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Experimental Study of Parameter Effect on Fracture Toughness of Hemp Fiber Reinforced Composite

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***Abstract*—Over the past few decades composite materials have taken over the convectional materials in very field right from aerospace to automobiles to construction. The reason being they are light, cheap and affordable. Further natural composites are biodegradable to a greater extent. Many works and researches have been undertaken to study the properties and characteristics in the recent past. This paper deals with the study the effect of parameters (Thickness, Crack length and NaoH %) on mechanical properties of hemp reinforced composite using DOE technique. This research helps to optimize the parameters. Fracture toughness and yield stress it depends on the thinness of the specimen. NaoH treatment also improves the mechanical properties for a optimum percentage of NaoH.**

***Index Terms*— Hemp, DOE, Fracture Toughness.**

I. INTRODUCTION

Conventional materials are widely used in many industries because of high strength. But these materials increase the amount of environment issues such as water disposal services, and disposal treatment and other issues. Composite materials have taken over the convectional materials in very field right from aerospace to automobiles to construction. The reason being they are light, cheap and affordable. Further natural composites are biodegradable to a greater extent. Composite materials are made by using two different materials they are of low cost and high strength.

Composite materials can be prepared by using two types of fibers they are natural fibers and synthetic fibers. Compared to natural fibers with synthetic fibers, Natural fibers have wide variety of advantages such as they are of low cost, easily available, they are biodegradability and recyclability.

Polymer reinforced composite materials have already found uses in aerospace applications, building, vehicle parts such as door made from natural fibre-polypropylene.

The untreated natural fibre reinforced thermoplastic composites associated with some problems include poor interfacial adhesion between the cellulose fibres and the thermoplastic matrix. Therefore untreated natural fibres poor adhesion, which then results in a composite material with poor mechanical properties. These drawbacks can overcome by fibre treatment.

We used natural fiber as hemp fiber because of low cost, it has high strength and easily available. The hemp fiber is treated with NaOH solution. In this paper the mechanical properties of hemp/epoxy composites were investigated. Composites were produced from treated fiber-reinforced polymer composite and the effects of

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fiber treatment on their mechanical properties were analysed.
Merits of Composites Advantages of composites over their conventional counterparts are the ability to meet diverse design requirements with significant weight savings as well as strength-to-weight ratio. Some advantages of composite materials over conventional ones are as follows:
Tensile strength of composites is four to six times greater than that of steel or aluminium (depending on the reinforcements).Improved torsional stiffness and impact properties.Higher fatigue endurance limit (up to 60% of ultimate tensile strength).30% - 40% lighter for example any particular aluminium structures designed to the same functional requirements. Lower embedded energy compared to other structural metallic materials like steel, aluminium etc. Composites are less noisy while in operation and provide lower vibration transmission than metals. Composites are more versatile than metals and can be tailored to meet performance needs and complex design requirements[1]

II. Literature Review

According to the literature conducted on the composite materials most of the study is based on the physical parameters and mechanical properties of the composites. Most of the study is limited to one or two properties of the materials without variation the concentration of the constituent materials. Whereas in the following study is based on determining the effect of concentration of NaOH, thickness, crack length on the composites with variation in concentration.

III. Methodology

Methodology comprises the theoretical analysis of the body of methods and principles associated with a branch of knowledge. In the above experimental research
•Preparation of the mould
•Selection of required constituent materials fiber, resin, filler)
•Preparation of composite specimen
•Testing for its mechanical properties.

IV. Experimentation

A. Materials

Hemp fibers are purchased from local dealer in rannebennur. Some quantity fibers were treated with 0.5%2%, 4% for 2 hours. Then fibers were dried in sunlight for 2 days. The dried fibers were made layers by sewing machine of dimension 300mm*300mm.

Fig1. Fiber treated with NaOH

Fig2. Fabricated composite material

B. Preparation of Composite Specimen

The composite material was used for the present investigation is fabricated by hand layup method, layers of hemp fiber laminates each of 0.7mm thickness alternatively 300 mm length and 300 mm width was put together to form a block. We place one by one layers on mould alternatively will apply epoxy resin according to calculation shown below for 0.5% naoh treated of 5 mm thickness similarly calculation is carried out for different thickness s and leave it get dry for one day.

