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Experimental Analysis of Effect of Process Parameters on Mechanical Properties of Groundnut Shell Powder Reinforced Epoxy Composites

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Abstract: The study emphasizes on the characterization of lignocellulosic composites using groundnut shell particles as reinforcement. The samples were prepared with different process parameters, namely, particle size, filler loading, addition of natural fibers and alkali treatment of particles, The relationships between process parameters and mechanical properties of a composite material will be established by developing design of experiments via taguchi based models. These composite specimens are tested for their mechanical properties like high tensile strength, modulus of elasticity, high compressive strength, shear modulus, flexural strength, bending strength by conducting the respective experiments on the each type of specimen. With this we could know the entire physical and mechanical properties of the specimen made. By conducting the taguchi experiments we could give the Optimized set of process parameters for the various individual output responses will be found. And also the Optimized set of process parameters for the overall output responses will be found. And then the Finite element analysis will be done for the optimized specimens. There by Comparison of experimental and analytical results, experimental validation of the analytical results will be done.
Keywords: Groundnut shell particle, Epoxy resin, Design of experiments (DOE), Taguchi L16 models, Grey relational analysis, optimization, Mechanical properties, Process Parameter, Tensile strength, Flexural Strength, Impact Strength, weight percentage, Alkali treatment, Banana Fiber.

I. INTRODUCTION

Most of the developing countries are very rich in agricultural fiber and a large part of agricultural waste is being used as a fuel. India alone produces more than 400 million tonnes of agricultural waste annually. It has got a very large percentage of total world production of rice husk, jute, stalk, baggase, groundnut shell and coconut fiber, etc. In the composites industry, natural fibers refer to wood fiber and agro based bast, leaf, seed, and stem fibers. These fibers often contribute greatly to the structural performance of the plant and when used in plastic composites, can provide significant reinforcement. Natural fibers are complex and three-dimensional polymer composites, which are made up of cellulose, pectin, hemicelluloses and lignin. The natural fibres have got high mechanical and thermal properties and hence used as an alternative for the artificial fibres. Low specific weight, which results in a higher specific strength and stiffness than glass is a benefit especially in parts designed for bending stiffness. Lignocellulosic natural fibers such as jute, flax, hemp coir and sisal have all proved to be good reinforcement in polymer matrices and are being used in automotive application, packaging industries and in construction.

The advantages of natural fibers over traditional reinforcing materials such as glass fibers and carbon fibers are: specific strength properties, low cost, low density, high toughness, good thermal properties, reduced tool wear, reduced dermal and respiratory irritation biodegradability, etc. The natural fibres have got high mechanical and thermal properties [1-2] and hence used as an alternative for the artificial fibres. Mechanical and physical characterization of agricultural waste reinforced polymer composites by G. U. Raju investigates the properties of groundnut shell particles reinforced polymer composite (GSPC)[14]. Composite samples were prepared with different weight percentages of particles in polymer matrix. These samples were tested for some physical and mechanical properties. Mechanical characteristics of groundnut shell particle reinforced polylactide nano fibre by Samson Adeosun, Omotayo Taiwo Groundnut Shell particle (GSP) weight fraction used was varied from 3 - 8 wt. %. Particle reinforced nanofibres were formed on the collector from the composite solution at 26 kV. These nanofibres were subjected to tensile test and the result indicates that at 6 wt. % untreated GSP reinforced fibre possessed the best tensile stiffness of 24.62 MPa. The advantage of the natural fibers over synthetic fibers like aramid, carbon or glass fiber are low densities, non abrasive, non-toxic, high filling levels possible resulting in high stiffness and specific properties, biodegradable, low cost, good thermal and acoustic properties, good calorific value and enhanced energy recovery. Extensive studies on the preparation and properties of thermosetting and thermoplastic composite filled with kenaf [4-5], jute [6-7], sisal [8-9], bagasse [10], bamboo [11-12] and pineapple [13] were carried out. Nor Azowa Ibrahim, et.al [18] prepared the composite material using kenaf fiber and Ecoflex using different fiber loadings and the fiber was treated with different concentrations of NaOH. The results showed that the alkaline treatment of fiber gave the better tensile strength and flexural strength of the composite when compared to untreated fiber. 40% of fiber loading improved the tensile strength properties and WSK fiber treated with 4% NaOH was found to enhance tensile and flexural properties

II. MATERIALS REQUIRED AND PROCESS PARAMETER SELECTION

Material selection: All reagents and solvents used in the experiments were reagent-grade unless specified otherwise. Groundnut shells were obtained from local agricultural fields. Epoxy resin (Diglycidyl either of bisphenol-A (DGEBA), Araldite LY 556) with equivalent weight per epoxide group of 195+5 and ambient temperature hardener TETA (HY951) were purchased from M/s Hindustan.

A. Groundnut-Shell Powder

Groundnut botanically known as Arachis hypogeae and belongs to Leguminosae family. Groundnut is the largest oilseed in India in terms of production. The chemical composition of groundnut shell along with the other selected natural fibers is illustrated in Table I. Clean and dried groundnut shells were first washed with water to remove dirt and impurities. The washed shells were chemically treated with different percentages of NaOH solution for 60 minutes and then washed with distilled water until all NaOH gets eliminated. Subsequently, the shells were solar dried and ground. The particles were then sieved through BS sieves to get different size groundnut shell particles. These particles are used as reinforcement materials in epoxy polymer matrix. Average length of the groundnut shell fibers was found to be 38mm and 0.25mm diameter. The selected groundnut shells are used in the present study. Clean and dried groundnut shells are initially washed withwater to remove the sand and other impurities. The washed shells are then chemically treated with 10 % NaoH solution for 1 hour and later washed with distilled water. Subsequently, the shells were dried at room temperature for 24 hours. The dried shells were ground andparticles were sieved through 600µm BS sieve. The similar procedure was followed for the preparation of other 2mm, 4mm and 8mm groundnut shell powder.

TABLE I
COMPOSITION OF NATURAL FIBERS

Species	Cellulose (Wt %)	Hemi cellulose (Wt %)	Lignin (Wt %)	Ash (Wt %)
Coir	32-43	0.15-0.25	40-45	-
Jute	67-71.5	12-20.4	11.8-13	2
Groundnut shell	35.7	18.7	30.2	5.9
Bagasse	40-46	24.5-29	12.5-20	1.5-2.4
Rice husk	31.3	24.3	14.3	23.5

TABLE III
COMPOSITION OF GROUNDNUT SHELL POWDER

Characteristic property	Inferences
Density (g/cc)	0.8
Thermal conductivity (W/mK)	0.04
Modulus of rupture (MPa)	97.1
Elastic modulus (GPa)	12.28
Tensile strength (MPa)	0.095

B. Matrix Material (Epoxy LY556)

In composite materials, the constituent which is continuous and present in greater quantity is called matrix. The main functions of the matrix are to hold or bind the fibre together, distribute the load evenly between the fibres and protect the fibre from the mechanical and environmental damage. Epoxy resins are unique among all the thermoset resins due to several factors. The distinct properties of epoxy such as high corrosion and chemical resistance, outstanding adhesion to various substrate, good thermal and mechanical properties, good electrical insulating properties, low shrinkage upon cure, and the ability to processed under a variety of conditions make it suitable matrix material for the fibre reinforced composite materials.

Due to several advantages over other polymers as mentioned above, epoxy (LY 556) is chosen as the matrix material for the present research work. It chemically belongs to the "epoxide" family and its common name is Bisphenol-A-Diglycidyl-Ether (commonly abbreviated to DGEBA or BADGE). Its molecular chain structure is shown in Fig 1. It provides a solvent free room temperature curing system when it is combined with the hardener tri-ethylene-tetramine (TETA) which is an aliphatic primary amine with commercial designation HY 951 (Fig 2).

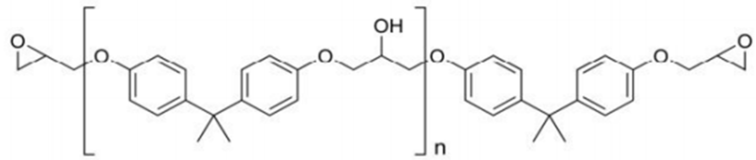

Fig. 1 Unmodified Epoxy-Resin (n denotes the number of the polymerized units)

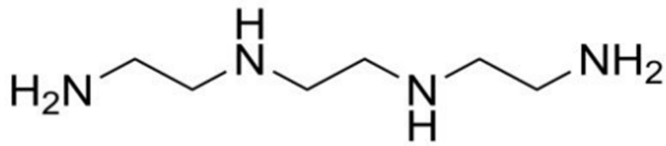

Fig. 2 Tri-ethylene-tetramine (hardener used for epoxy matrix)

C. Fibre Material (Banana Fibre)

In Fibre reinforced polymer (FRP) composites, fibre acts as a reinforcing agent. Fibres are the load carrying members which provide strength, stiffness, thermal stability and other structural properties in FRP. If the fibres are derived from the natural resources like plants or some other living species, they are called natural fibres. For fabrication of subsequent sets of polymer composites, a typical natural fiber i.e. banana fiber is chosen as the reinforcing material. Scientific name of banana is musa acuminata. At present the banana fiber is a waste product of banana cultivation, therefore without any additional cost these fibers can be obtained for industrial purpose. They have a high tensile strength and resistrot. Main organic constituents of banana fiber are: cellulose, hemicellulose, pectin, lignin and some extractives. Banana fiber is considered to be remarkable filler because of its very low density (0.2 gm/cc), low cost, nontoxicity, biodegradability and eco-friendliness. It possesses very low thermal conductivity (0.09 W/m-K) which is the prime requirement for present investigation. Banana fibers used in present investigation are procured from M/s ROPE (Rural Opportunity Production Enterprises) International, India and are cut into pieces so as to get banana fibers of average length 5-20 mm. Table III provides some of the important properties of banana fiber

TABLE IIIII

PROPERTIES OF BANANA FIBER

Property	Values
Density	0.2 gm/cc
Thermal conductivity	0.09 W/mK
Tensile strength	49.85 MPa
Compressive strength	22.25 MPa

D. Alkali Treatment

In order to get improved mechanical and physical characters of the composites, Banana fiber is subjected to alkali treatment process. In alkali treatment, fibers are firstly prewashed with huge amount of distilled water and dried at constant temperature of 50 C. The alkalization process consisted of immersing banana fibers of certain weight in a 5% (w/v) NaOH aqueous solution for 3h at 70 C. After that, fiber is removed from alkali solution and is dipped in 5 % acetic acid solution for neutralizing. Then it is washed with plenty of distilled water and is dried in an electric oven at a temperature of 110 C for 2hr.

