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Research Article

Influence of basalt and E-glass fiber on mechanical properties of jute reinforced composite material

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Abstract

The current work focuses on investigating mechanical properties of novel material by considering three levels and three process parameters as input for developing orthogonal array. Based on orthogonal L9 array, nine different samples were fabricated by hand layup technique and vacuum bagged. The samples were tested for tensile and hardness. This experimental data is input for minitab software to perform statistical analysis. By considering the best composition further investigations were conducted by replacing basalt with E-glass to compare. Mechanical properties were evaluated like flexural in addition to tensile and hardness, and found which material is supporting high to increase the strength of jute fiber.

Keywords: *Orthogonal array, mechanical properties, Hand layup technique.*

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1. Introduction

The practice of combining two or so more elemental materials to create a 'composite' with properties superior to those of its constituents has long been practiced. A recent example of this technique is the use of synthetic polymers as matrices for stiffer reinforced materials. This has grown rapidly in the last 30 years as improved materials have been created to suit modern and challenging applications. Since the days when glass-reinforced polyesters ruled the industry, the appearance of epoxy and polyimide resins, as well as the growth of natural, inorganic, and aromatic polyamide fibers, have broadened the use of composites. Because of their excellent mechanical properties and higher operating temperatures, epoxy or polyimide composites are preferred over polyester composites in critical systems where cost is not the only determining factor. Glass-reinforced polyesters are used in a variety of uses, including vessels, housing frames, car bodies, and water tanks. Glass, carbon, or engineered fiber-reinforced epoxy and polyimide resins are often used in heavy load bearing and engineering applications. T.Vu-Khanh carried out a study in different markets on the status and potential developments in enhanced plastics (T.Vu.Khanh, 1987). The survey included the study of reinforced plastics industry use and rates of growth developments in the use of high-performance composites, trends of high volume composites and different obstacles to reinforced plastics expansion. He concluded that the most successful future with an impressive growth rate of about 16 percent per year was promised by advanced composites (T.Vu.Khanh, 1984, D Prown, 1985). The composites with high volumes will expand more slowly. However, for large volume composites, the thermoset was projected to be the chosen resin. The shortcomings of reinforced plastics, such as high rigidity and strength at the cost of strength, thermal resistance restriction, coding baggage, requirements as well as basic measurement programs were obstacles. The author proposed that these obstacles had to be addressed so that the use of composite plastics in the aerospace, military and technology sectors, etc. would be accelerated.

Several composite strength theoretical experiments have been carried out on the basis of different postulated fracture mechanisms (J.F.Knotl, 1973). By changing the formula of the linear superposition of each component's strength in the composite, Riley investigated the strength and shown that failure could begin if the fiber stress met its last tensile strength (V.R. Riley, 1968). Fukuda and Choua have taken a probabilistic approach to the analysis of the composite fracture, considering the fiber loss caused by the neighboring fiber end (H.Fukuda *et al*, 1981). The resilience of a composite was examined by Taya, which failed with penny-shaped cracks in the matrix (M.Taya, 1981). Curtis et al, have shown that cracks at the fiber ends have a significant influence on the composite's mechanical behavior (Curtis *et al*, 1978). Sato et al, revealed that the glass-fiber-reinforced Nylon 6/6's failure took place in three stages: the start of the fiber end interfacial cracks, the spread of these fiber sides

