Optimization on Mechanical properties of Polymer Matrix Composites Using Taguchi (ANOVA)

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Abstract- *Natural fibres are used in a wide range of applications because of their high strength, good mechanical properties, low cost and an effective reinforcement for reinforced polymer (FRP). In this project to develop a new composite material by using hand lay up method as per ASTM standards. It is made up of collection of materials to be used for the composite material were used the natural fibres like jute, sisal, feathers. These materials were developed as per sequence. The objective of project work is to evaluate the mechanical properties of composite by using taguchi method. It is a statistical approach to optimize the process parameters and improve the quality of components that are manufactured. In the present study (JSFFRP) composite were fabricated and tested for the mechanical properties. Experiments were conducted using taguchi L9 orthogonal array with two factorial design of JSFFRP. The experimental results were analysed by using taguchi optimization method. Orthogonal arrays of taguchi, the Signal to noise (S/N) ratio, the analysis of variance (ANOVA) are employed. Analysis of variance (ANOVA) was carried out to obtain the significant values of Impact strength and hardness at 95% confidence level.*

Keywords- Natural Fibres, Taguchi Method, Orthogonal Array L9, Analysis of Variance (ANOVA)

I. INTRODUCTION

A composite is a combination of at least two materials, each of which maintains its identity in the combination. A mixture of clay and rocks could therefore be considered a composite, but ordinarily, our minds turn to more exotic systems. Combinations of synthetic polymers with advanced engineering fibres, or plant fibres as amalgamations of the natural polymers, cellulose, hemicelluloses, and lignin, provide examples of sophisticated composites.According to jartiz"Composites are multifunctional material systems that provide characteristics not obtainable from any discrete materialThey are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form". The weakness of this definition resided in the fact that it allows one to classify among the composites any mixture of materials without indicating either its 4 specificity or the laws which should give it which distinguishes it from other very banal, meaningless mixtures.Chicken feather fiber commonly described waste product possesses hydrophobic properties, thermal insulation & teak wood dust having excellent wear characteristics, strengthening properties so both can be advantageously used as reinforcing material. So in this paper Composite specimens are prepared referring to ASTM standard by pouring the mixture of epoxy matrix and natural fiber Teak wood dust of particular size and using different percentage of weight and chopped chicken feather into metallic mould.Natural and biomaterial composites have directed in the enlargement of various innovative materials and products which are eco-friendly as well as biodegradable. Importance is being given by many researchers to the natural plant fibers like bamboo, coir, jute, sisal, cotton, wheat straw and wood etc. Here the review based information is pileup to get the wide-ranging information about the Mechanical properties, Physical properties, Thermal properties etc. of Chicken Feather Fiber (CFF) based Composites. Also the application and making of different CFF based composites for industrial application.This study focuses on the use of control factors(volume fraction of fibers (A), aspect ratio of fibers (B) and fibers orientation (C)) to determine the optimum tensile strength of plantain fibers reinforced polyester resin. Tensile tests was conducted on the replicated samples of plantain empty fruit bunch fiber reinforced polyester composite(PEFB) and plantain pseudo stem fiber reinforced polyester (PPS) respectively using Archimedes principles in each case to determine the volume fraction of fibers. To obtain the optimum properties a Monsanto tensometer were used conduct tensile tests to establish the control factor levels quality characteristics needed to optimize the mechanical properties being investigated. Taguchi robust design technique was applied for the greater the better to obtain the highest signal to noise ratio (SN ratio) for the quality characteristics being investigated employing Minitab 15 software.[1] –[3]. The objective of our project is to improve the impact resistance, tensile strength and strength-weight ratio of the material which is going to be made by the combination of carbon, aramid and glass fibres using pairing method. But the analysis is done only for the impact resistance. The fabrication of the hybrid composite done by Hand Lay Up method. The impact resistance of the parameters are determined through experiments that are planned, conducted and analysed using Taguchi method.Taguchi Method is a statistical approach to optimize the process parameters and improve the quality of components that are manufactured. *In the present study, Flax-Sisal-Hemp Fiber reinforced composites were fabricated* and tested for their mechanical properties. The resins used in this study are polyester and epoxy. Experiments were conducted using Taguchi L9 orthogonal array considering the three deign parameters viz. weight fraction of the Flax, weight fraction of the sisal and weight fraction of the Hemp. The experimental results were analyzed using Taguchi optimization method. Orthogonal arrays of Taguchi, the signal-to-noise (S/N) ratio, the analysis of variance (ANOVA), and regression analyses are employed. Analysis of variance (ANOVA) was carried out to obtain the significant values of tensile strength, flexural strength and impact strength at 95 % confidence level. [4] [6].