III. PROCESS PARAMETERS AND THEIR RANGE

Every process parameter is having its own range. The composite material physical, mechanical and thermal properties will change depending on the process parameter range used for the making of the composite material. The process parameter concentration can be freely varied with in its own range. Depending on the previous literature the range of the process parameters are selected as shown below Table IV. And levels of process parameters showed in Table V

TABLE IVV

PROCESS PARAMETERS AND THEIR RANGE

S/No	Process parameter	Range
1	Reinforcement particle size	1 µm to 2mm
2	Reinforcement weight percentage	1 to 70
3	Percentage of alkali treatment	1 to 30
4	Weight percentage of banana fiber	1 to 50
5	Length of banana fiber	1 mm to 200 mm

TABLE V

FACTORS AND LEVELS OF EXPERIMENTS

S/NO	Process parameters/Factors	LEVELS			
		LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
1	Particle size	0.2	0.4	0.6	0.8
2	Filler loading (weight %)	10	20	30	40
3	% Of NaOH	1	5	10	15
4	Weight % of banana fiber	5	10	15	20
5	Length of banana fiber	5	10	15	20

IV. EXPERIMENTAL AND DESIGN METHODOLOGY

A scientific approach to plan the experiments is a necessity for efficient conduct of experiments. By the statistical design of experiments the process of planning the experiment is carried out, so that appropriate data will be collected and analyzed by statistical methods resulting in valid and objective conclusions. When the problem involves data that are subjected to experimental error, statistical methodology is the only objective approach to analysis. Thus, there are two aspects of an experimental problem: the design of the experiments and the statistical analysis of the data. These two points are closely related since the method of analysis depends directly on the design of experiments employed.

A. Factorial Design Method:

The technique of laying out the conditions of experiments involving multiple factors was first proposed by the Englishman, Sir R.A.Fisher. The method is popularly known as the factorial design of experiments. A full factorial design will identify all possible combinations for a given set of factors. If the number of levels considered are L, and the number of factors considered are F. Then total numbers of experiments to be performed are L*F (Levels*Factors) Since most industrial experiments usually involve a significant number of factors, a full factorial design results in a large number of experiments. To reduce the number of experiments to a practical level, only a small set from all the possibilities is selected. Taguchi constructed a special set of general design guidelines for factorial experiments that cover many applications.

B. Taguchi Method

Taguchi has envisaged a new method of conducting the design of experiments which are based on well defined guidelines. This method uses a special set of arrays called orthogonal arrays. These standard arrays stipulates the way of conducting the minimal number of experiments which could give the full information of all the factors that affect the performance parameter. The Taguchi technique for determining the optimal setting of process parameters concentrates only on product single response. But in today scenario peoples‟ requirements have been changed from single response to multiple quality characteristics. According to the requirements, the industrialist is also keen to produce items and maintaining a balance between quantity and quality with minimum production cost to earn maximum profit. So the multiple quality characteristics optimizations is another task. Here, the grey relational analysis comes into play, where a mathematical technique optimizes two or more than two quality characteristics.

Selection of an orthogonal array: Before selecting the orthogonal array, the minimum number of experiments to be conducted shall be fixed based on the total number of degrees of freedom present in the study. The minimum number of experiments that must be run to study the factors shall be more than the total degrees of freedom available

Degrees of freedom : Degree of freedom is the number of fair comparisons that can be made with the available data. This forms the basis in selecting the required orthogonal array.

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If the levels are denoted by L, Degree of freedom associated with levels = L-1, Total DOF = No. of factors * (L-1)
According to this experiment,
Number of levels = 4, Number of factors = 5, Total DOF = 5*(4-1) = 15
As per the rule, Degree of freedom of orthogonal array >= Degree of freedom of factors & levels, Here the degree of freedom of factors and levels is 15. So a suitable orthogonal array must be selected whose degree of freedom is greater than or equal to 15. Also by satisfying the levels and factors L16 orthogonal array is selected L16 Orthogonal array comprises of five factors and four levels. Orthogonal array shows that the number of experiments to do and set of process parameters of each experiment. After completion of all these experiments and analysis we can conclude that the optimised parameter set for which we are looking will be known. The below table shows 16 experiments were conducted by using the taguchi experimental design methodology. It shows that the number of experiments to do and also the process parameters set for each and every experiment.

TABLE VV
COMPOSITION OF 16 SPECIMENS

S/No	Particle size	Filler loading	Percentage of NaOH	Wt% of Banana	Length of Banana
1	0.2	10	1	5	5
2	0.2	20	5	10	10
3	0.2	30	10	15	15
4	0.2	40	15	20	20
5	0.4	10	5	15	20
6	0.4	20	1	20	15
7	0.4	30	15	5	10
8	0.4	40	10	10	5
9	0.6	10	10	20	10
10	0.6	20	15	15	5
11	0.6	30	1	10	20
12	0.6	40	5	5	15
13	0.8	10	15	10	15
14	0.8	20	10	5	20
15	0.8	30	5	20	5
16	0.8	40	1	15	10

1) *Taguchi-Grey Relational Analysis:* Taguchi-Grey relational analysis attracts many researchers for solving multi response optimization problems. Taguchi Orthogonal array (OA) provides a set of well-balanced (minimum experimental runs) experiments and signal-to-noise ratios (S/N), which are logarithmic functions of desired output serve as objective functions for optimization. This technique helps in data analysis and prediction of optimum results. With selection L16 orthogonal array using five parameter and four levels for each, the number of experiments required can be drastically reduced nine, which in classical combination of method using full factorial experimentation would require 4^5=1024 number of experiments to capture the influencing parameters. A set of 2 or more output parameters ex. Tensile strength, flexural strength and impact strength are considered and converted into a single output parameter, called the Grade. The calculation of the grade requires the calculation of the normalized, Δ and Grey relational coefficient (ξ) values for each of the output parameters The average of the grey relational coefficient (ξ) values for each of the 5-input parameters of the output parameters gives the value of the grade of the entire output parameters.
2) *Signal-To-Noise Ratio:* In order to evaluate optimal parameter settings, the Taguchi method uses a statistical measure of performance called signal-to-noise ratio. The S/N ratio takes both the mean and the variability into account. The S/N ratio is the ratio of the mean (signal) to the standard deviation (noise). The standard S/N ratios generally used are as follows:

a) Larger the better
b) Smaller the better
c) Nominal the best

The equation for calculating S/N ratios for smaller the better (LB), larger the better (HB) and nominal the best (NB) types of characteristics are as follows:

1. $\frac{S}{N_{HB}} = -10\log(MSD)$ where $MSD = \frac{1}{R}\sum_{j=1}^{R}(\frac{1}{y^2})$
2. $\frac{S}{N_{lb}} = -10\log(MSD)$ where $MSD = \frac{1}{R}\sum_{j=1}^{R}({Y^2}_j)$
3. $\frac{S}{N_{HB}} = -10\log(MSD)$

As the objective is to obtain the best tensile strength (TS) and highest impact strength (IS), and the highest flexural strength. it is concerned with obtaining the least value of flexural strength and large values for tensile strength and impact strength. Hence, the required quality characteristic is smaller the better, which states that the output must be as low as possible, tending to zero for flexural strength and larger the better, which states that the output must be as large as possible for high tensile strength and impact strength

C. Fabrication of Composites

The fabrication from banana fiber into a specific length banana fiber sample is divided into two stages, which are helps in improving the mechanical and thermal properties of the composite. 1st stage is the preparation stage and 2nd is Alkali treatment. In the 1st stage, banana fiber was cut into 5-20 mm length. Then it was dried under sun for approx. 1 week and further heated in the furnace at 80°C for at least 5 minutes, so that the excess moisture in the fibre gets evaporated. Fabrication of composite is done by conventional method called hand lay-up method. A mold of dimension 210 × 210 × 40 mm^3 is used. Epoxy resin with its corresponding hardener in a ratio of 10:1 is thoroughly mixed. Mold releasing silicon spray is applied to mold releasing sheet and then the chopped banana fiber and Ground nut shell powder, mixed in the ratio of the weight percentages as shown in the Table vi. with the resin is gently poured on the sheet which is placed inside the mold. The purpose of releasing agent is to facilitate easy removal of the composite from the mold after curing. The mixture is allowed to set inside the mold for a period of 24 hr under a pressure of 20kg over the cast. Then the specimen is cut into appropriate dimension for mechanical and thermal tests. In this fabrication procedure, sixteen classes of composites are made with different compositions are shown in the table VI.