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and the spread of cracks to a matrix resulting in the final material fractured (Sato *et al*, 1984). The fracture behavior of many glass-fiber strengthened and unreinforced thermoplastics was studied (Zango *et al*, 1985). The crack in short-fibre-reinforced polymers (SFRP) has been shown to grow such that the fiber agglomerations (forms of round masses) at low test rates are prevented. The tension of a fiber that debonds and pulls back also contributes to the resistance to fracture. The increase in testing tendency reduces fiber avoidance mode, which leads to a smoother and smoother growth direction for cracks. The degree of fiber degradation and flow was also decreased and the fracture hardness was improved. The fibre-breakage level is high at high frequencies, but this did not add much to the resistance of the fracture. The failure behavior at high load rates of reinforced polymers thus seemed to be governed by the matrix properties. During the last couple of decades the dynamics and properties of discontinuous fiber reinforced composites were thoroughly studied. Theoretical simulations show that very strong shear stresses exist on the interface of matrix and fiber if a fibre composite is stressed (HL Cox *et al*, 1952, 1965, 1966). The mechanical characteristics, Piggot said, of short-fiber composites depending both on their interface and on their matrix and fiber characteristics (Piggott *et al*, 1982). Sata et al, showed that interfacial "debonding" happens before short fiber enhanced thermoplastics have failed (Sato *et al*, 1983). In the short glass-fiber reinforced polyvinyl chloride (PVC) composites under superimposed hydrostatic strain, Yuan et al, found in 1984 three forms of conduct for the deformation. Once again examined the impact on these pressure-dependent deformation processes in 1985 from interfacial adherence. No major effect on the upper shear yield of the short-fiber composites was found by the authors because of enhanced fibre-matrix adhesion. The matrix flow was stated to be lower during debonding in the post yield area. The mechanical characteristics of an SFRP composite are dependent on many factors such as the fiber length, fiber orientation and the structure of the fiber-matrix bond (Yuan *et al*, 1985). In an analysis on a graphite fibre-epoxy-resin device in which the fibre, fiber and interface length were varied separately and the effects on composite properties were established, the functions of this factors were clearly demonstrated (AR Sanadi *et al*, 1985). There have also been reports of the impact of fiber length and fiber orientation on the strength and rigidity of a glass-epoxy system (K Lacir *et al*, 1977). The theoretical impact of fiber length can be assessed with the Kelly and Tyson model (A Kelly *et al*, 1965). For short fiber-reinforced thermoplastics, this model is very simple and powerful (RK Mittal *et al*, 1982). This model calls a stress distribution since the structure is subject to a uniaxial load in the direction of the fibre-axis with a single short fiber embedded in a matrix. Bowyer and Bader proposed a computational algorithm for that model for determining the interface shear stress as well as the aspect of fiber orientation (WH Bowyer *et al*, 1972).

The use of 'comonomers' strengthens the steel, raises the pressure of fractures, and enhances thereby the machinability (PT Kurtis *et al*, 1978). By conducting uniaxial tensil experiments before a failing occurred, weis et al analyzed the structure and mechanical behavior of short glass-built ethylene tetrafluoroethylene (ETFE) co-polymers and observed changes to mechanical characteristics. After the analysis, the authors sought a straightforward way to describe mechanical behavior for small strains where there had yet to be a fiber debonding. Special importance was the deformation zone under the yield point (WT Schrodi, EM Weis *et al*, 1985, 1992). They attempted to connect the relaxation and delay achieved with the microscope characteristic of their materials using the simple rheological elements (EP Plueddamann, 1984). In many design applications the heat tolerance is a critical consideration currently the limiting factor. Silane coupling agents are commonly used in order to achieve good heat strength for the printed circuit boards as finishing agents for glass fiber fabrics composite with fiber/matrix. A silane coupler agent is an adhesive medium that serves as a bridge between the glass fibers and the matrix, so silana couplers have a significant impact upon the thermal resistance of the laminate. The relationship between the adhesive properties and the resulting composite mode I fracture tightness in glass fiber fabric laminate was investigated (Y Suzuki *et al*, 1993). (GFFL). They tested and assessed the hardness of GFFL interlaminary fracture Mode I, which were done with three concentrations of two silane couple agents. It was discovered that the strength of the fracture and the behavior of crack propagation depended on silane couplings. In the mechanical behavior of different synthetic as well as natural fibers and composites some investigators have also examined the impact of flaws. In 1992, in relation to fibre material, fiber angle, direction of external flow and temperature the influence of external flow on tensile strength of short kevlar fiber - thermoplastic polyurethane (tpu) composites studied at a length. The composites demonstrated an increase in the flow size with three stages of reduced tensile strength. With the increased fiber content, the critical flow length area has been changed into higher flux ranges. In the event of unfilled TPU the critical flow duration has been increased with increasing temperature, whereas for short kevlars fiber-filled TPU composites it has remained more or less stable. In terms of composite friction and wear, it has been found that fiber inclusion reduces the friction coefficient in most polymers. As added fibers are long, most of the fiber composites increase their wire resistance because of the inclusion of fibre (AG Thomas *et al*, 1975, 1964, 1980, 1981, 1958). Composites seem to be more resistant to wear than short-fiber composites in abrasive conditions (DK Setua *et al*, 1985). Sinha et al, investigated the friction and wear of Kevlar-phenolic resin composite continuous fiber. The Kevlar-phenolic resin composite formed by compression was slid against a steel disk composed of continuous fibers of 30 Wt percent such that the fiber axis was natural to a sliding plane. The fibrous axis of the fiber was natural into the sliding plane with a compression modeled Chevlar Phenol resin composite composed of 30% wt percent continuous fibre. It was observed that the initial sliding contact was abrasive. The contact becomes adhesive with more slipping. There was then a steady-state friction. The wear strength of the polymer is linked to the stability of the transmission film (SK Sinha *et al*, 1992).