The control factors which included aspect ratio of fibres, volume fraction of fibres and fibres orientation were the focus for determining the optimum tensile strengths of coir fibres reinforced polyester resin composites. After using Archimedes principle to determine the volume fraction of fibres. For the optimum properties to be obtained, a Universal Testing Machine-TUE-C-100 was used for the conducted tensile tests which established the levels of control factors settings for quality characteristics needed to optimize the mechanical properties being investigated. Applying Taguchi robust design technique for the greater-the-better, the highest signal-to-noise ratio (S/N ratio) for the quality characteristics being investigated was obtained employing Minitab 16 software. The optimum values of the control factors were established for treated coir fibres reinforced polyester resin composites and untreated coir fibres reinforced polyester resin composites. The treated coir fibres reinforced polyester matrix composite has the optimum tensile strength of 42.7 N/mm2 while the untreated coir fibres reinforced matrix composite has the optimum tensile strength of 21.9 N/mm2. The reinforcement combinations of control factors contribute greatly to the tensile properties, and the treated coir fibres reinforced polyester composites are stronger intension than the untreated coir fibres reinforced polyester composites[8].

A. EXPERIMENTAL

2.1 MATERIALS

2.1.1 FLAX FIBRE:

Jute is a natural fiber popularly known as the golden fiber. It is one of the cheapest and the strongest of all natural fibers and considered as fiber of the future. Jute is second only to cotton in world's production of textile fibers. India, Bangladesh, China and Thailand are the leading producers of Jute.

2.1.2 SISAL FIBRE:

It is a type of plant which is rich in fibre of tensile stremgth. It is produce many part of the world like USA, Brazil, Australia, etc.

2.1.3 FEATHER FIBRE:

Chicken feathers are deliberated as a waste product of the poultry industry. Large amount of waste feathers generated and disposed each year by poultry processing plants results in severe solid waste trouble. Feathers are greatly ordered, hierarchical branched structures, that is standing among the most complex of keratin structures establish in vertebrates.

2.1.4 EPOXY RESIN (LY-556):

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.

2.1.5 HARDENER (HY-951):

Hardener is the curing agent for epoxy of fibres. Epoxy resin requires a hardener to initiate curing, it is also called as catalyst, the substance that hardness the adhensive when mixed with resin. It is the specific selection and combination of the epoxy and hardener components that determines that final characteristics and suitability of the epoxy coating for given environment.

B. DESIGN OF EXPERIMENTS BY TAGUCHI METHOD:

The design of experiments is the most power full tool for analyzing the influence of control factors on performance output. Taguchi method systematically reveals the complex cause and effect relationship between design parameter and performance. The two Process parameter (Sequence and orientation) and impact energy absorbed (Impact value) was studied using L9 orthogonal array using MINITAB 18 software. In proposed work Jute, Sisal and Feather fibre were selected for specimen. The various input parameters were taken under experimental investigation and then model were prepared then again experimental work would be performed. Therefore, 9 trials were conducted on Tensile testing, Izod impact testing and Brinell hardness testing machine. The results obtained were analyzed and model was produced using MINITAB 18. Taguchi method is used to find out the optimum condition of Significance of each factor. In this study, "higher is better" is considered to maximize the impact strength of materials. For this case, S/N ratio is calculated as a logarithmic transformation of loss of function as shown below:

S/N = -10 *log (Σ (1/Y2)/n)

Table 1 Control Factors and their Levels

Sampl e	Control Factor	Level 1	Level 2	Level 3
A	Sequence	JSFFSJSF J	JFSSFJFS J	JFFJSSFS J
B	Orientatio n	0	45	60

The most suitable orthogonal array forexperimentation is L9array as shown in table 2. Therefore, a total nine experiments are to be carried out.

Table 2 Orthogonal Array (OA) L9

Samples	Sequence	Orientation
1	1	1
2	1	2
3	1	3
4	2	1
5	2	2
6	2	3
7	3	1
8	3	2
9	3	3

C. CONDUCTINGTHE MATRIX EXPERIMENT:

After substituting all the values substituted matrix table was created. The combination parameters of the L9 orthogonal array is derived as table 3.