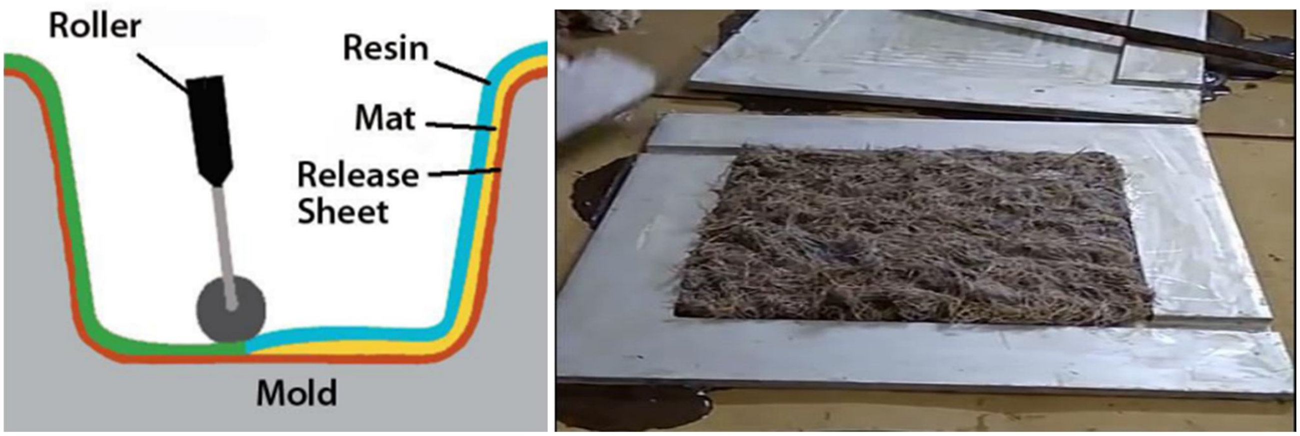

Fig. 3 Fabrication of composite by Hand Layup Technique.

Fig. 4 Fabricated composite plate.

D. Composite Physical Characterization

Density and void fraction The densities of composite materials and their components are normally measured using one of three methods: The Archimedes method, the sink-float method, or the density gradient method. In the present work, the actual density (ρ_a) of composite is determined by the Archimedes principle using distilled water as the medium. This method is covered in ASTM standard D 792. According to this principle when an object is immersed in a liquid the apparent loss in its weight is equal to the up thrust and this is equal to the weight of the liquid displaced. The density of the composite is obtained by using below equation.

$$\rho_a = \frac{\rho_w W_a}{W_a - W_w} \quad \text{Equation 1}$$

Here ρa is the actual/measured density of composite, ρw is the density of distilled water, Wais weight of the sample in air and Ww is weight of the sample in water. The theoretical density of composite materials (ρ_t) in terms of weight fraction can easily be obtained as per the following equation given by Agarwal and Broutman

$$\rho_t = \frac{1}{{W_p}/{\rho_p} + {W_m}/{\rho_m} + {W_f}/{\rho_f}} \quad \text{Equation 2}$$

Where, W and ρ represent the weight fraction and density respectively. The suffix p, m and f stand for the particulate filler and matrix material and fiber respectively. The presence of voids will add to the total volume, but not the weight of the composite. Vv is the void content which is then expressed as:

$$V_v = \frac{(\rho_t - \rho_a)}{\rho_t} \quad \text{Equation 3}$$

E. Composite Mechanical Characterization

Tensile Strength: Tensile strength of any composite indicates the maximum axial pull it can withstand without failure.The cured rectangular shaped composite samples of required dimension (length 150mm, width 20mm and thickness 3mm) are used for the tensile test as per ASTM E 1309 standard. A uniaxial load is applied through both the ends. In the present work, this test is performed in the universal testing machine Instron 1195 (Figure 5) at a cross head speed of 10 mm/minute and the results are used to calculate the tensile strength of the composite samples. The loading arrangement is shown in Figure 5.A. Typical rectangular shaped samples used for tensile test are shown in Figure 5.B. In this case, the test is repeated three times on each composite type and the mean value is reported as the tensile strength of that composite

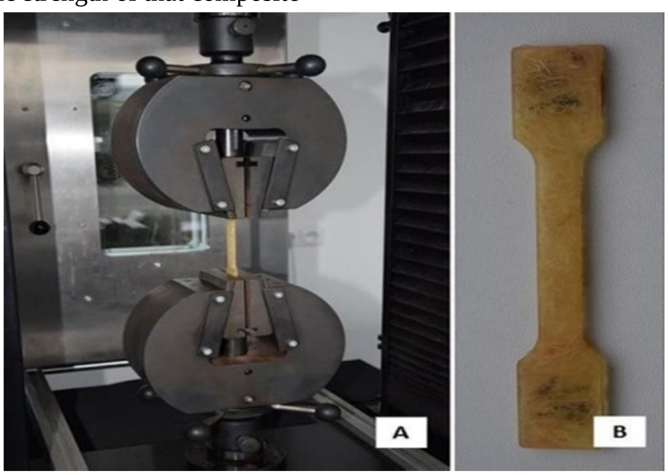

Fig. 5. Tensile Test of Composite Specimen.

1) *Flexural Strength (FS)*: The flexural strength of a composite is the maximum tensile stress that it can withstand during bending before reaching the breaking point. The three point bend test is conducted on all the composite samples as per ASTM D 7264 in the universal testing machine Instron 1195 for evaluating flexural strength. The dimension of each specimen is 60 mm × 10 mm × 3 mm. Span length of 40 mm and the cross head speed of 10 mm/min are maintained. The test is repeated three times for each composite type and the mean value is reported. The flexural strength of the composite specimen is determined using the following equation:

$$\mathbf{F.S} = \frac{3PL}{2bt^2}$$

Where, L is the span length of the sample (mm), P is maximum load (N), b is the width of the specimen (mm) and t is the thickness of the specimen (mm).

The specimens on which the flexural test is conducted is shown in figure 6. by looking at the specimens and the broken location we can conclude that these specimens are slightly behaves like a brittle material under the flexural test. Figure 6.a shows the specimens before conducting the flexural test. Figure 6.b shows the specimens after conducting the flexural test.

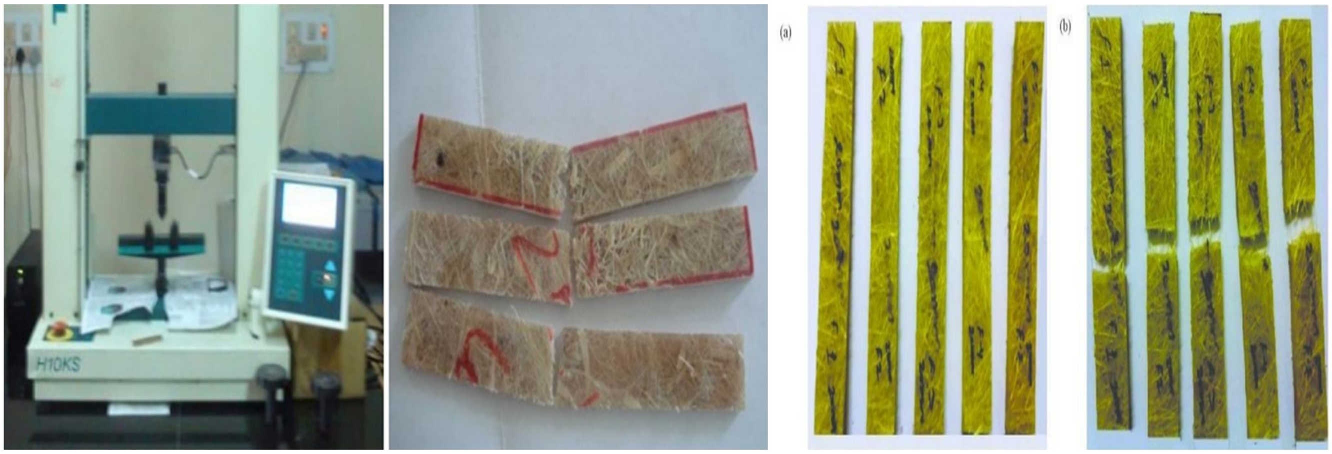

Fig. 6. Flexural Test Machinery and Specimens.

2) *Impact Test*: Impact tests were performed to understand the toughness of material. During the test, specimens were subjected to a large amount of force for a very short interval of time. For any material, the higher amount of impact strength indicates that it can absorb a large amount of energy before failure. As the impact energy increases the toughness of material increases and its plasticity will be also large. The pictorial view of impact tester is shown in fig. 7. The specimen was clamped into the tester and the pendulum was released from a height to strike the specimen. The corresponding values of impact energy of different specimens were getting directly from the dial indicator. The size of the specimen for the impact test was 64 x 12.7 x 3.2 mm^3

Fig.7. Impact Test Setup and Specimens.

V. RESULTS AND DISCUSSIONS

Physical and Mechanical Characteristics of the Composites

A. Density And Volume Fraction Of Voids

The theoretical and measured densities along with the corresponding volume fraction of voids in the ground nut shell powder reinforced-epoxy composites are presented in Tables VII. It may be noted that the composite density values calculated theoretically from weight fractions using Eqn.2 and Eqn.3 are not equal to the experimentally measured values. This difference is a measure of voids and pores present in the composites.

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TABLE VII
DENSITY VALUES OF THE 16 COMPOSITE SPECIMENS

S/No	Specimen	Theoretical density	Actual density	Void percentage
1	1	0.8713	0.8394	3.661196
2	2	0.7213	0.7095	1.635935
3	3	0.61535	0.6058	1.551962
4	4	0.5365	0.5198	3.112768
5	5	0.6423	0.6195	3.549743
6	6	0.556978	0.5291	5.005225
7	7	0.8224	0.8125	1.203794
8	8	0.92632	0.8963	3.240781
9	9	0.56774	0.5432	4.322401
10	10	0.62857	0.6095	3.033871
11	11	0.70400	0.6941	1.40625
12	12	0.8	0.7862	1.725
13	13	0.739497	0.7195	2.704135
14	14	0.846153	0.8362	1.176265
15	15	0.5465	0.5242	4.080512
16	16	0.60277	0.5884	2.383994

Density of a composite depends on the relative proportion of matrix and reinforcing materials and this is one of the most important factors determining the properties of the composites. The void content is the cause for the difference between the values of true density and the theoretically calculated ones. The voids significantly affect some of the mechanical properties and even the performance of the composites in the workplace. Higher void content usually mean lower fatigue resistance, greater susceptibility to water penetration and weathering. The knowledge of void content is desirable for better estimation of quality of the composites. It is understandable that a good composite should have fewer voids. However, presence of void is unavoidable particularly in composites made through hand-lay-up route

B. Mechanical Characteristics

1) *Tensile Strength:* Tensile strengths of the composite specimens are evaluated and the test results for the composites fabricated for this work are presented in Tables VIII. It is noticed that with addition of Ground-nut shell particles content (Filler loading), tensile strength of the composite is increase with Ground-Nut shell particle size up to some extent and then decreases. and this decrement is a function of the filler content also. From the taguchi analysis rankings are given to the process parameters depending on the rate of affect of process parameter on the mechanical properties of the composite. That is rank 1 is given to the process parameter that affect the most and then rank 2 is for next parameter which affect somewhat less than the previous one but more than the remaining parameters. Here in this case, Ground-Nut shell particle size will affect the mechanical properties of the composite most. And then filler loading that is, weight percentage (Wt%) of the ground-nut shell powder will affect the mechanical properties most.

