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OPTIMIZATION OF HYBRID COMPOSITE USING TAGUCHI METHOD

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***Abstract*—In the present days, composites play a vital role in the auto motives, marine and electronics and so on. Composites are being used in the aerospace to obtain much efficiency. Instead of using the highly weighed materials that are made by using casting and machining processes, composites can be used due to its low weight and high strength. 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.**

***Index Terms*—Impact resistance, pairing method, hybrid composite, carbon, glass and aramid fibers.**

I. INTRODUCTION

A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties. The two constituents are reinforcement and a matrix. The main advantages of composite materials are their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for a weight reduction in the finished part. The reinforcing phase provides the strength and stiffness. In most cases, the reinforcement is harder, stronger, and stiffer than the matrix. The reinforcement is usually a fiber or a particulate. Particulate composites have dimensions that are approximately equal in all directions. They may be spherical, platelets, or any other regular or irregular geometry. Particulate composites tend to be much weaker and less stiff than continuous fiber composites, but they are usually much less expensive. Particulate reinforced composites usually contain less reinforcement due to processing difficulties and brittleness. A fiber has a length that is much greater than its diameter. The length-to-diameter ratio is known as the aspect ratio and can vary greatly. Continuous fiber has long aspect ratios, while discontinuous fibers have short aspect ratios. Continuous-fiber composites normally have a preferred orientation, while discontinuous fibers generally have a random orientation. Examples of continuous reinforcements include unidirectional, woven cloth and helical winding while examples of discontinuous reinforcements are chopped fibers and random mat. Continuous-fiber composites are often made into laminates by stacking single sheets of continuous fibers in different orientations to obtain the desired strength and stiffness properties with fiber volumes as high as 60 to 70 percent. Fibers produce high-strength composites because of their small diameter; they contain far fewer defects compared to the material produced in bulk.

II. MATERIALS USED

A.CARBON FIBERS

Carbon fibers were mainly used to improve fatigue behavior and impact strength. Glass fibers suffer from low elastic stiffness (of course, possess excellent strength characteristics) and limited char strength (relatively low melting point) for ablative applications. This necessitated the use of carbon fibers in place of glass fibers for ablative and structural applications. These are produced from certain precursors-polyacry1onitrile (PAN) fiber and viscose rayon fiber. The work on manufacture of carbon fiber from jute and pitch which are abundantly available in India has also been reported recently. Carbon fibers have strength and modulus vastly superior to glass fibers. Although, they are at present much more costly, they will undoubtedly lead to further development of composite materials for more exciting applications. In view of their superior heat stability, carbon fibers can be used for reinforcing ceramics, metals, and

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plastics, giving engineers and technologists a completely new range of materials.

B.ARAMID OR KEVLAR FIBERS

Kevlar fabrics are widely used to produce personnel protection systems because of their high strength properties and impact-resistant properties. Kevlar fibers are popular as they exhibit superior mechanical properties than nylon and E-glass fibers. Great interest has aroused in developing high impact resistant fabrics based on the incorporation of a shear thickening fluid (STF) into high performance fabrics (Kevlar).Polyaramid fibers have superior wettability compared to carbon fibers and do not require treatment with a coupling agent. The incidence of flaw at the site of reinforcement in denture base was found to be less with Kevlar fibers. They were found to improve both tensile.

C.GLASS FIBERS

The most extensively used class of fibres in composites are those manufactured from E-glass. E-glass is a low alkali borosilicate glass originally developed for electrical insulation applications. It was first produced commercially for composite manufacture in 1940's, and its use now approaches 2 MT per year worldwide. Many different countries manufacture E-glass and its exact composition varies according to the availability and composition of the local raw materials. It is manufactured as continuous filaments in bundles, or strands, each containing typically between 200 and 2000 individual filaments of 10-30 µm diameters. These strands may be incorporated into larger bundles called roving and may be processed into a wide variety of mats, clothes, and performs and cut into short-fibre formats. Glass filaments have relatively low stiffness but very high tensile strength.