Table 3 Orthogonal Array with Control Factors

SAMPLES	FIBRES SEQUENCE	TYPES OF ORIENTATION (deg)
1	JSFFSJSFJ	0
2	JSFFSJSFJ	45
3	JSFFSJSFJ	60
4	JFSSFJFSJ	0
5	JFSSFJFSJ	45
6	JFSSFJFSJ	60
7	JFFJSSFSJ	0
8	JFFJSSFSJ	45
9	JFFJSSFSJ	60

D. PROCESSING:

Many techniques are available in industries are manufacturing of composites such as compression mouldings, vaccummouldings, pultruding and resin transfer mouldings are few examples. The hand lay up process of manufacturing is one of the simplest and easiest methods for manufacturing composites. A primary advantage of the hand lay up technique is to fabricate very large complex parts with reduced manufacturing times. Additional equipments are simple equipment and tooling that are relatively less expensive than other manufacturing processes. The fibres were added to the resin mixed hardener with required weight percentages. The fibre resin hardener mixture was poured in to the moulds for different testing prepared as per ASTM standards. The setting time taken by the composites was approximately 24 hours. The required composites were subjected to impact, hardness and tensile tests.

E. IMPACT, HARDNESS AND TENSILE TESTS:

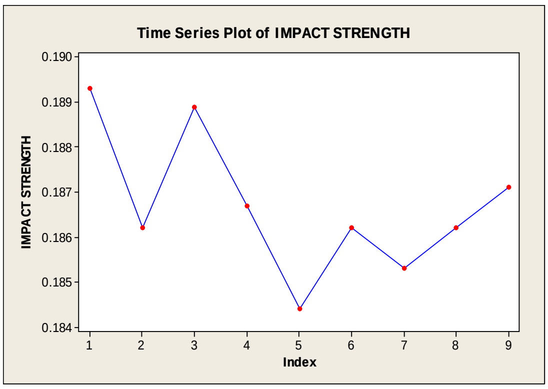
The Izod impact test also known as the Izod V-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. The apparatus consists of a pendulum of known mass and length that is dropped from a known height to impact a notched specimen of material.Impact is a test which is used to measure sudden force which is applying on the component or materials. Here the impact test was done on Izod impact testing machine with the specimen area of 55*10 mm. In the current study hardness is measured in Brinell Hardness Testing machine with 500 Kgf (load) * 10 mm ball. Range of hardness on desired surface of the part is measured. Tensile is the test which is used to measure tensile force which is applying on the component or materials. Here the tensile test was done on tensile testing machine with the specimen required area.For Brinell hardness number the specimen is cut as per ASTM E10, for Izod impact test the specimen is cut as per ASTM E23 and for Tensile test the specimen is cut as per ASTM D3039.

III. RESULTS AND DISCUSSION

3.1TAGUCHIANALYSISOFIMPACTANDHARDNESS TESTS:

Table 4 Experimental Results for Impact and Hardness Test

SAMPLE NO	FIBRE SEQUENCE	TYPES OF ORIENTATION (deg)	IMPACT STRENGTH (J/mm^2)	BRINELL HARDNESS NUMBER (HBN)
1	JSFFSJSFJ	0	0.1893	12.14
2	JSFFSJSFJ	45	0.1862	14.51
3	JSFFSJSFJ	60	0.1889	21.37
4	JFSSFJFSJ	0	0.1867	17.50
5	JFSSFJFSJ	45	0.1844	13.26
6	JFSSFJFSJ	60	0.1862	12.14
7	JFFJSSFSJ	0	0.1853	26.52
8	JFFJSSFSJ	45	0.1862	21.37
9	JFFJSSFSJ	60	0.1871	15.92



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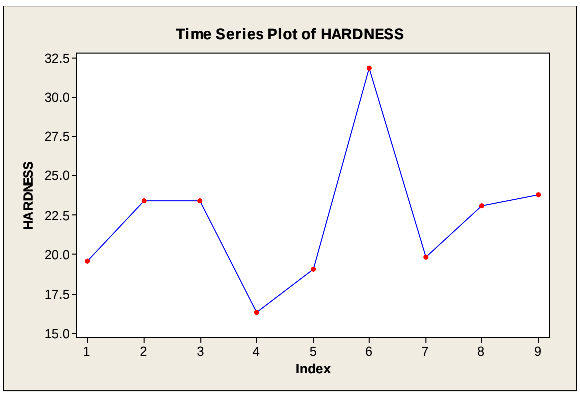