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TABLE VIII
TENSILE STRENGTH OF 16 COMPOSITE SPECIMENS.

S/No	Particle size	Filler loading	%of NaOH	Wt % of Banana	Length of banana	Tensile strength (TS) (MPa)	S/N ratio
1	0.2	10	1	5	5	36.4	31.2220
2	0.2	20	5	10	10	37.4	31.4574
3	0.2	30	10	15	15	37.9	31.5728
4	0.2	40	15	20	20	37.1	31.3875
5	0.4	10	5	15	20	43.7	32.8096
6	0.4	20	1	20	15	44.9	33.0449
7	0.4	30	15	5	10	46.1	33.2740
8	0.4	40	10	10	5	44.3	32.9281
9	0.6	10	10	20	10	44.0	32.8691
10	0.6	20	15	15	5	45.5	33.1602
11	0.6	30	1	10	20	43.4	32.7498
12	0.6	40	5	5	15	37.0	31.3640
13	0.8	10	15	10	15	38.9	31.7990
14	0.8	20	10	5	20	40.5	32.1491
15	0.8	30	5	20	5	42.7	32.6086
16	0.8	40	1	15	10	41.2	32.2979

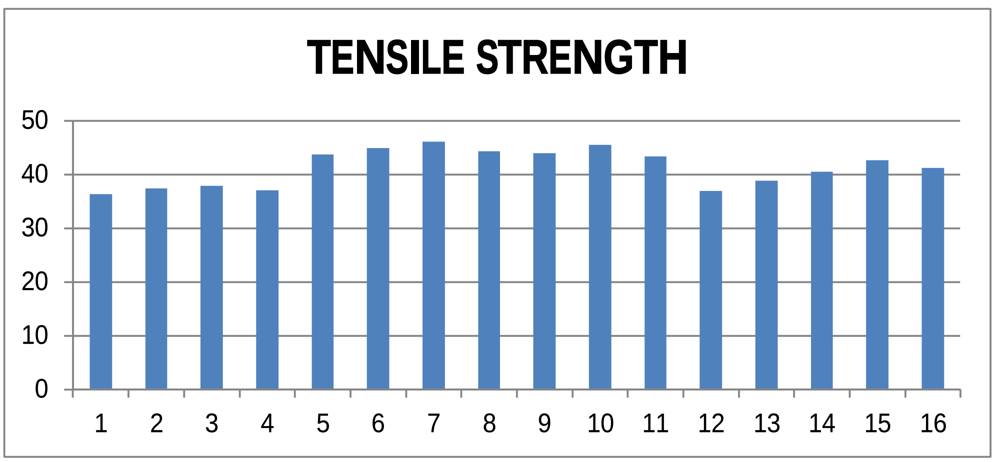

Fig. 8. Tensile strength of 16 specimens

Response Table for Signal to Noise Ratios

Larger is better

Level	PS	FL	NaOH	Wt B	len B
1	31.41	32.17	32.33	32.00	32.48
2	33.01	32.45	32.06	32.23	32.47
3	32.54	32.55	32.38	32.46	31.95
4	32.21	31.99	32.41	32.48	32.27
Delta	1.60	0.56	0.35	0.48	0.53
Rank	1	2	5	4	3

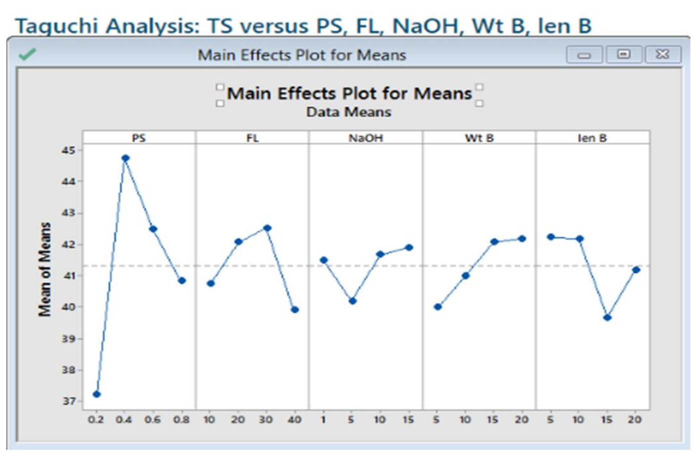

Fig. 9 Responses for signal to noise ratios and means of tensile strength

From the above figure we can find out the order of the process parameters which will affect the tensile strength mostly. The order of the process parameters are.

a) Ground nut shell powder reinforcement particle size (PS represents the particle size).
b) Weight percentage of the Ground nut shell powder (FL represents the Filler loading).
c) Length of Banana fibers used for fabrication of composite (Len B).
d) Weight percentage of Banana fibers (Wt B)
e) NaOH represents the Concentration of the NaOH used for alkali treatment.

Analysis of Results (Effect of process parameters on Tensile Strength of the composite): The Tensile Strength will increase with respect to the reinforcement particle size of the ground nut shell powder from 0.2mm to 0.4 mm. And then the Tensile Strength will Decrease with increase in the Reinforcement size from 0.4mm to 0.8mm. this decrement is because of the formation of the agglomerations and void formations.

As the reinforcements size is increasing the probability of the formation of the agglomerations also increases and the probability of thevoid formations also increases, this results in the decrement of the Tensile Strength. When thereinforcement size is less that adds an advantage to the tensile strength because of thehomogeneous mixing is possible. We can get the Max tensile strength at the reinforcement sizeof 0.4mm.

The Tensile Strength will increase with respect to the filler loading (Weight percentage %) of the ground nut shell powder from 10% to 30% mm. And then the Tensile Strength will Decrease with increase in the filler loading from 30 % to 40 % . this decrement is because of the formation of the agglomerations.

As the filler loading is increasing from 10% to 30% this ground nut shell powder forms a strong bond with the epoxy resin and the banana fibers thus results in the increment of the tensile strength. Beyond the 30% the probability of the agglomerations is increasing thus results in the decrement of the tensile strength.

We can get the Max tensile strength at the Filler loading of the 30%.

Alkali treatment shows a random results on the tensile strength of the composites. When the NaOH concentration (alkali treatment percentage %) is increased from the 1% to 5%, the tensile strength decreases and further increment in the concentration of NaOH increases the tensile strength of the composite.

NaOH treatment of particles above 5% would be advantageous for increased tensile strength, certainly due to the increase in adhesion property of the particles.

Weight percentage % of the banana fiber has an accountable effect on the tensile strength (tensile properties) of the composite. When the weight % of the banana fiber is increased from 5% to 20% the tensile strength is increased without decrement. The tensile strength of the composite is increased with respect to the increment in the weight percentage % of the banana fibers. The addition of the banana fibers increases the load bearing capacity of the composites. The part of load which is coming on the matrix of the composite will get transferred to the banana fiber.

Thus the load bearing capacity of the composite will be increased. From the results graph we can say that the increment in tensile strength is more in between 5% to 15% of weight percentage of the banana fiber when compared to 15% to 20% of weight percentage of banana fiber.

The effect of length of banana fiber on tensile strength of the composite can be analysed from the graphs shown above. increment in the length of banana fiber from 5mm to 10mm don’t have much effect on the tensile strength of the composite. But when the length of banana fiber is increased from 10mm to 15mm it will decrease the tensile strength drastically. Then after when the length of the banana fiber is increased from the 15mm to 20mm the tensile strength increases.

2) *Flexural Strength:* Composite materials used in structures are prone to fail in bending and therefore development of new composites with improved flexural characteristics is essential. In the present work, flexural strengths of the composite specimens are evaluated by conducting three point bend test in accordance with ASTM D7264 and the test results for the ground nut shell particle reinforced banana fiber composites are presented in table IX. from the experimental results it is noted that the flexural strength is maximum for the third specimen and the max value is 50.8MPa. And the minimum value of the flexural strength is noted for the first specimen the value is 35.2 MPa. Measured flexural strength values of ground nut shell particle reinforced-epoxy composites with different filler and fiber proportions are also graphically illustrated in figure 8.

TABLE IX
FLEXURAL STRENGTH OF 16 COMPOSITE SPECIMENS.

