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Experimental Study on Fracture Toughness of Natural Fibres Reinforced Hybrid Composites

Madhusudhana H K[1*], Ruhi.K[1], Anand R L[1] Dr. C S Venkatesha[2]
[1*]Depertment of Mechanical, K L E Technological University,Hubbal1i, India
[2]Depertment of Mechanical, University B.D.T College of Engineering,Davangere,India

[*]Corresponding Aouthor: hkmadhu30@gmail.com

Abstract :The continuous use of materials with metal matrix like mild steel, aluminium and other non-renewable materials are depleting which are not cost effective. Hence Natural fibres are considered as new emerging eco friendly materials as they are renewable, cost effective, light weight, eco friendly and biodegradable. Composites by name is a combination of many materials made of different reinforcing agents and matrix, are considered more useful because they have better strength and stiffness values, light in weight and strength to weight, strength to stiffness ratios are much higher compared to steel or aluminium metals and with these composites it is more feasible to achieve various combinations of different properties which is found to be difficult to achieve with those of metals, ceramics or polymers. The project is carried out to fabricate natural fibre reinforced hybrid composites and is tested for various mechanical properties through fracture toughness testing and tensile testing, analysed using tools like DOE and RSM. The specimens are tested and analysed and is found that it has similar mechanical properties of any synthetic fibres and can replace them.

1.Introduction

Natural fibre reinforced hybrid composites are considered to be one of the new class in engineering materials. Interest in these fields is increasing higher both in terms of their applications in industries and as well as fundamental researches as they are renewable, low cost, recyclable, and biodegradable with low environmental issues. Compared to many other reinforcement materials with natural fibres, hemp is found to be most promising material due to its relative inexpensiveness and commercial availability in the required form. Natural Fibre Reinforced hybrid composite material here is made of a polymer matrix reinforced by hemp fibre with added filler material to provide high compression strength.

1.1 Problem definition

Fabrication of natural fibre reinforced hybrid composite materials and validation of obtained experimental values of various mechanical properties tested. The analysis is done using various software’s.

1.2 Obljectives

- Preparation of polymer matrix.
- Preparation of test specimen.

- Testing the specimen for its mechanical properties like tensile strength, compression, impact and hardness.
- Analysis of the parameters affecting the response.

2. Methodology

Methodology is a systematic approach and theoretical analysis of various methods applied to a field of study, or the theoretical analysis of the body of methods and principles that are associated with a branch of knowledge

Figure 1 Flow chart

3. Fabrication

Materials used: Selection of matrix material: polymer composite (thermo set)
Resin: Epoxy lapox L-12
Fibre: Hemp
Filler material: coconut shell powder, kolam powder, saw dust.
Steps:

- Cutting of hemp fibres to a desired length of 30cm
- The cut fibres are treated with NaOH solution for half a hour, containing 5% of NaOH crystals dissolved in 1lt of distilled water. The treatment of fibres makes easy in separating the fibre strands and also increases its adhesive property.
- The treated fibres are dried in room temperature and mats are prepared with dimensions 30*30cm.
- Matrix is prepared by mixing resin(epoxy), filler powder and hardener(K6) in proportion according to the experimental plan.
- Using Hand layup method the specimens are prepared, firstly aluminum foil is wrapped around a flat surface like a tile and peel plyer material is placed on to the foil for good texture, then a mat is placed as the first layer and then the matrix(resin) is applied on to it as a next layer and this process is continued until we get required thickness. Once all the layers are laid up again peel plyer is put on to it and uniform load is applied (using bricks), and is kept for curing under room temperature for 24 hrs.

- The prepared panel once cured is cut to a required dimension (20*2cm) using switch board cutting machine.

Figure 2 Hand layup technique

4. Design of Experiments

The design of experiment process is carried out step by step. It included:

- Planning or designing the experiment
- Conducting experiments
- Analyzing the experimental data
- Interpreting the results

4.1 Planning or designing the experiment

The major factors affecting the strength of natural fibre reinforced hybrid composite material are as follows

- Resin percentage
- Filler type
- Thickness

Based on the experimental procedure [{3}3 levels 3, factors 3 and 2 replications] factorial design has been formulated which is as shown in the table below.