Calculation:
Laminated thickness = 0.7 mm = 0.07 cm
Epoxy $\int_m$= 1.3 gm. /cm^3
Hemp $\int_f$= 1.5 gm. /cm^3
Weight fraction of hemp fibre Wf=20%
Weight fraction of epoxy resin Wm=80%
Thickness t= 5 mm

Weight of composite = Wf x Wc ,
Where Wc = Weight of composite
155 gm. = 0.2 x Wc
Wc= 775 gm.
Weight of epoxy Mc = Wm x Wc = 0.8 x 775 = 620 gm

Similarly the calculation was carried out for the other entire specimen and the composite specimens were prepared.

C. Mechanical Testing

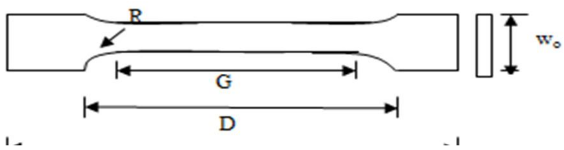
The prepared specimen are subjected to various mechanical test such as fracture failure, fatigue, wear, impact etc to determine its force withstanding capacity. In this case the specimen of varied constituent's elements is subjected to tensile and fracture test.

a) Tensile Test

According to ASTM D638 standard of tensile test specimens were prepared. The dimensional view of specimen is shown in fig below and table shows the standard dimensions of the tensile test specimen. The nine different specimens were prepared according percentage to NaOH treated and according to different thickness as shown in the experimental design table. The specimens were placed in the machine and applied a load until the specimens get fracture. During testing the stress vs strain and load vs displacement were recorded.

TABLE I. ASTM STANDARD SPECIMEN

W_o-Overall width	20mm
G-gauge length	50mm
T-thickness of specimen	5mm,10mm,15mm
D-distance between grips	115mm
L_o-Overall length	165mm
R-radius of fillet	76mm



The tensile specimens were prepared as per the ASTM standards as shown in the figure above. There were total 9 specimens of different combination of thickness and percentage of NaOH. The specimens were tested in UTM available in BVB College and results were analysed.

Fig3. Tensile test specimen

Fig 4. UTM machine

b) Fracture test

Tensile test results apply to material that does not contain cracks or stress concentrators, such as brittle inclusions. When crack like defects are present either as surface cracks or internal ones, failure may begin at much lower applied stresses. The applied stress is greatly magnified at the crack tip due to zero area (theoretically). For a ductile material, it can deform locally when the stress is high, blunting the crack tip reducing the intensity of stress [2]. For brittle material, the crack will propagate through the stressed region with little deformation. The small scale plastic region around the crack will continue to propagate across the specimen. Fracture may be defined as the mechanical separation of a solid owing to the application of stress. Fractures of engineering material are categorized as ductile or brittle fractures. Ductile fractures absorb more energy, while brittle fractures absorb little energy, and are generally characterized by fracture with flat surfaces. Fracture toughness is related to the amount of energy required to create fracture surfaces. In brittle materials such as glass the energy required for fracture is simply the intrinsic surface energy of the material, as demonstrated by Griffith. For structural alloys at room temperature considerably energy is required for fracture because plastic deformation accompanies the fracture process. The application of fracture mechanics concepts has identified and quantified the primary parameters that affect structural integrity. These parameters include the magnitude and range of the applied stresses, the size, shape, orientation of cracks / crack like defects, rate of propagation of the existing cracks and the fracture toughness of the material. Two categories of fracture mechanics are Linear Elastic Fracture Mechanics (LEFM) and Elastic-Plastic Fracture Mechanics (EPFM). The Linear Elastic Fracture Mechanics (LEFM) approach to fracture analysis assumes that the material behaves elastically at regions away from the crack, except for a small region of inelastic deformation at the crack tip. The fracture resistance is determined in terms of the stress- intensification factor, K and strain energy release rate G. The energy released during rapid crack propagation is a basic material property and is not influenced by part size. According to ASTM the stress intensity factor K can be written as

K_I= PS/(BW^3/2) f(α) (1)

Whereas,

P= peak load, S= Gauge length, B= Specimen thickness, W= Width

f(α)=(3α^0.5[1.99-α(1-α)(2.15-3.93α+2.7α^2)])/(2(1+2α)(1-α)^1.5)

Where, α=a/w

a=crack length,w= width, Fracture toughness test is conducted according to ASTM standards[3]

D. Result and Discussion

The prepared specimens were subjected to tensile tests with the help of UTM. The samples were subjected with uniform load until failure. The basic idea of a tensile test is to place a sample of a material between two fixtures called "grips" which clamp the material. The material has known dimensions, like length and cross-sectional area. We then begin to apply weight to the material gripped at one end while the other end is fixed. After testing the tensile strength for 2% NaOH composite were higher than the 0.5% and 4% NaOH. The tensile strength gave the optimum value of yield limit until the material failed. The results obtained are shown in the table below and can be used for further analysis.