S/No	Particle size	Filler loading	% of NaOH	Wt% of banana	Length of banana	Flexural strength (FS) Mpa	S/N Ratio
1	0.2	10	1	5	5	35.2	30.9309
2	0.2	20	5	10	10	39.1	31.8435
3	0.2	30	10	15	15	50.8	34.1173
4	0.2	40	15	20	20	47.9	33.6067
5	0.4	10	5	15	20	37.9	31.5728
6	0.4	20	1	20	15	41.2	32.2979
7	0.4	30	15	5	10	48.8	33.7684
8	0.4	40	10	10	5	42.4	32.5473
9	0.6	10	10	20	10	37.0	31.364
10	0.6	20	15	15	5	43.3	32.1061
11	0.6	30	1	10	20	49.7	33.9271
12	0.6	40	5	5	15	44.6	32.9867
13	0.8	10	15	10	15	36.1	31.1501
14	0.8	20	10	5	20	43.7	32.8096
15	0.8	30	5	20	5	48.7	33.7506
16	0.8	40	1	15	10	45.8	33.2173

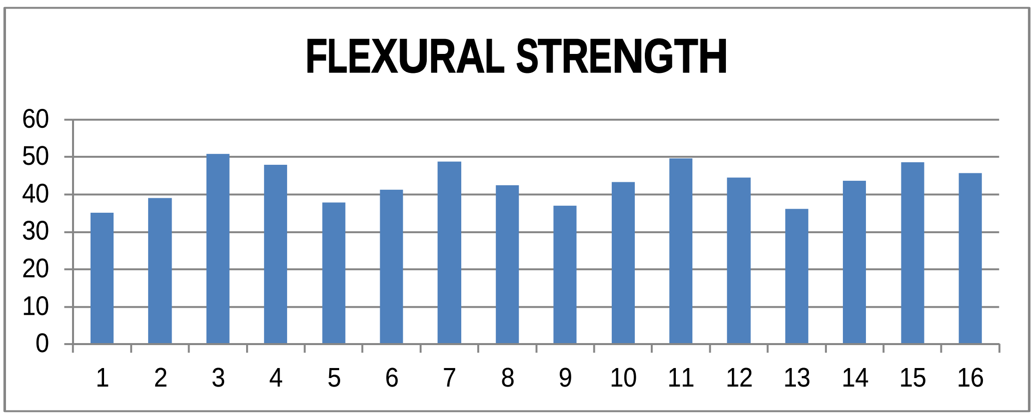

Fig. 10. Flexural Strength Of 16 Composite Specimens

Response Table for Means

Level	PS	FL	NaOH	Wt B	len B
1	43.25	36.55	42.98	43.08	41.65
2	42.57	41.08	42.58	41.82	42.67
3	42.90	49.50	43.47	43.70	43.17
4	43.58	45.17	43.27	43.70	44.80
Delta	1.00	12.95	0.90	1.88	3.15
Rank	4	1	5	3	2

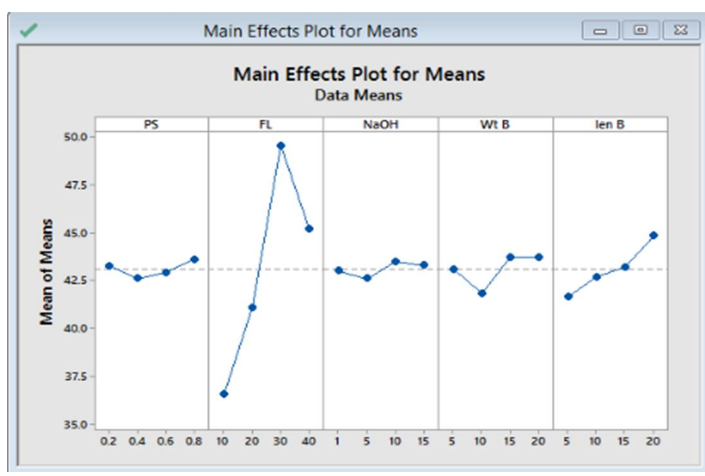

Fig. 11. Individual effect of process parameters on flexural strength.

The response table for the signal to noise ratios and means are shown in the fig 11. In this response table the flexural strength is considered as the larger is better.

And the ranks are given to the each and every parameter depending on their effect on the mechanical properties of the composite fabricated. From the ranking data we can clearly conclude that the Filler loading or weight percentage % of the reinforcement (Ground nut shell powder) shows the most effect on the flexural strength of the composite.

And then Length of the banana fiber will show the most effect. The alkali treatment of banana fibers will shows the least effect on the composites manufactured.

C. Analysis Of Results (Effect Of Process Parameters On Flexural Strength Of The Composite):

The most effecting process parameter of the flexural test is filler loading or weight percentage (wt%) of the ground nut shell powder reinforcement.

In this research the flexural strength of the composite is increases with increment in the filler loading from 10% to 30% and then the flexural strength decreases with increment in the filler loading from 30% to 40%. This decrement might happened because of the formation of the agglomerations with incrementing the filler loading. The flexural strength is almost 30% increased with the increment of filler loading from 10% to 30%.

The second most effecting process parameter of the flexural strength is the length of the banana fiber. The flexural strength of the composite increases with increment in the length of banana fiber from the 5mm to 20mm. no decrement in the flexural strength is observed with respect to the length of the banana fiber.

As the length of the banana fiber is increasing the flexural strength is increased this is because, the long banana fiber can bear more load or the long banana fibers can withstand to the highest loads as compared to the sort banana fiber composite.

The part of the load which is coming on to the matrix will get transferred to the banana fiber and these banana fibers are much longer enough to withstand the load. The flexural strength is almost 7.5% is increased when length of the banana fiber is increased from 5mm to 20mm.

As the weight percentage (Wt%) of the banana fiber is increasing, flexural strength of the composite is first decreases and then increases.

When the weight percentage of the banana fiber is increased from 5% to the 10% the flexural strength is decreased 2.3%. And then when the weight percentage of the banana fiber is increased from the 10% to the 15% the flexural strength is increased almost 4.2% . later only 1% increment is observed in the flexural strength when the weight percentage of the banana fiber is increased from 15% to 20%. So we can consider weight percentage banana fiber 15% as the most preferable for the maximum flexural strength.

Particle size of the ground nut shell powder reinforcement and the alkali treatment don’t show considerable effects on the flexural strength of the composite.

When the particle size of the reinforcement increased continuously the flexural strength of the composite is first decreased and then increased.

But the change in flexural strength is less than the 1% in both the cases decrement and increment. Alkali treatment of the banana fiber shows random effect on the flexural strength of the composite. When the concentration of the NaOH is increased continuously from 1% to 15%, the Flexural strength is first decreased and then decreased and later on decreased. And this increment and increments of flexural strength are less than the 1%.

1) *Impact Strength:* Impact tests were performed to understand the toughness of material. During the test, specimens were subjected to a large amount of force for a very short interval of time. For any material, the higher amount of impact strength indicates that it can absorb a large amount of energy before failure. As the impact energy increases the toughness of material increases and its plasticity will be also large. The pictorial view of impact tester is shown in figure 7. The specimen was clamped into the tester and the pendulum was released from a height to strike the specimen. The corresponding values of impact energy of different specimens were getting directly from the dial indicator. The size of the specimen for the impact test was 64 x 12.7 x 3.2 mm^3. from the experimental results it is noted that the impact strength is maximum for the fourteenth specimen and the max value is 9.66 J/mm^2 . And the minimum value of the impact strength is noted for the eigth specimen the value is 6.07 J/mm^2 . Measured Impact strength values of ground nut shell particle reinforced-epoxy composites with different filler and fiber proportions are also graphically illustrated in Figure 12.

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TABLE X
IMPACT STRENGTH OF 16 COMPOSITE SPECIMENS.

S/No	Paricle size	Filler loading	% of NaOH	Weight % of Banana	Length of Banana fiber	Impact strength (IS) J/mm^2	S/N Ratio
1	0.2	10	1	5	5	6.36	16.06914231
2	0.2	20	5	10	10	7.69	17.7185268
3	0.2	30	10	15	15	8.91	18.99755408
4	0.2	40	15	20	20	9.13	19.20941555
5	0.4	10	5	15	20	9.32	19.38831825
6	0.4	20	1	20	15	8.69	18.78039553
7	0.4	30	15	5	10	7.95	18.00734257
8	0.4	40	10	10	5	6.07	15.66377382
9	0.6	10	10	20	10	7.05	16.96378234
10	0.6	20	15	15	5	6.51	16.27161977
11	0.6	30	1	10	20	9.64	19.68154068
12	0.6	40	5	5	15	8.32	18.40246653
13	0.8	10	15	10	15	8.25	18.32907897
14	0.8	20	10	5	20	9.66	19.69954253
15	0.8	30	5	20	5	6.62	16.41715979
16	0.8	40	1	15	10	7.38	17.36112724

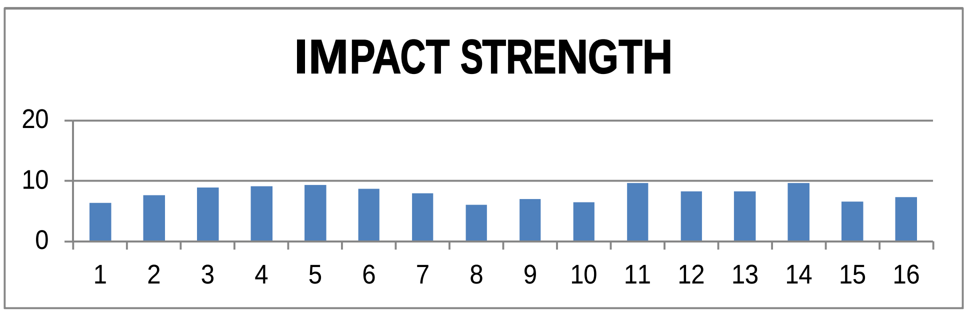

Fig. 12. Impact Strength of 16 Specimens

Response Table for Signal to Noise Ratios

Larger is better

Level	PS	FL	NaOH	Wt B	len B
1	18.00	17.69	17.97	18.04	16.11
2	17.96	18.12	17.98	17.85	17.51
3	17.83	18.28	17.83	18.00	18.63
4	17.95	17.66	17.95	17.84	19.49
Delta	0.17	0.62	0.15	0.20	3.39
Rank	4	2	5	3	1