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Fig 1 Time plot series of Impact and Hardness Test

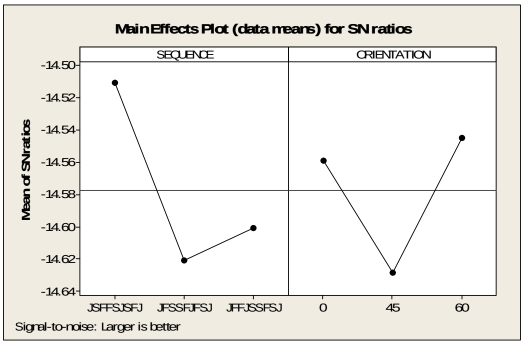
Larger is better condition is used for response variableImpact strength needs to maximize to get good results.

Table 5 Impact Response Table of S/N Ratio

LEVELS	FIBRE SEQUENCE	ANGLE ORIENTATION
1	-14.51	-14.56
2	-14.62	-14.63
3	-14.60	-14.54
DELTA	0.11	0.08
RANK	1	2

Table 6 Impact Response Table of Mean

LEVELS	FIBRE SEQUENCE	ANGLE ORIENTATION
1	0.1881	0.1871
2	0.1858	0.1856
3	0.1862	0.1874
DELTA	0.0024	0.0018
RANK	1	2



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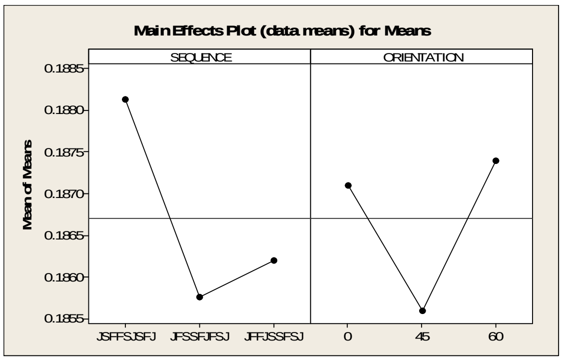

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Fig 2 Main Effects plot for S/N Ratio and Mean for Impact Strength

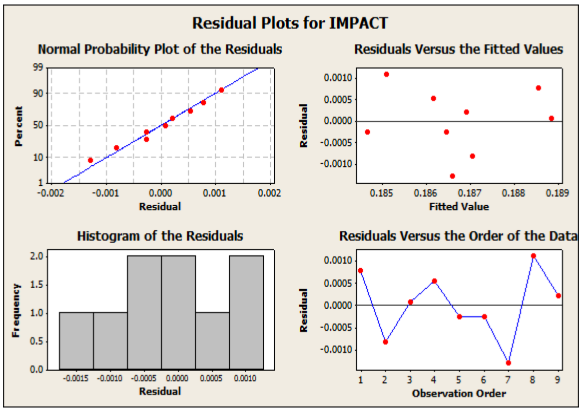


Fig 3 Residual Plots for Impact Strength

Table 7 Analysis of Variance for Impact Value of Impact Strength

Source	DF	SS	MSS	F Cal	F table	% C
Sequence	2	0.000009527	0.000004763	4.09	4.46	48.21
Orientation	2	0.000005580	0.000002790	2.40	4.46	28.23
Error	4	0.000004653	0.000001163	-	3.84	23.54
Total	**8**	**0.000019760**	-	-	-	**100**

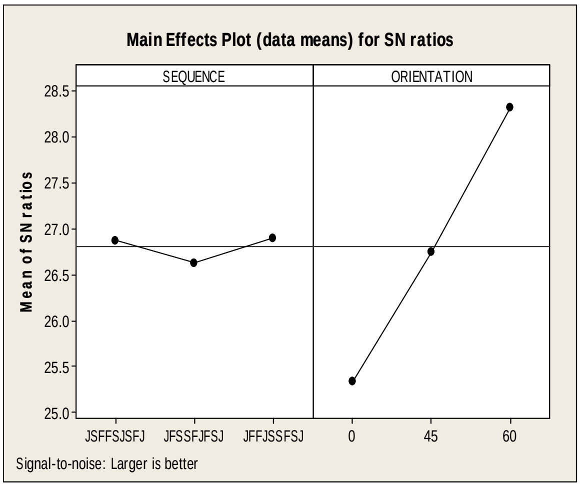
Larger is better condition is used for response variable Hardness strength needs to maximize to get good results.