TABLE II. TENSILE STRENGTH (N/MM^2)

Thickness	Percentages of NaOH		
	0.5%	2%	4%
5mm	40.16	47.50	23.85
10mm	33.02	35.9	10.85
15mm	29.27	30.50	07.44

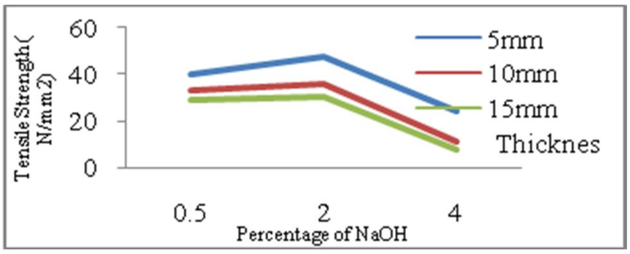


Fig5. Graph of tensile strength results

The above table clearly depicts that the tensile strength of the material was best obtained at 2% concentrated NaOH. This can be confirmed with help of the graphs.

TABLE III. FRACTURE TOUGHNESS VALUE FOR 0.5 % NAOH (MPA√M)

Crack Length	Fracture Toughness (MPa√m)		
	Thickness		
	5 mm	10mm	15mm
9 mm	106.79	74.56	55.17
10 mm	166.54	149.89	99.92
11 mm	200.03	185.95	131.01

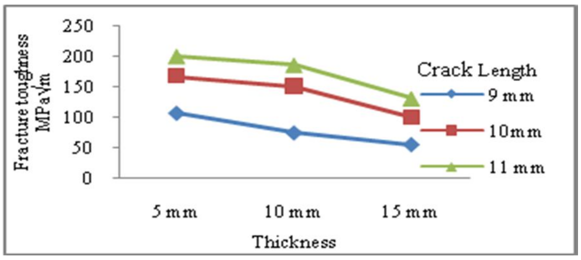


Fig 6 Fracture toughness for 0.5% NaO

The fracture toughness value for 0.5% NaOH treated hemp fibre is shown in below table. As the crack length is increased from 9 mm to 11 mm the value of fracture toughness is increased which can be clearly seen below graph. For 11 mm crack and 5 mm thickness the fracture toughness value is found to be 200.03 and found to be best amongst the combination.

TABLE IV. FRACTURE TOUGHNESS VALUE FOR 2 % NAOH (MPA√M)

Crack Length	Fracture Toughness (MPa√m)		
	Thickness		
	5 mm	10mm	15mm
9 mm	165.5	162.86	158.41
10 mm	206.99	192.71	110.63
11 mm	236.6	236.6	131.01

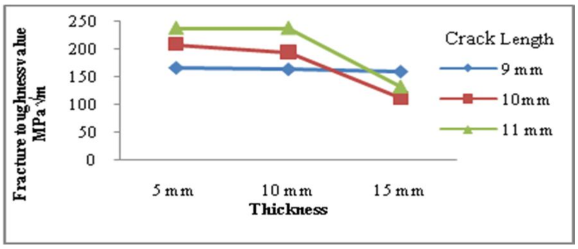


Fig 6 Fracture toughness value graph for 2% NaOH

The fracture toughness value for 2 % NaOH treated hemp fibre is shown in below table. As the crack length is increased from 9 mm to 11 mm the value of fracture toughness is increased which can be clearly seen below graph. For 11 mm crack and 5 mm as well as for 10 mm thickness the fracture toughness value is found to be 236.6 and found to be best amongst the combination.