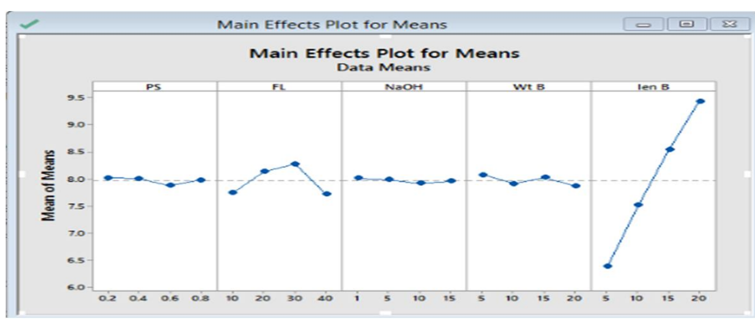

Fig. 13. Individual Effect Of Process Parameters On The Impact Strength

D. Analysis of Results (Effect of process parameters on impact Strength of the composite):

The most effecting process parameter of the impact test is length of the banana fiber which is used for the fabrication of the composite. In this research the impact strength of the composite is increases with increment in the length of the banana fiber from 5mm to 20mm and there is no decrement is observed in the impact strength throughout the increment in the length of the banana fiber. the increment in the length of banana fibers favors the impact strength. The impact strength is almost 50% increased with the increment of length of banana fiber from 5mm to 20mm. The second most effecting process parameter of the impact strength is the filler loading or the weight percentage of the reinforcement (wt%).when the weight percentage of reinforcement increases continuously the impact strength is first increases and then decreases. The impact strength of the composite increases with increment in the weight percentage of the reinforcement from the 10% to 30%. When filler loading is increased from 30% to 40% the impact strength is decreased. As the weight percentage of the banana fiber is increasing the impact strength is increased this is

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because, the reinforcement blends with the epoxy resin and offers the more stability or resistance towards the sudden loads or impact loads. The impact strength is almost 7% is increased when filler loading is increased from 10% to 30%. As the weight percentage (Wt%) of the banana fiber is increasing, impact strength of the composite is first decreases and then increases. When the weight percentage of the banana fiber is increased from 5% to the 10% the impact strength is decreased 2.53%. And then when the weight percentage of the banana fiber is increased from the 10% to the 15% the impact strength is increased almost 2% . later only 1% decrement is observed in the impact strength when the weight percentage of the banana fiber is increased from 15% to 20%. The particle size place a minor role in the case of impact strength. When the particle size is increase from 0.2mm to 0.4mm the changes in the impact strength are almost negligible. And beyond 0.4mm to 0.8mm the impact strength is decreased and then increased. The overall change in the impact strength almost leas than the 1% but the weight percentage of the reinforcement plays a major role in the case of the impact strength Alkali treatment of the banana fibers has less impact on the impact strength results. No increment or decrement in observed in the magnitude of the impact strength with the alkali treatment.
Therefore we can conclude that the alkali treatment has a neutral effect on the impact strength of the composite fabricated.

E. Results And Discussion- II (Effects Of Process Parameters On The Combination Of Mechanical Properties.)

1) *Grey Relational Analysis:* Grey relational analysis emphasizes on the optimization of more than one output parameters, rather than optimizing a single output parameters. S/N ratio for all the output parameters like tensile strength, flexural strength and impact strength is considered as the larger is better.
2) *For larger is better:* $\boldsymbol{X_i(k)} = \frac{Y_i(k)-minY_i(k)}{\max Y_i(k)-\min Y_i(k)}$ *For smaller is better:* $\boldsymbol{X_i(k)} = \frac{max\,Y_i(k)-Y_i(k)}{max\,Y_i(k)-min\,Y_i(k)}$

Here, Yi (k) is the value of the Signal to Noise ratio of the corresponding output parameter. Max Yi(k) is the maximum value of the Yi for the kth response and Min Yi(k) is the minimum value for the kth response. Here, the value of "I" varies from 1 to 16.

3) *Evaluation Of Grey-Relational Coefficient:* The evaluation of Grey-relational coefficient has been done by using the below formulae.

$$\xi = \frac{\boldsymbol{\Delta min + \psi\Delta max}}{\boldsymbol{\Delta oi(s) + \psi\Delta max}}$$

Where, Δ min and Δ max are the minimum and maximum values of the absolute differences, While, $\boldsymbol{\Delta o_i = 1-Xi(s)}$
Ψ is the distinguishing coefficient, whose value varies from 0 to 1 and is generally considered to weaken the effect of larger value of Δmax .In the present article, it is taken to be 0.5.

F. Effect Of Process Parameters On The Tensile Strength And Flexural Strength:

TABLE XI
RANKS OF TENSILE STRENGTH AND FLEXURAL STRENGTH.

S/ No	TS	S/N	$X_i(k)$	Δoi(k)	TS ξ	TS Rank	FS	S/N	$X_i(k)$	Δoi(k)	FS ξ	FS Rank	Overal rank
1	36.4	31.222	0	1	0.333333	16	35.2	30.9309	0	1	0.333333	16	16
2	37.4	31.4574	0.114717	0.885283	0.360937	13	39.1	31.8435	0.286405	0.713595	0.411999	12	14
3	37.9	31.5728	0.170955	0.829045	0.37621	12	50.8	34.1173	1	0	1	1	4
4	37.1	31.3875	0.080653	0.919347	0.352275	14	47.9	33.6067	0.839756	0.160244	0.757296	5	9
5	43.7	32.8096	0.773684	0.226316	0.688406	6	37.9	31.5728	0.20145	0.79855	0.385045	13	11
6	44.9	33.0449	0.888353	0.111647	0.817465	3	41.2	32.2979	0.429011	0.570989	0.466858	10	6
7	46.1	33.274	1	0	1	1	48.8	33.7684	0.890503	0.109497	0.820349	3	1
8	44.3	32.9281	0.831433	0.168567	0.747868	4	42.4	32.5473	0.507281	0.492719	0.503667	9	7
9	44	32.8691	0.80268	0.19732	0.717031	5	37	31.364	0.135921	0.864079	0.366548	14	10
10	45.5	33.1602	0.944542	0.055458	0.900158	2	40.3	32.1061	0.368817	0.631183	0.442015	11	5
11	43.4	32.7498	0.744542	0.255458	0.66185	7	49.7	33.9271	0.940309	0.059691	0.89335	2	2
12	37	31.364	0.069201	0.930799	0.349455	15	44.6	32.9867	0.64518	0.35482	0.584918	7	13
13	38.9	31.799	0.281189	0.718811	0.410236	11	36.1	31.1501	0.068792	0.931208	0.349355	15	15
14	40.5	32.1491	0.451803	0.548197	0.47701	10	43.7	32.8096	0.5896	0.4104	0.549209	8	12
15	42.7	32.6086	0.675731	0.324269	0.606598	8	48.7	33.7506	0.884917	0.115083	0.812899	4	3
16	41.2	32.2979	0.524318	0.475682	0.512462	9	45.8	33.2173	0.71755	0.28245	0.639018	6	8

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From the above table we can easily find out the set of process parameters that will give the best results of the tensile strength and the flexural strength. So the specimen which is made out of the 7th set of process parameter will give you the best tensile strength and the flexural strength

Response Table for Means

Level	PS	FL	NaOH	Wt B	len B
1	40.22	38.65	42.22	41.54	41.94
2	43.66	41.57	41.39	41.41	42.42
3	42.69	46.01	42.57	42.89	41.42
4	42.20	42.54	42.59	42.94	42.99
Delta	3.44	7.36	1.20	1.53	1.56
Rank	2	1	5	4	3

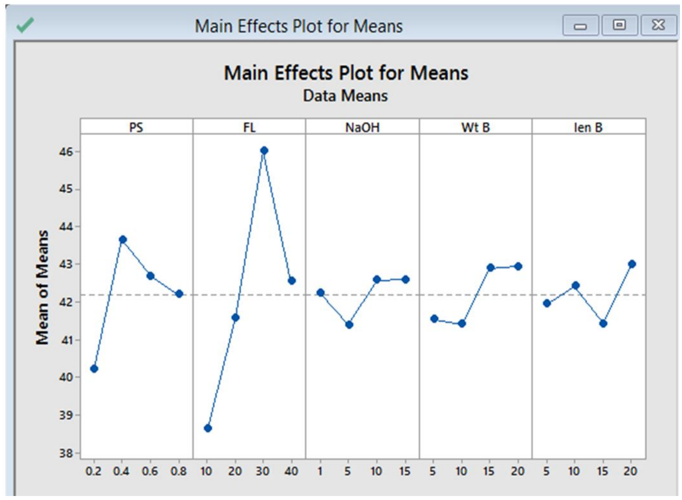

Fig. 14. Individual Effect Of Process Parameters On The Tensile Strength and Flexural strength

From the above figure we can find out the order of the process parameters which will affect the both flexural Strength(FS) and Impact strength(IS) mostly. The order of the process parameters are.

1) Filler loading or weight percentage (wt%) of the reinforcement.
2) Length of the banana fiber.
3) Weight percentage of the banana fiber.
4) Reinforcement particle size (ground nut shell powder)
5) Percentage of the NaOH (Alkali treatment)

As the weight percentage of the ground nut shell reinforcement (Wt%) increases, the flexural strength and the tensile strength both will get increase initially and the decreases.

When the filler loading is increased from 10% to 30% the tensile strength and the flexural strength will increased almost 19.5%. and the it will decreased up to 7.5%.

Ground nut shell powder Reinforcement particle size also shows an accountable effect on the both tensile strength and the flexural strength. When the reinforcement size increased from 02mm to 0.4mm then the flexural strength and tensile strength both will increase up to 8.7 % and when reinforcement size is increased from the 0.4mm to 0.8mm the tensile strength and flexural strengthwill be decreased 3.5%.

The third most effecting process parameter of the tensile strength and flexural strength is length of the banana fiber used for the fabrication of the composite. Length of banana fiber has random effect on the tensile strength and flexural strength of the composite. As the length of the banana fiber is increasing the tensile strength and flexural strength are increases first and then decreases then after increases again.

When the length of banana fiber is increasing from 5mm to 10mm the improvement in tensile and flexural strength is up to 1.66 %. When the length is increased from 10mm to 15mm the decrements in output responses is less than the 1%. And again when the length of the banana fiber is increasing from 15mm to 20mm then the increment in tensile strength and flexural strength is up to 3.65%. the overall increment is up to 4%.

The weight percentage of the banana fiber also plays a major role in the case of the tensile strength and flexural strength. When the weight percentage of the banana fiber increases from 5% to 20% then both the tensile strength and the flexural strength both will be increased almost 3.9%.