In spite of their initial very high strength, glass filaments are relatively delicate and may become damaged by abrasion and by attack from moist air. It is therefore always necessary to protect the newly drawn strands with a coating or size (also referred to as a "finish"). This is usually applied as a solution or emulsion containing a polymer that coats the fibres and binds the fibres in the strand together (film former), a lubricant to reduce abrasion damage and improve handling, additives to control static electric charges on the filaments, and a coupling agent, usually a silane, that enhances the adhesion of the filaments to the matrix resin and reduces property loss on exposure to wet environments.

D.EPOXY

The term epoxy is a general description of a family of polymers which are based on molecules that contain epoxide groups. An epoxide group is an oxirane structure, a three-member ring with one oxygen and two carbon atoms. Epoxies are polymerizable thermosetting resins containing one or more epoxide groups curable by reaction with amines, acids, amides, alcohols, phenols, acid anhydrides, or mercaptans. The polymers are available in a variety of viscosities from liquid to solid. Epoxies are used widely in resins for prepregs and structural adhesives. The advantages of epoxies are high strength and modulus, low levels of volatiles, excellent adhesion, low shrinkage, good chemical resistance, and ease of processing. Their major disadvantages are brittleness and the reduction of properties in the presence of moisture. The processing or curing of epoxies is slower than polyester resins.

The cost of the resin is also higher than the polyesters. Processing techniques include autoclave moulding, filament winding, press moulding, vacuum bag moulding, resin transfer mouldings, and pultrusion. Epoxy used is LY556 and the hardener used is HY9561.

III. HAND LAYUP METHOD

Hand lay-up or wet lay-up process is one of the oldest composite manufacturing technologies. It is labour intensive method, in which liquid resin is applied to the mould and fiber reinforcement is placed manually on top. Metal laminating roller is used to impregnate the fiber with resin and remove any trapped air. Several steps are repeated until a suitable thickness is reached. Hand lay-up is the simplest and oldest open moulding method of the composite fabrication processes. Glass or other reinforcing mat or woven fabric or roving is positioned manually in the open mould, and resin is poured, brushed, or sprayed over and into the glass plies. Entrapped-air is removed manually with squeegees or rollers to complete the laminate structure. Room temperature curing epoxies are the most commonly used matrix resins. Several limitations of hand lay-up include inconsistency in quality of produced parts, low fiber volume fraction, and environmental and health concern of styrene emission. A catalyst initiates curing in the resin system, which hardens the fibre-reinforced resin composite without external heat, and kept them at room temperature.

Figure-1-Hand layup method

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IV. IZOD IMPACT TESTING

Izod impact testing is an ASTMstandard method of determining the impact resistance of materials. An arm held at a specific height (constant potential energy) is released. The arm hits the sample. The specimen either breaks or the weight rests on the specimen. From the energy absorbed by the sample, its impact energy is determined. A notched sample is generally used to determine impact energy and notch sensitivity. The test is similar to the Charpy impact test but uses a different arrangement of the specimen under test. The Izod impact test differs from the Charpy impact test in that the sample is held in a cantilevered beam configuration as opposed to a three-point bending configuration.

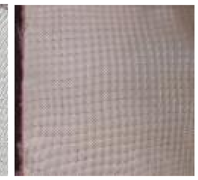
V. FABRICATION OF SPECIMENS

The bidirectional fibers were spread over the table and cut into 9 pieces of size 125x125mm to form a composite plate(different orientation). The composites are fabricated using hand layup method.In this method, the resin should be prepared carefully as its composition plays a vital part in the properties of the composite. Before using any resin to use its gel time as to be estimated first. Gel time is the time taken for a resin to come to gel state once the hardener is added from its initial (liquid) state. The entire process of winding should be complete before the gel time of the resin. Thus if the gel time of a resin is to short it is inconvenient. The gel time of the resin should be optimum for the process. Christo Ananth et al.[1] discussed about E-plane and H-plane patterns which forms the basis of Microwave Engineering principles.