Table 8 Hardness Response Table of S/N Ratio

LEVELS	FIBRE SEQUENCE	ANGLE ORIENTATION
1	26.87	25.34
2	26.64	26.75
3	26.91	28.32
DELTA	0.27	2.98
RANK	**2**	**1**

Table 9 Hardness Response Table of Mean

LEVELS	FIBRE SEQUENCE	ANGLE ORIENTATION
1	22.14	18.57
2	22.40	21.85
3	22.22	26.34
DELTA	0.26	7.76
RANK	**2**	**1**



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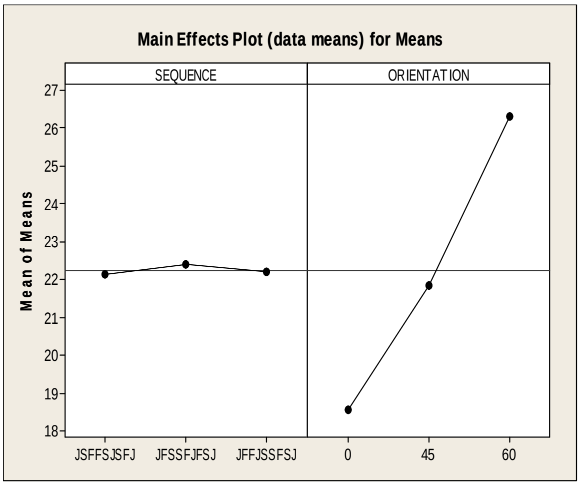

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Fig 4 Main Effects plot for S/N Ratio and Mean for Hardness Strength

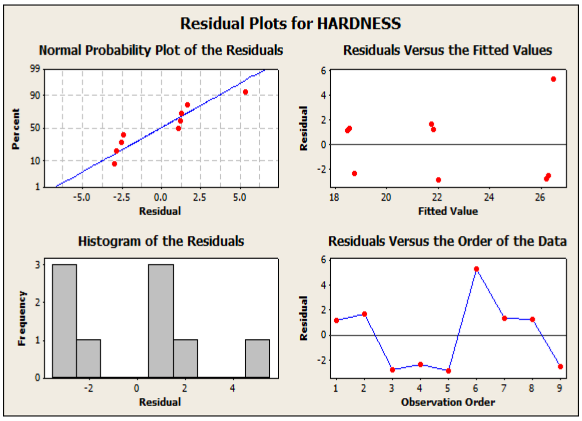

Fig 5 Residual Plots for Hardness Strength

Table 10 Analysis of Variance for Hardness Value of Hardness Strength

Source	DF	SS	MSS	F_{Cal}	F_{table}	% C
Sequence	2	0.11	0.05	0.003	4.46	0.07
Orientation	2	91.10	45.55	2.82	4.46	58.44
Error	4	64.67	16.17	-	3.84	41.48
Total	8	155.88	-	-	-	100

IV. CONCLUSION

As a result of the analysis of Jute, Sisal, Feather fibre composites according to the Taguchi method, the following information, results and conclusions were obtained in terms of Impact strength and Brinell hardness number.

1. Fibre sequence (48.21%) was found to be significant in ANOVA for Izod Impact test. Orientation (28.23%) was found to be insignificant for Izod Test. Main effective plot for Impact testvalue shows maximum impact value for 1st, 3rd and 9th sequence. Change in orientation has less significant effect on impact value of Izod impact test.
2. Fibre sequence (0.07%) was found to be significant in ANOVA for Brinell hardness test. Orientation (58.44%) was found to be insignificant for Brinell hardness test. Main effective plot for Brinell hardness test value shows maximum hardness value for 3rd, 7th and 8th sequence. Since larger the S/N ratio, optimum is the process parameters. Fibre sequence has less significant effect on hardness value of Brinell hardness test.

It is observed that the analysis of the fabricated composite has given the optimum values. Each one of the test shows different results over fibre sequence. Impact test shown the good result and over fibre orientation hardness shown the good result in this two factors concerns reinforced fibre has been contributed a lot. Hence it is recommended for automobile and avation.

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