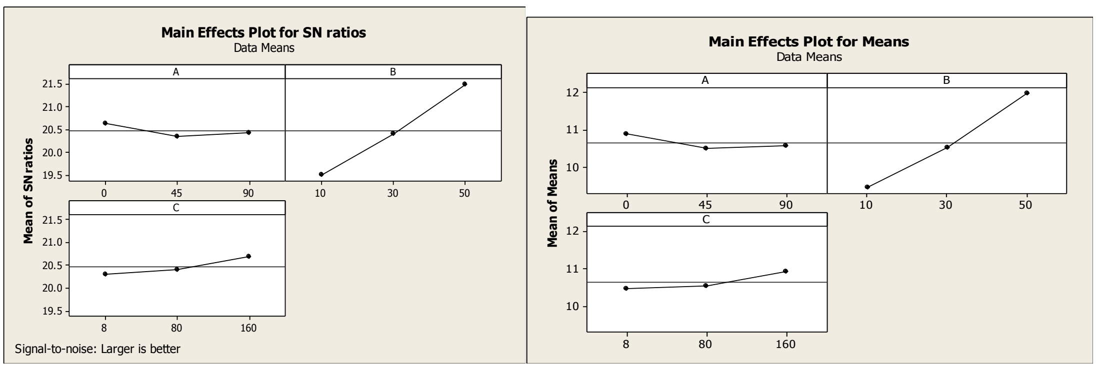


Figure 2: Microsoft Excel Visual Basic output for Optimization of Impact Strength Response of ukam plant fiber reinforced CNSL Composite applying Taguchi Robust Design

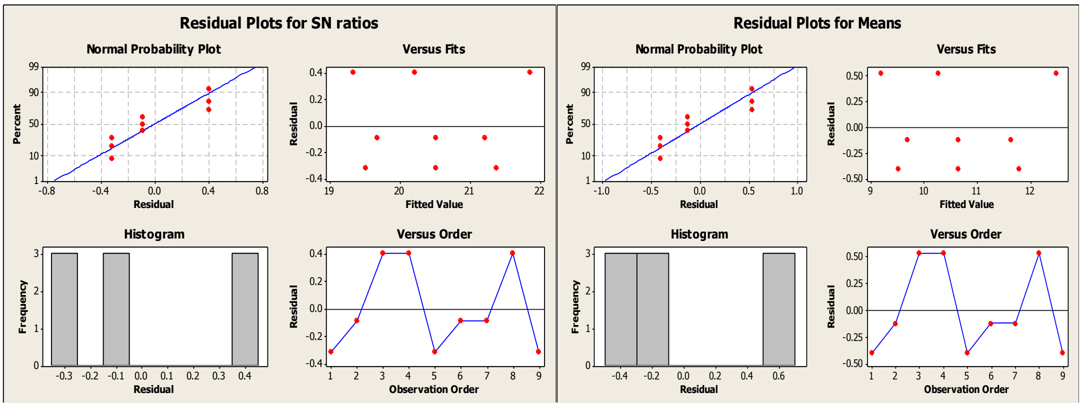


Figure 3: Minitab output for main effects plot for SN ratios, main effects plot for means, residual plots for means and residual plots for SN ratio of Impact strength response

Table7: Optimum Setting of Control Factors and Expected Optimum Impact Strength of Ukam Plant fiber Reinforced CNSL Composite

Composite	Control Factors	Optimum Level	Optimum Setting	Optimum Impact Strength kJ/m^2
Ukam Plant Fiber	A: Fiber Orientation	3	90	
Reinforced	B: Volume Fraction	3	50	11.12963KJ/m^2
CNSL Composite	C: Aspect Ratio	3	160	

The regression analysis of the factors affecting impact energy is obtained from Minitab 16 and tabulated below.

Table 8: Regression Analysis for Impact Strength of Ukam Plant fiber Reinforced CNSL Composite

Predictor	Coef	SE Coef	T	P
Constant	3.6940	0.6258	5.90	0.002
A: Fiber Orientation (deg)	0.004938	0.006158	0.80	0.459
B: Volume Fraction (%)	0.10417	0.01386	7.52	0.001
C: Aspect Ratio (mm/mm)	0.007790	0.003645	2.14	0.086

S = 0.678808, R-Sq = 92.5%, R-Sq (adj) = 88%

The Linear Regression Equation is:

$$Mean = 3.69 + 0.00494\, FibreOrientation + 0.104\, Volume\ Fraction + 0.00779\, Aspect\ Ratio$$

Table 9: Analysis of Variance (ANOVA) for the regression equation

Source	DF	SS	MS	F	P
Regression	3	28.4430	9.4810	20.58	0.003
Residual Error	5	2.3039	0.4608		
Total	8	30.7469			

The optimum setting of control factors and the expected optimum impact strength for the optimization of impact strength response of Ukam plant fiber reinforced CNSL composite is shown in table 7. The result captured the impact strength at 11.12963KJ/m2.The regression analysis and analysis of variance (ANOVA) for the regression equation obtained from Minitab release 16 output of optimization of impact strength response is shown in table8 and 9 respectively. The coefficient of determination showed that the predictors explained 92.5% of the variance in impact strength of ukam plant fiber reinforced CNSL composite. The adjusted coefficient of determination is evaluated and results obtained as 88%.The Main Effects plot for SN ratios and means; residual plots for SN ratios and Means is shown in Figure3.The p-value of the analysis of variance table 9 evaluated as 0.003 showed that the regression model is significant at the significance level of 0.05.The residual plot of figure 3 shows that the linear regression model provides a good fit for the data.

Conclusion

The optimization of impact strength response of ukam plant fiber reinforced CNSL biocomposite have been studied extensively and the following deductions are made:

1. The optimal setting of the impact strength response is as follows: Fiber orientation of 0 degree, Fiber volume fraction of 50% and aspect ratio of 160 while the optimum response is captured as 11.12963KJ/m2
2. Fiber volume fraction is the most significant factor affecting impact strength response of ukam plant fiber reinforced CNSL biocomposite.

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