The resin that is being used in this case is epoxy resin with a certain amount of hardener. The hardener is mixed with the resin so that the resin is allowed solidify. 10% the weight of the resin of diaminodiphenyl methane is used as hardener here. The gel time this mixture is found of to be 15-20 minutes. Fiber to resin mass ratio is one of the important factor that has an overall effect on the properties of the composite.it is therefore very important to maintain an optimum ratio of their masses. The amount of resin (weight of resin M_r) is equal to weight of set of fibre mats (M_f).The fibre to resin ratio is 1:1.

The resin was poured on the polythene sheet before placing the fibers. One piece of the fiber mat with particular arrangement is placed. Then it is impregnated using roller to prevent the air bubbles inside the plates. After this the corresponding fibers according to the arrangement are placed one after the other.Likewise the other plates are fabricated according to their composition. Total no of plates-9. Curing time -48 hours.

The plates are prepared according to the following sequences:

0° 45°

60°

Figure-2-Kevlar fiber

VI. TAGUCHI METHOD

The quality design first proposed by Taguchi in the 1960s is widely applied because of its proven success in greatly improving industrial product quality. Therefore, this study uses the Taguchi method to identify the optimum combination of parameters in hybrid composites. The method is used to formulate the experimental layout, analyze the effect of each parameter on thefabrication characteristics and predict the optimal association for each fabrication parameter.

In the preliminary study, impact strength was set as the objective function of the fabrication of the hybrid composite using hand layup method and two factors fibre arrangement and angle orientation were considered as the main fabricating parameters.

A.*CALCULATION OF THE TAGUCHI METHOD*

The objective function in this work is maximization, the ratio of signal-to-noise (S/N ratio) defined according to the Taguchi method.

$$S/N = -10 * \log (\Sigma(1/Y^2)/n)$$

Where n denotes the observed value, and Y represents the impact strength according to the experimental results.

The number of experimental parameter levels was chosen based on the fabrication conditions, fibre arrangements and angle orientation, resulting in three levels

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of each of the two controlled factors. Following the handlay up process, the material was cut as per ASTM D 256 norms and the impact strength was measured by using Izod method. For the tested impact strength for L9 orthogonal array to calculate its average and root-mean-square deviation (MSD).

Table-1- Experimental layout using L_9 orthogonal array

SAMPLE NO	FIBRES SEQUENCE	TYPES OF ORIENTATION(deg)
1	GCACAGAGC	0
2	GCACAGAGC	45
3	GCACAGAGC	60
4	GACCGAACG	0
5	GACCGAACG	45
6	GACCGAACG	60
7	GGGAAACAG	0
8	GGGAAACAG	45
9	GGGAAACAG	60

The above sequences are obtained using Taguchi method.The following are the specimens made using hand layup method.

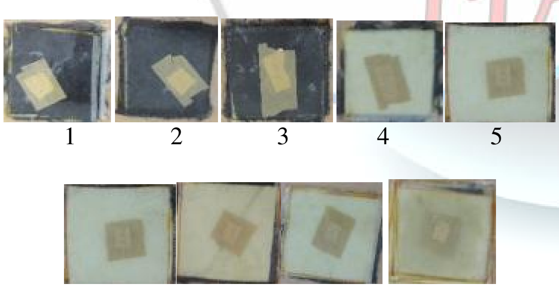

Figure-3-Fabricated specimens

VII. TESTING THE SPECIMENS

The specimens are tested in the Izod impact testing machine to find the effective impact resistance. The specimens are tested in the impact testing machine according to the ASTM D 256.

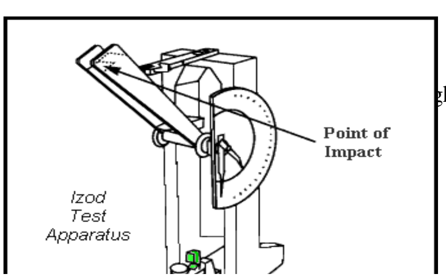

Figure-4-Izod impact testing machine

Figure-5-Tested specimens

VIII. RESULTS AND DISCUSSIONS

It is found that the plates that are made according to the third, fifth and sixth sequences have more impact resistance than the plates that are made according to the other sequences.The impact strength of the material depends on the fibre arrangement and the angle orientation. The impact values obtained are analyzed using Taguchi method. The mechanical property of the hybrid composite is greater than the mechanical property of the individual materials.