Length of the banana fiber has the random effect on the tensile and flexural strength as shown in the graph figure 12.alkali treatment of the banana fibers also improves the tensile strength and the flexural strength but this improvement is only about 2%. All the process parameters have the significant effect on the tensile and the flexural strength, and this effect is shown in figure 14.

G. Effect Of Process Parameters On The Flexural Strength (FS) And Impact Strength (IS):

TABLE XII

RANKS OF FLEXURAL STRENGTH AND IMPACT STRENGTH.

S/No	FS	S/N	$X_i(k)$	$\Delta O_i(k)$	FS ξ	FS Rank	IS	S/N	$X_i(k)$	$\Delta O_i(k)$	IS ξ	IS Rank	Overall Rank
1	35.2	30.9309	0	1	0.333333	16	6.36	16.06914	0.10044	0.899556	0.357256	15	16
2	39.1	31.8435	0.286405	0.71359	0.411999	12	7.69	17.71853	0.50913	0.490865	0.50461	10	12
3	50.8	34.1173	1	0	1	1	8.91	18.99755	0.82605	0.173942	0.741904	5	2
4	47.9	33.6067	0.839756	0.16024	0.757296	5	9.13	19.20942	0.87855	0.121446	0.804575	4	3
5	37.9	31.5728	0.20145	0.79855	0.385045	13	9.32	19.38832	0.92288	0.077116	0.866376	3	6
6	41.2	32.2979	0.429011	0.57098	0.466858	10	8.69	18.7804	0.77225	0.22775	0.687049	6	9
7	48.8	33.7684	0.890503	0.10949	0.820349	3	7.95	18.00734	0.58069	0.419301	0.543892	9	5
8	42.4	32.5473	0.507281	0.49271	0.503667	9	6.07	15.66377	0	1	0.333333	16	13
9	37	31.364	0.135921	0.86407	0.366548	14	7.05	16.96378	0.32212	0.677878	0.424492	12	15
10	40.3	32.1061	0.368817	0.63118	0.442015	11	6.51	16.27162	0.15061	0.849385	0.370539	14	14
11	49.7	33.9271	0.940309	0.05969	0.89335	2	9.64	19.68154	0.99553	0.004461	0.991158	2	1
12	44.6	32.9867	0.64518	0.35482	0.584918	7	8.32	18.40247	0.67860	0.321395	0.608721	7	7
13	36.1	31.1501	0.068792	0.93120	0.349355	15	8.25	18.32908	0.66042	0.339579	0.595536	8	11
14	43.7	32.8096	0.5896	0.4104	0.549209	8	9.66	19.69954	1	0	1	1	4
15	48.7	33.7506	0.884917	0.11508	0.812899	4	6.62	16.41716	0.18667	0.813323	0.380714	13	8
16	45.8	33.2173	0.71755	0.28245	0.639018	6	7.38	17.36113	0.42057	0.579423	0.463211	11	10

The above table gives the overall ranking for the specimens. From the overall ranks we can conclude that the specimen made out of the 11th set of process parameter will give the best results for both flexural strength and impact strength. And the worst will be given by specimen made out of 1st set of process parameters. The overall rank 1 represents the best results and 16 represents the worst results.

Response Table for Means

Level	PS	FL	NaOH	Wt B	len B
1	25.64	22.15	25.50	25.57	24.02
2	25.29	24.61	25.28	24.87	25.10
3	25.39	28.89	25.70	25.86	25.86
4	25.78	26.45	25.62	25.79	27.12
Delta	0.48	6.74	0.42	1.00	3.10
Rank	4	1	5	3	2

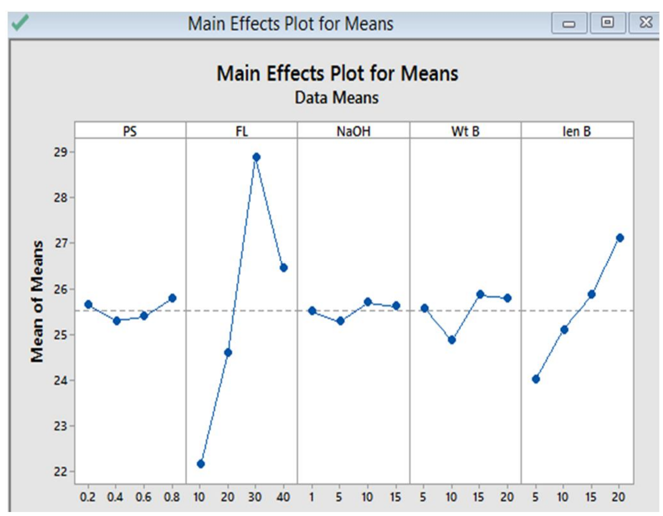

Fig.15. Individual Effect Of Process Parameters On The Flexural Strength And Impact Strength.

From the above figure we can find out the order of the process parameters which will affect the both flexural Strength(FS) and Impact strength(IS) mostly. The order of the process parameters are.

1) Filler loading or weight percentage (wt%) of the reinforcement.
2) Length of the banana fiber.
3) Weight percentage of the banana fiber.
4) Reinforcement particle size (ground nut shell powder)
5) Percentage of the NaOH (Alkali treatment)

H. Individual Effect Of Process Parameters On The Flexural Strength (Fs) And Impact Strength (IS)

Filler loading(FL) or weight percentage (wt%) of the ground nut shell reinforcement plays a major role on the flexural strength and impact strength. As the weight percentage of the reinforcement is increasing the Impact strength and flexural strength both will increase first and then decreases. As the filler loading is increasing from 10% to 30% the increment in the impact strength and flexural strength is almost up to 31.5% and then when filler loading is increasing from 30% to 40% the decrement in flexural strength and impact strength is up to 8.5%.

Length of banana fiber is the second most effecting process parameter of the flexural strength and impact strength. As the length of banana fiber is increasing the flexural strength and impact strength both will increase continuously. The increment in flexural strength and impact strength is up to 12.5%.

Weight percentage of the banana fiber is also plays a key role in the case of the flexural strength and impact strength. As the weight percentage of the banana fiber is increasing the flexural strength and impact strength is first decreases and then increases. When the weight percentage of the banana fiber is increasing from 5% to 10% the flexural strength and impact strength decreases up to 4.3%. and then when weight percentage of the banana fiber is increasing from 10% to 20% the flexural strength and impact strength will increased up to 6.25%.

Ground nut shell particle reinforcement size (PS) and the alkali treatment (NaOH) of banana fibers shows a less impact on the flexural strength (FS) and impact strength (IS). When reinforcement size increases the flexural strength and impact strength both will decrease and then increases. The total increment is less than the 1%. When the concentration of the NaOH alkali treatment is consciously increasing then the flexural strength (FS) and impact strength (IS) both will decrease first and then increases. The decrement and the increments are almost same. So that we can conclude that the alkali treatment of banana fiber shows almost neutral effect on the flexural strength (FS) and impact strength (FS).

I. Effect Of Process Parameters On The Tensile Strength (TS), Flexural Strength (FS) And Impact Strength (IS)

TABLE XIII

RANKS OF FLEXURAL STRENGTH AND IMPACT STRENGTH.

S/No	TS	TS ξ	TS Rank	FS	FS ξ	FS Rank	IS	IS ξ	IS Rank	Overall Rank
1	36.4	0.333333	16	35.2	0.333333	16	6.36	0.357256	15	16
2	37.4	0.360937	13	39.1	0.411999	12	7.69	0.50461	10	15
3	37.9	0.37621	12	50.8	1	1	8.91	0.741904	5	3
4	37.1	0.352275	14	47.9	0.757296	5	9.13	0.804575	4	7
5	43.7	0.688406	6	37.9	0.385045	13	9.32	0.866376	3	6
6	44.9	0.817465	3	41.2	0.466858	10	8.69	0.687049	6	5
7	46.1	1	1	48.8	0.820349	3	7.95	0.543892	9	2
8	44.3	0.747868	4	42.4	0.503667	9	6.07	0.333333	16	11
9	44	0.717031	5	37	0.366548	14	7.05	0.424492	12	13
10	45.5	0.900158	2	40.3	0.442015	11	6.51	0.370539	14	9
11	43.4	0.66185	7	49.7	0.89335	2	9.64	0.991158	2	1
12	37	0.349455	15	44.6	0.584918	7	8.32	0.608721	7	12
13	38.9	0.410236	11	36.1	0.349355	15	8.25	0.595536	8	14
14	40.5	0.47701	10	43.7	0.549209	8	9.66	1	1	4
15	42.7	0.606598	8	48.7	0.812899	4	6.62	0.380714	13	8
16	41.2	0.512462	9	45.8	0.639018	6	7.38	0.463211	11	10

The above table will let you know the composition of the process parameters to be used while fabrication of the composite to get the optimum results. The specimen which is made out of the 7^{th} set of process parameters gives the best Tensile strength (TS) results. And the specimen which is made out of the 3rd set of process parameters gives the optimum results for flexural strength. If the customer wants the best impact test results then the specimen should be made out of the 14th set process parameters.

If the customer wants the optimum results among tensile strength (TS), flexural strength (FS) and impact strength (IS), then the specimen should be made out of the 11th

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Response Table for Means

Level	PS	FL	NaOH	Wt B	len B
1	29.49	28.35	30.82	30.38	30.09
2	31.78	30.43	30.25	30.25	30.79
3	31.08	33.44	31.02	31.27	30.46
4	30.79	30.93	31.04	31.25	31.80
Delta	2.29	5.09	0.79	1.02	1.72
Rank	2	1	5	4	3

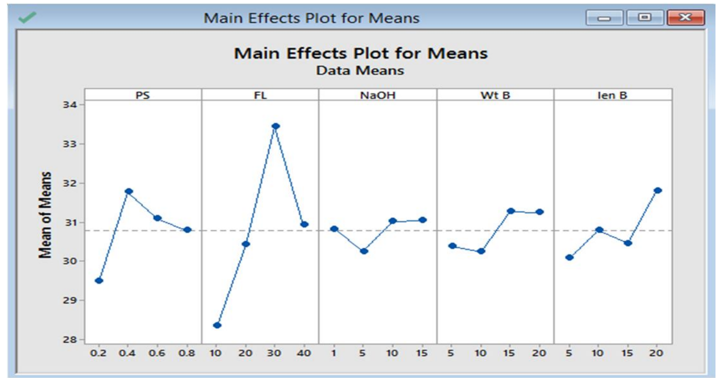

Fig. 16. Individual Effect Of Process Parameters On The Tensile Strength, Flexural Strength And Impact Strength.