2. Materials and Methods

2.1 Fabrication of specimens

Composites of jute/basalt fiber reinforced polymers (JBFRP) are the selected experimental source. Specimen manufacture is needed using jute fiber, blade fiber, hardener (HY951) and epoxy resin (CY230). Specimens are made using the technique of manual layout. Then, the specimens are reduced to a 250 mm x 25 mm size by changing the fiber orientation and thickness of JBFRP/epoxy contents.

2.2 Selection of process parameters

In order to measure tensile and hardness at various stages and parameters, JBFRP composites are tested and fixed using the minitab17. The tests are carried out. The parameters considered, which are seen in the following table, are jute, basalt and orientation with various layers as input.

Table 2.1: Levels and Parameters

Factors	Levels		
	L1	L2	L3
Jute	6	8	9
Basalt	2	3	4
Orientation	0^0	45^0	60^0

2.3 Design of experiments

For the current work, three parameters are selected, including jute, basalt and orientation, and their scope refers to the literature study. According to the Taguchi experiment design, the L9 array is selected.

Table 2.2: Taguchi L9 Array

Jute (Layers)	Basalt (Layers)	Orientation (deg)
6	2	0
6	3	45
6	4	60
8	2	45
8	3	60
8	4	0
10	2	60
10	3	0
10	4	45

2.4 Specimen Fabrication

An initial effort was made to manufacture the Jute and Basalt composite specimens. The various jute, epoxy orientations are shown as a matrix in the above table. The mechanical properties, such as tensile hardness, are experimentally performed and then assessed by Taguchi method.

Fig: 2.1 Applying Resin and Vacuum bagged after hand lay-up

2.5 Fabrication Procedure

The manual method for the preparation of laminates is selected for this study. First of all, the release gel is sprayed to resist epoxy attachment to the skin on the top of the mould. On the top and bottom of the moulding plate small plastic sheets are used to ensure that the component has a fair surface finish. The enhancer is to be cut in the form and spread on top of the mold, only after a coat of perspex, of matt jut materials and basalt fibres, on the basis of the mold's dimension. Liquid epoxy is then thoroughly mixed in the required proportion with the stated hardener (curing agent) and poured onto the top of the mat already in the mold. The epoxy is applied evenly by means of a brush. The second plate of mat is then positioned at the top of the epoxy and the roller has a small pressure through move to the mat-epoxy layer, to eliminate all excess epoxy and compressed air. Per sheet of epoxy and mat is replicated until the required layers have been stacked. Once the plastic sheet has been assembled, the release gel is pumped into the interior area of the top molding plate and attached to the stacked layers. After cured, the formulated part is opened at the right temperature at 60-80 degrees and then withdrawn and further refined by the mold at a room temperature or at proper temperature. For epoxy-based structures, the estimated healing time is 24-48 hours at ambient temperature.

3. Testing of Composites

The mechanical properties are carried out by different instruments for composites manufactured. The table displays laminate designations and substrate sequences for each layer. The thickness of each Jute layer is 0.4 mm and 0.28 mm for each basalt plate. Under ASTM D3039, laminates for various formulations are prepared by taking into account levels and parameters. Responses like tensile and hardness are taken as feedback to conduct Taguchi analysis.

3.1 Tensile Test

The composite specimen are cut to D3039 (samples 250 X 25x 3 mm) in accordance with standard ASTM, which results in a tensile measure. The computerized Universal Testing Machine (UTM) is used for testing under a cumulative load of 100 KN. Composite tests of different fiber combinations are conducted. In each case three samples are tested and the average is measured and registered. The specimen is subsequently closed and the load applied to the grip and the necessary deflections are noted. Before the sample breaks and the break load is applied, ultimate tensile forces are noted.

3.2 Flexural Test

The 3-point bending test is used to find the flexural modulus, flexural strength and strain at break of the Basalt fiber and glass fiber reinforced polymer composites. Flexural test is conducted on the cured samples using universal testing machine with cross head Speed of 2 mm/min according to ASTM 790- 98. Five samples are taken from each test and the results are averaged.

3.3 Hardness of samples

The hardness value of samples is evaluated on “krystal hardens tester: model KB-3000(J)” with a maximum test height is 250 mm, throat depth is 150 mm and height is 860 mm, The machine is operated at a net weight of 210 kg. The hardness value of each combination is the average of three indentations.