Table-2-Impact values of the fabricated specimens

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SAMPLE NO	FIBRES SEQUENCE	TYPES OF ORIENTATION(deg)	IMPACT VALUES(kgm)
1	GCACAGAGC	0	0.41
2	GCACAGAGC	45	0.40
3	GCACAGAGC	60	0.42
4	GACCGAACG	0	0.41
5	GACCGAACG	45	0.42
6	GACCGAACG	60	0.42
7	GGGAAACAG	0	0.40
8	GGGAAACAG	45	0.41
9	GGGAAACAG	60	0.40

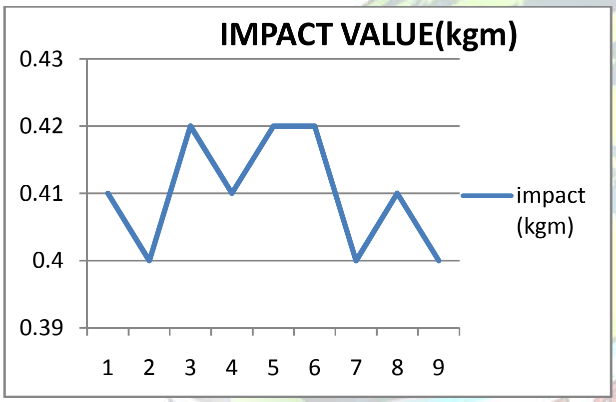

Figure-6-Impact values of the specimens

IX. TAGUCHI ANALYSIS

The Taguchi method uses S/N ratio instead of the average value to interpret the trial results data into a value for the evaluation, characteristic in the optimum setting analysis This is because the S/N ratio can reflect both average and variation of the quality characteristics.

In the present work, the optimization of fabrication of hybrid composite process parameters using Taguchi's robust design methodology characteristics is proposed.

Table 3-Response Table for Signal to Noise Ratios

LEVELS	FIBER ARRANGEMENT	ANGLE ORIENTATION
1	-7.746	-7.816
2	-7.605	-7.746
3	-7.887	-7.676
DELTA	0.283	0.140
RANK	1	2

Table 4-Response Table for Means

LEVELS	FIBER ARRANGEMENT	ANGLE ORIENTATION
1	0.4100	0.4067
2	0.4167	0.4100
3	0.4033	0.4133
DELTA	0.0133	0.0067
RANK	1	2

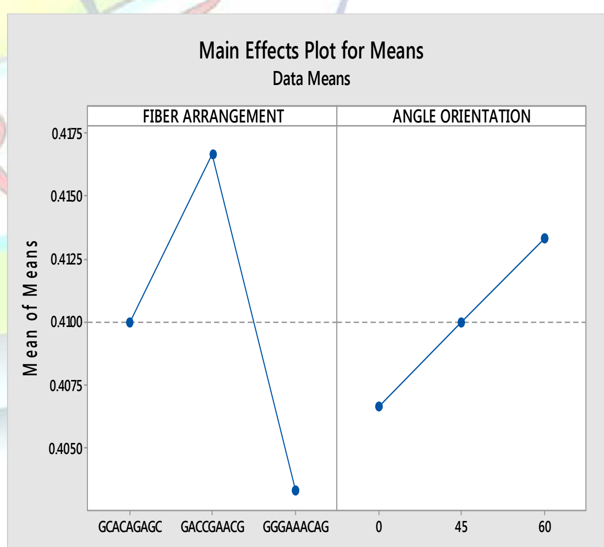

Figure-7-Main effects plot for means

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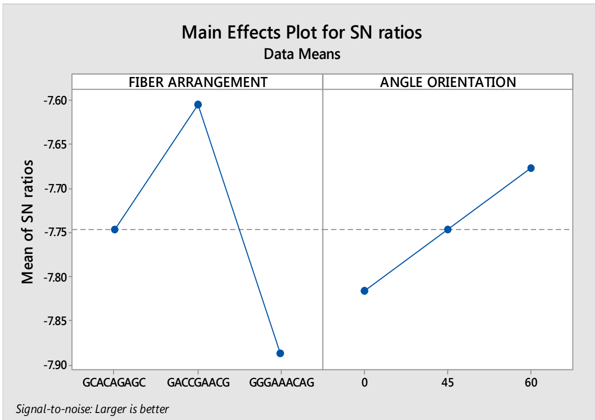