Table 1 Identified Factors and Levels

Factors	Level 1	Level 2	Level 3
Resin %	60	65	70
Filler type	Coconut shell powder	Saw dust	Kolam powder
Thickness	3	5	9

4.2 Conducting of Experiment

Tensile test: with ASTM D3039 standard tensile tests are used to measure the force that is required to break a polymer composite specimen and the extent to which the specimen stretches or elongates in its dimensions to that breaking point.

Fracture toughness: In materials science, fracture toughness is a property that describes the ability of a material containing a crack to resist fracture, and is one of the most important properties of any material for many design applications.

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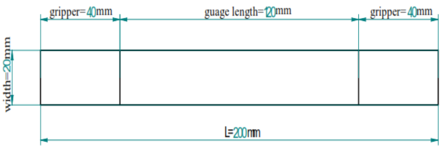

Figure 3 Tensile test specimen

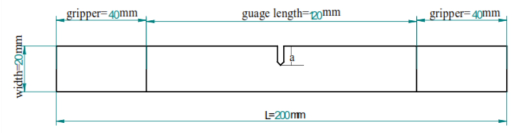

Figure 4 Single Edged Notched Tensile specimen (SENT)

Figure 5 Specimens with different fillers

Figure 6 Fracture and Tensile specimens

4.3Analysis of Experiment Data

Interaction between the factors reinforcement %, filler and thickness on the response Fracture toughness.

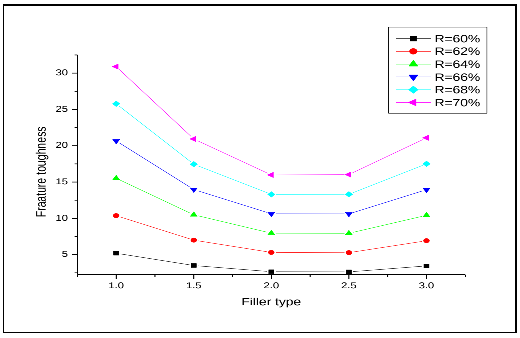

Figure 7 Fracture Toughness Vs Filler Type

From the graph of fracture toughness vs filler type we can infer that the thickness is kept constant and the interaction between the reinforcement% and the filler type is determined. It is observed that highest fracture toughness is obtained for reinforcement % of 70 and for coconut shell powder as filler. We can also observe that by increasing the reinforcement percentage the fracture toughness can be increased. Coconut shell powder is more significant factor compared to other fillers saw dust powder and rangoli powder(kolam) on the response fracture toughness.

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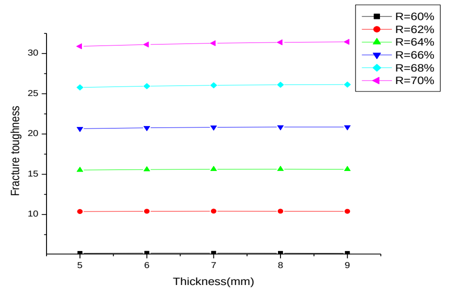

Figure 8 Fracture Toughness Vs Thickness

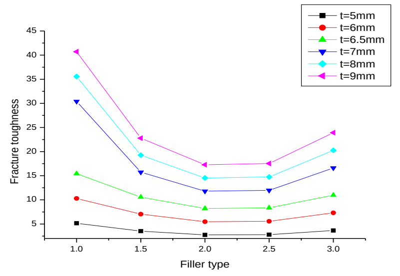

Figure 9 Fracture Toughness Vs Fill

From the fig.8 fracture toughness vs thickness we can infer that the filler type is kept constant and the interaction between the reinforcement% and thickness is determined. It is observed that the graph follows a parallel pattern i.e. the same reinforcement% for different thickness results in same fracture toughness value. Thus by increasing the reinforcement% the fracture toughness can be increased irrespective of the thickness of the specimen.