Fig: 3.1 Tailored sample to ASTM

4. Results and Discussion

4.1 Taguchi Technique

The Taguchi technique is simple, systematic and highly effective to maximize the design of experiments. This technology is better than conventional laboratory design, reducing the number of trials, time and costs. The Taguchi technology orthogonal array provides a range of balanced experiments. In the current analysis, a L9 orthogonal sequence of 9 rows and three columns was selected. Table displays grades and operational parameters. The tests consist of nine experiments with orthogonal arrays (OA). In OA, the first column is for Jute, the second is for Basalt and the third column is for Jute.

4.2 Selection of the orthogonal array

The set of Orthogonal Array (OA) depends on a variety of variables and levels that relate to each of the variables. Cumulative DOF determined for each element is 2 (3x2=6) and thus 6 (3x2=6). The degree of freedom selected should be greater than the total DOF of all current variables. Eight is OA's DOF. For the study, L9 is also mentioned. The selected OA is shown in the following table.

Table 4.1: Taguchi orthogonally array with experimental results and Signal-to-Noise ratio

Jute (Layers)	Basalt (Layers)	Orientation (deg)	Tensile Strength (N/mm^2)	Hardness (BHN)	SNRA1	MEAN1
6	2	0	89.26	59.26	35.45	59.26
6	3	45	107.08	71.38	37.07	71.38
6	4	60	96.85	64.56	36.19	64.56
8	2	45	101.09	67.93	36.64	67.93
8	3	60	92.97	61.98	35.84	61.98
8	4	0	95.69	63.79	36.09	63.79
10	2	60	93.98	62.65	35.93	62.65
10	3	0	93.54	62.36	35.89	62.36
10	4	45	116.41	77.6	37.79	77.6

E-glass fiber is used extensively in case of polymer materials which is performing better with mechanical and thermal properties. There are vast number of indoor and outdoor applications observed through literature. In the present research a Comparative experimental investigations are performed by replacing the outer layer of the highest strength exhibiting composition. A new sample is fabricated with E-glass as replacement for basalt composition based on ASTM standard, in addition to tensile and hardness, flexural test is also performed. Comparisons were made based on the experimentation of Basalt and E-glass. The experimental results of both the samples are tabulated.

Table 4.2: Experimental results of laminate

Tests	Basalt/jute	E-glass/jute	Error
Tensile (N/mm^2)	116.41	101.16	15.25
Hardness (BHN)	77.6	86.91	9.31
Flexural (N/mm^2)	161.43	124.23	37.2

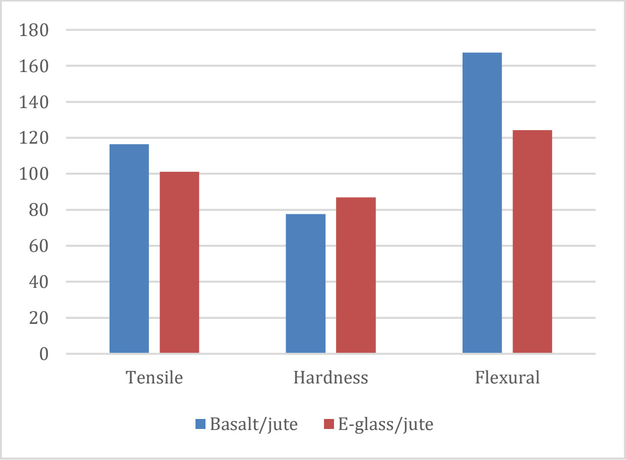

Fig 4.4: Comparison of Tensile, Hardness and flexural properties of basalt and E-glass composites.

Conclusion

In this study, the influence of the process parameters and optimization of the material proposed is analyzed by the orthogonal approach Taguchi L9. The findings are focused on the analysis of the variance (i.e. ANOVA) and the influence of process parameters on variables like Jute/Basalt/Epoxy composites based on experimental outcomes. The conclusions are based on the importance of the parameters and also their individual contributions and consequences for intensity and hardness is determined by ANOVA. For the strength-to-weight ratio, the new parameter was considered to be the strongest. The following are the findings from the experimental results.

1) The orientation of all method parameters to the high strength and stiffness of the desired material is known as the main consideration.
2) The number of basalt layers were replaced by E-glass, it is found that basalt is adding more strength than E-glass.
3) When basalt/jute used as reinforcement, the flexural strength noted is 161.43 N/mm^2. It is 124.23 N/mm^2 for E-glass/jute.
4) There is an increase of 15.25 N/mm^2 in tensile strength of basalt/jute reinforcement.
5) Hardness of the proposed material is high for E-glass, this indicates that the basalt reinforced material is having ductile behavior

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