Figure-8-Main effects plot for SN ratios

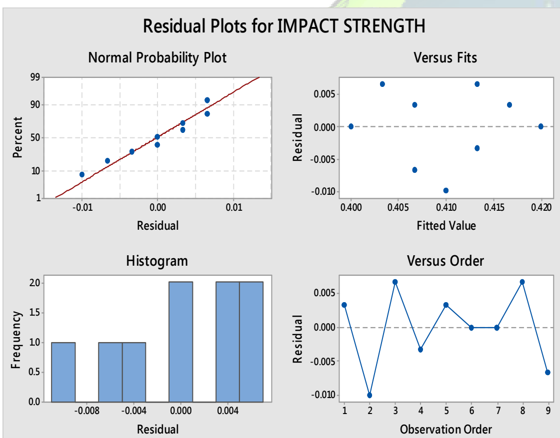

Figure-9-Residual plots for Impact Strength

Analysis of Variance:

Analysis of variance (ANOVA) is a collection of statistical models used to analyze the difference between group means and their associated procedures, in which the observed variance in a particular variable is partitioned into components attributable to different sources of variation.

In order to find out statistical significance of various factors like fibre arrangements and angle orientations on impact strength, analysis of variance (ANOVA) is performed on experimental data.

Table-5 shows the results of the ANOVA with the impact resistance. This analysis is undertaken for 5% confidence level of significance.

Table-5- Analysis of Variance

SOURCE	DF	SUM OF SQUARES	MEAN SUM OF SQUARES	F_{CAL}	F_{TABLE}	REMARKS
FIBER ARRANGEMENT	2	0.000267	0.000133	2.00	6.94	Insignificant
ANGLE ORIENTATIONS	2	0.000267	0.000133	0.50	6.94	Insignificant

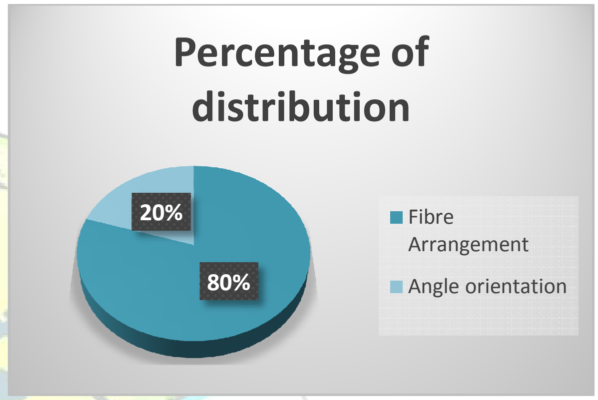

Figure-10-Comparing results with Minitab

Table-6-Existing Impact values of the materials used

MATERIAL	EXISTING IMPACT VALUE(kgm)
CARBON FIBER	0.34
KEVLAR FIBER	0.37
GLASS FIBER	0.32
EPOXY RESIN	0.21

From the experiment it is found that the third, fifth and sixth sequences have more impact resistance than the plates that are made according to the other sequences.

X. CONCLUSIONS

The following conclusions can be drawn from the present investigation on fabrication of hybrid composite at different process parameters:

(i) Fibre arrangement and orientation is not highly influencing in impact resistance.

(ii) But compared to angle orientation, Fibre arrangement is slightly influencing in impact resistance.

The results clearly show that the values giving the optimum result for impact resistance. So, it is recommended that these values can be used for the best results.

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Optimization is carried out in a sequential manner by taking fibre sequences and angle orientations as a factors. From the analyzed result it is concluded that the following sequences give the best results.

Table-7- Specimens with best results

SAMPLE NO	FIBRES SEQUENCE	TYPES OF ORIENTATION(deg)	IMPACT VALUES
3	GCACAGAGC	60	0.42
4	GACCGAACG	45	0.42
5	GACCGAACG	60	0.42

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