From the figure 12. we can find out the order of the process parameters which will affect the both flexural Strength(FS) and Impact strength(IS) mostly. The order of the process parameters are.

1) Filler loading or weight percentage (wt%) of the reinforcement (FL).
2) Reinforcement particle size (ground nut shell powder)(PS)
3) Length of the banana fiber(Len B).
4) Weight percentage of the banana fiber (Wt B).
5) Percentage of the NaOH (Alkali treatment).

The individual effect of the input process parameters on the output parameters can be understand from the figure 12. The most effecting process parameter of all three output response parameters is filler loading. As the filler loading increases, the three output responses like tensile strength, flexural strength and impact strength are first increases and then decreases. When the filler loading is increasing from 10% to 30%, the improvement in all the three output responses is almost up to 18.5%. and then when the filler loading is increasing from 30% to 40% the decrement in the all three output responses is about 7.5%. so the optimum percentage of the filler loading to be used to get best tensile strength, flexural strength and impact strength is 30%.

The second most effecting process parameter of the three output responses is reinforcement particle size of the ground nut shell powder. When the reinforcement size is increasing the tensile strength, flexural strength and impact strength will increase initially and then decreases. When the reinforcement size is increasing from 0.2mm to 0.4mm the three output responses will increases almost up to 8.2 % and then when the reinforcement size is increasing from 0.4mm to 0.8mm then the decrement in all three output responses is up to 3.4%. so the best optimum size of reinforcement to be used to get the optimum results of tensile strength, flexural strength, and impact strength is 0.4mm.

Length of the banana fiber is also plays a major role in finding out of optimum results for tensile strength, flexural strength and impact strength. When the length of the banana fiber is increasing form the three output responses will increases first and then decreases slightly and then increases. When the length of the banana fiber is increasing from 5mm to 10mm, we can observe 3% increment in the output results. And then when length of banana fiber is increasing from 10mm to 15mm there is a slight decrement in the output responses is observed, this decrement is less than 1%. And finally when the length of banana fiber is increased from 15mm to 20mm, the improvement in the output responses is up to 5%.

Weight percentage of the banana fiber has a valuable impact on the all output responses. As the weight percentage of the banana fiber is increasing initially the output responses are neutral then after that it will start increasing. As the weight percentage of the banana fiber is increasing from 5% to 10% then the output responses are slightly decreasing and this decrement is less than 1%, it might be because of the experimental errors also. So we can consider it as a neutral effect. And then when the banana fiber increasing from 10% to 15% the tensile strength, flexural strength, and impact strength will also start increasing, this increment is up to 3.8%. and then when the weight percentage of the banana is increasing from the 15% to 20% then the out put responses will increase only 0.5%.

The least effecting process parameter of the tensile strength, flexural strength and impact strength is Alkali treatment of the banana fibers. When the alkali treatment is increasing from then the output responses decreases first and then increases. When concentration of NaOH used for alkali treatment is increasing from 1% to 5% then the decrement in output responses is almost 1%. And then, when the alkali treatment is increases from 5% to 15% the improvement in output response is 2.5%.

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VI. CONCLUSIONS

In the present study, quantitative analyses of tensile properties, flexural properties, and impact properties of groundnut shell particles reinforced Epoxy composites within the ranges of the proposed process parameters were carried out. The experiments have been planned as per Design of experiments (DOE) Taguchi methodology has been used to analyze the experimental results. And impact of process parameters on the tensile, flexural and impact properties is analyzed using Grey relational analysis technique. There exist non-linear relationships between the proposed tensile properties and the process parameters for groundnut shell particles reinforced epoxy composites. The Tensile Strength will increase with respect to the reinforcement particle size of the ground nut shell powder from 0.2mm to 0.4 mm. And then the Tensile Strength will Decrease with increase in the Reinforcement size from 0.4mm to 0.8mm. this decrement is because of the formation of the agglomerations and void formations. As the reinforcements size is increasing the probability of the formation of the agglomerations also increases and the probability of the void formations also increases, this results in the decrement of the Tensile Strength. When the reinforcement size is less that adds an advantage to the tensile strength because of the homogeneous mixing is possible. We can get the Max tensile strength at the reinforcement size of 0.4mm.

The maximum and minimum values of the tensile strength obtained among the all 16 composite specimens are shown in the below table.

PS	FL	%NaOH	Wt B %	Len B	TS (MPa)	Max/Min
0.4	30	15	5	10	46.1	Maximum
0.2	10	1	5	5	36.4	Minimum

The most effecting process parameter of the flexural test is filler loading or weight percentage (wt%) of the ground nut shell powder reinforcement. In this research the flexural strength of the composite is increases with increment in the filler loading from 10% to 30% and then the flexural strength decreases with increment in the filler loading from 30% to 40%. This decrement might happened because of the formation of the agglomerations with incrementing the filler loading. The flexural strength is almost 30% increased with the increment of filler loading from 10% to 30%. The maximum and minimum values of the flexural strength obtained among the all 16 composite specimens are shown in the below table.

PS	FL	%NaOH	Wt B%	Len B	FS(MPa)	Max/Min
0.2	30	10	15	15	50.8	Maximum
0.2	10	1	5	5	35.2	Minimum

The most effecting process parameter of the impact test is length of the banana fiber which is used for the fabrication of the composite. In this research the impact strength of the composite is increases with increment in the length of the banana fiber from 5mm to 20mm and there is no decrement is observed in the impact strength throughout the increment in the length of the banana fiber. the increment in the length of banana fibers favors the impact strength. The impact strength is almost 50% increased with the increment of length of banana fiber from 5mm to 20mm.the long banana fiber can bear more load or the long banana fibers can withstand to the highest loads as compared to the sort banana fiber composite. The part of the load which is coming on to the matrix will get transferred to the banana fiber and these banana fibers are much longer enough to withstand the load .

The maximum and minimum values of the impact strength obtained among the all 16 composite specimens are shown in the below table.

PS	FL	%NaOH	Wt B %	Len B	IS (J/mm^2)	Max/Min
0.8	20	10	5	20	9.66	Maximum
0.4	40	10	10	5	6.07	Minimum

The maximum and minimum values of the tensile strength and flexural strength obtained among the all 16 composite specimens are shown in the below table.

PS	FL	%NaOH	Wt B %	Len B	Max/Min
0.4	30	15	5	10	Maximum
0.2	10	1	5	5	Minimum

The most affecting process parameter of the tensile strength and flexural strength is Filler loading or weight percentage (Wt %) of the reinforcement. And the least affecting parameter is Alkali treatment (% of NaOH).

The maximum and minimum values of the flexural strength and impact strength obtained among the all 16 composite specimens are shown in the below table.

PS	FL	%NaOH	Wt B %	Len B	Max/Min
0.6	30	1	10	20	Maximum
0.22	10	1	5	5	Minimum

The most affecting process parameter of the flexural strength and Impact strength is Filler loading or weight percentage (Wt %) of the reinforcement. And the least affecting parameter is Alkali treatment (% of NaOH).

The theoretical and measured densities along with the corresponding volume fraction of voids in the ground nut shell powder reinforced-epoxy composites are presented in Tables 6.1. It may be noted that the composite density values calculated theoretically from weight fractions using Eqn.5.2 and Eqn. 5.3 are not equal to the experimentally measured values. This difference is a measure of voids and pores present in the composites.

The maximum and minimum values of the theoretical density and actual density and void percentage obtained among the all 16 composite specimens are shown in the below table.

Specimen	Theoretical density	Actual density	Void percentage	Max/Min
8	0.92632	0.8963	3.240781	Maximum
3	0.61535	0.6058	1.551962	Minimum

If the customer wants the optimum results among tensile strength (TS), flexural strength (FS) and impact strength (IS), then the specimen should be made out of the 11^{th}

The groundnut shell particle reinforced epoxy composites satisfy the minimum requirement as specified by EN Standard 312-2 (11.5 MPa), which is used for the general application such as interior fitment. This developed composite could be used for substitution of wooden material in the application of some automobile and structural applications such as hood, roof panel, heavy-duty racks, interior designs, etc.

These groundnut shell particle reinforced epoxy composites have potential applications in packaging, tissue engineering, and drug delivery. As India is one of the largest groundnut producing countries in the world, the use of its wastes such as shell for producing useful components would be very attractive for the economy.

Groundnut shell reinforced composites can be further attractive by a suitable cost-effective method of composite production and may increase its application to a greater extent. The groundnut shell particles can be considered as an alternative for the wood material in the manufacture of particleboard used in indoor environment due to moderate mechanical properties, lower moisture content and water absorption.

A. Scope Of Future Work

The present research work leaves a wide scope for future investigators to explore many other aspects of such particulate filled composites. Some recommendations for future research include:

1) Use of other natural fibres and their behavior on the basis of same parameters used here,
2) Study of composite properties on the basis of different fabrication techniques other than hand lay-up method like spray up method, compression molding method, filament winding method etc. can be done.
3) Evaluation and optimization of tribological, electrical, physical, thermal properties etc. and the experimental results can be analyzed.
4) Possible use of organic fillers other than Groundnut shell powder and polymeric resins other than epoxy in the development of new composites.
5) Exploring the possibility of using natural fibers other than banana fibers along with ceramic particulates to fabricate hybrid composites with improved functional properties.
6) Cost analysis of these composites to assess their economic viability in domestic/industrial applications

VII. ACKNOWLEDGMENT

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