From the fig.9 fracture toughness vs filler type we can infer that the reinforcement% is kept constant and the interaction between the thickness and the filler type is determined. It is observed that highest fracture toughness is obtained from coconut shell powder as filler and higher thickness value of the specimen. By increasing thickness fracture toughness can be increased. The Coconut shell powder is more significant factor compared to other fillers saw dust powder and rangoli powder (kolam) on the response fracture toughness.

Interaction between the factors reinforcement %, filler and thickness on the response Tensile strength.

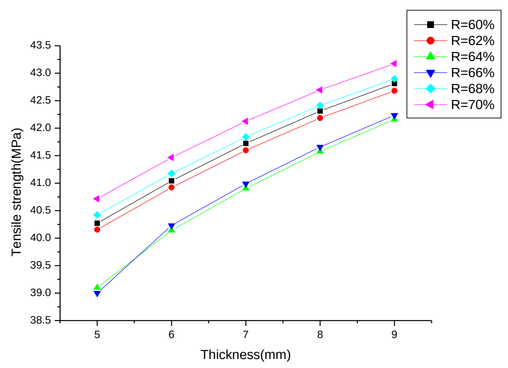

Figure 10 Tensile strength vs thickness

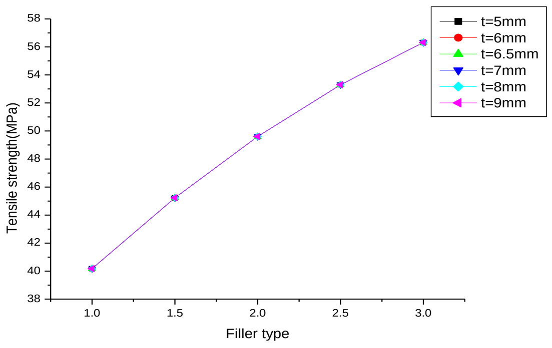

Figure 11 Tensile strength vs filler type

From the fig.10 tensile strength vs thickness in which the filler type is kept constant and the interaction between the thickness and the reinforcement% is determined. We can infer that the effect on reinforcement% and the thickness is exponential to the response tensile strength. Thus maximum tensile strength of 43MPa is obtained by using reinforcement% of 70 and thickness of the specimen as 9mm. From the fig.11 tensile strength vs filler type in which the reinforcement% is kept constant and the interaction between the thickness and the filler type is determined. We can infer that the effect on filler type and the thickness is exponential to the response tensile strength. Thus we can obverse that the effect of thickness is negligible. The maximum tensile strength of 56MPa is obtained by using kolam as filler type. Kolam is significant factor compared to sawdust and coconut shell powder on Tensile strength.

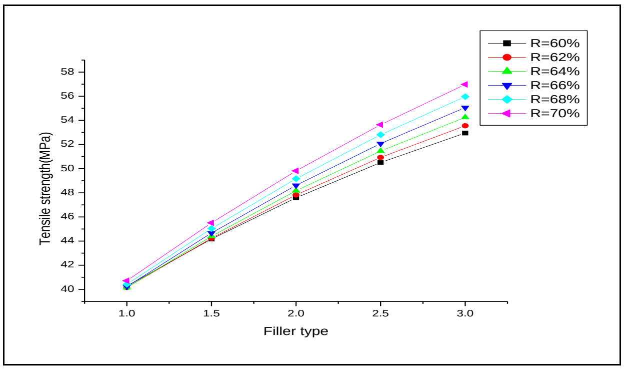

Figure 12: Tensile strength vs filler type

From the graph of tensile strength vs filler type in which thickness is kept constant, the interaction between the filler type and the reinforcement% is determined. We can infer that the effect on reinforcement% and the filler type is exponential to the response tensile strength. Thus maximum tensile strength of 56MPa is obtained by using reinforcement% of 70 and kolam as filler type.

4.4 Interpretation

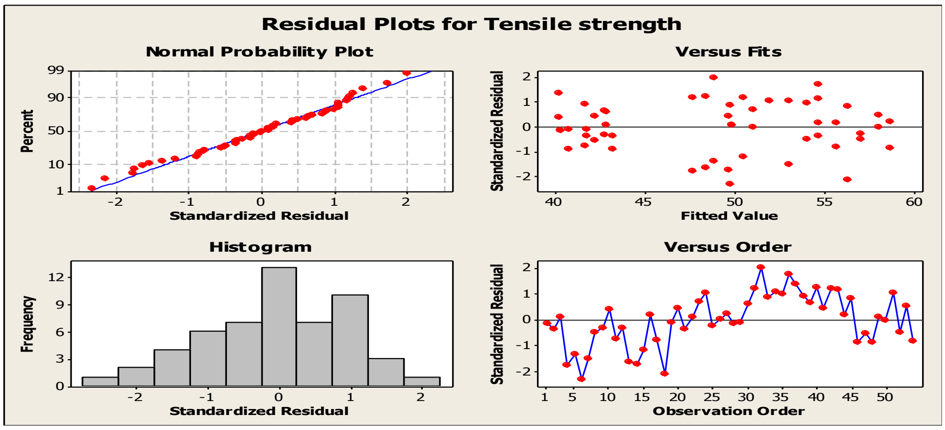

Figure 13: Residual plots for tensile strength

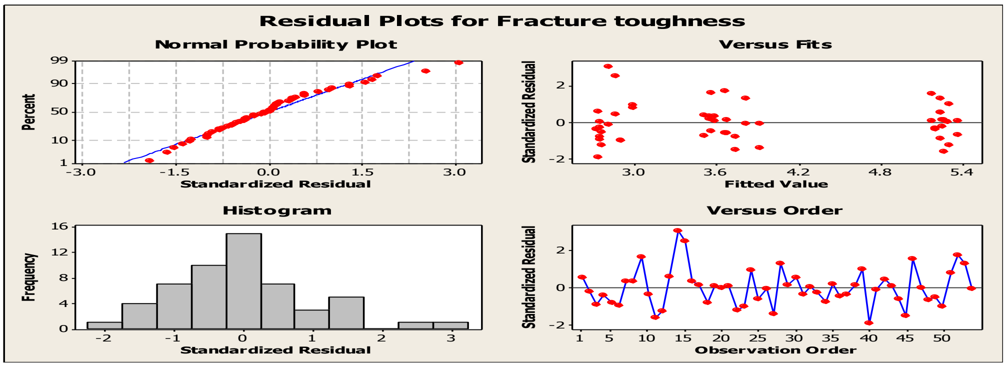

Figure 14: Residual plots for fracture toughness

Interference

Normal Probability Plot:

The plot detects non-normality. Points in both figures approximately follow a straight line indicating that the residuals are normally distributed.

Histogram:

This plot detects multiple peaks, outliers, and non-normality. The histogram in both the figures is a normal histogram, which is approximately symmetric and bell-shaped.

Versus Fits:

This plot detects non-constant variance, missing higher-order terms, and outliers. The residuals for tensile strength are more randomly scattered than residuals of fracture toughness that are scattered randomly around zero.

Versus Order:

This plot detects the time dependence of the residuals. In both the figures the plot ensures that the residuals display no obvious pattern [3].

5. Conclusions

An experimental study on natural fibre reinforced hybrid composite material is been successfully carried out using Hand lay-up fabrication technique by varying three parameters i.e, filler type, % reinforcement and thickness. The prepared specimens are tested for tensile strength and fracture toughness which are further evaluated using DOE techniques and response surface methodology.

The conclusions drawn from the study are:

- The treatment of fibres yields to improved adhesive and flexural properties. The mechanical properties are enhanced due to the addition of filler materials.
- It is been found that the material has greater tensile strength for specimen with kolam as filler material with thickness of 7mm. And an improved fracture toughness for specimen with coconut shell powder as filler.
- The methodology of DOE and RSM is found to be a most powerful statistical tool in analysing the effect of various parameters on the responses and the interaction between the input parameters and the responses.
- The mathematical models developed using Full Factorial Design is found to be useful in predicting the values of controllable variables for achieving optimum response values.
- Maximum value of tensile strength of 59Mpa of composites is found at 70% reinforcement
- Maximum value of Fracture toughness is obtained at 70% reinforcement and by using coconut shell powder as filler material.
- Thus by significantly controlling the input parameters, optimal responses can be obtained.

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