TABLE V. FRACTURE TOUGHNESS FOR 4 % NAOH

Crack Length	Fracture Toughness (MPa√m)		
	Thickness		
	5 mm	10mm	15mm
9 mm	352.43	196.02	170.87
10 mm	235.80	235.80	214.13
11 mm	202.86	185.95	177.5

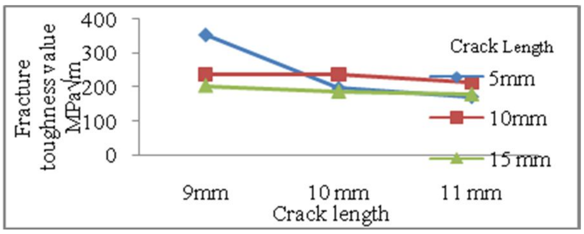


Fig 7 Fracture toughness 4% NaOH

The fracture toughness value for 4 % NaOH treated hemp fibre is shown in below table. As the crack length is increased from 9 mm to 11 mm the value of fracture toughness is increased which can be clearly seen below graph. For 9 mm crack and 5 mm thickness the fracture toughness value is found to be 352.43 and found to be best amongst the combination.

E. Analysis of result by using mini tab software

Tensile strength: After tabulating the Tensile strength, the reading were analysed using MINITAB-16 software and the results were tabulated and following graphs, anova table, least square means were obtained as follows.

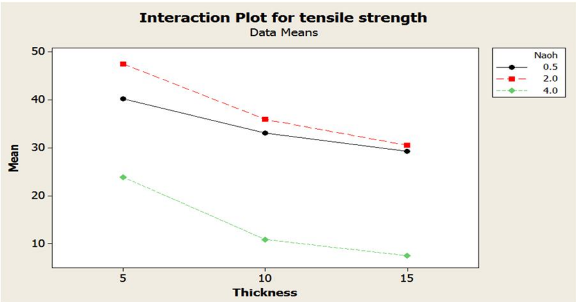


Fig 8 Interaction Plot

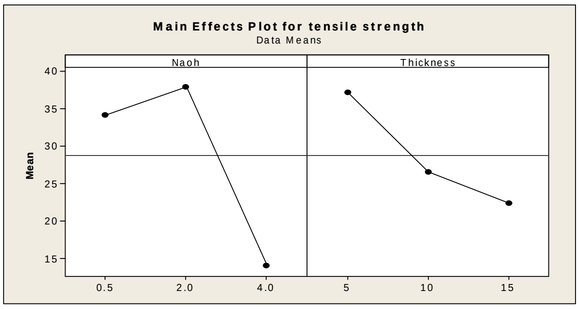


Fig 9 Main Effect plot

After performing the analysis using MINITAB software, the interaction plot is obtained and following interpretations can be made Table 4 and figure 7 shows Factors 2% NaOH and 0.5% NaOH show severe interaction between them at 15mm thickness. Factors 2% NaOH have high tensile strength value at 5mm thickness compare to other factors. Factor 4% NaOH have lower tensile strength value. Individual effect can be studied through main effect plot.

After studying the individual effects using main effects plot, following interpretations can be made.

Table 5 figure 8 shows 4% NaOH has less tensile strength value and the tensile strength value increases for 0.5% NaOH and increases further for 2% NaOH, hence 4% NaOH can be considered as tensile strength value is less.5mm thickness has strength value and has thickness increases from 5mm to 15mm the tensile strength decreases, hence for 15mm thickness tensile strength value is less.

General Linear Model: tensile strength versus Naoh, Thickness

Factor	Type	Levels	Values
Naoh	fixed	3	0.5, 2.0, 4.0
Thickness	fixed	3	5, 10, 15

Analysis of Variance for tensile strength, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Naoh	2	990.88	990.88	495.44	136.01	0.000
Thickness	2	347.52	347.52	173.76	47.70	0.002
Error	4	14.57	14.57	3.64		
Total	8	1352.97				

S = 1.90861 R-Sq = 98.92% R-Sq(adj) = 97.85%

Least Squares Means for tensile strength

Naoh	Mean	SE Mean
0.5	34.15	1.102
2.0	37.97	1.102
4.0	14.05	1.102
Thickness		
5	37.17	1.102
10	26.59	1.102
15	22.40	1.102

Fig 10 Anova Results

From the anova table above, we observe the P-value (probability value) is less than the confidence level (0.05) and hence we can conclude that all the two factors have significant effect on the Tensile strength value.

Fracture test: After tabulating the Tensile strength, the reading were analysed using MINITAB-16 software and the results were tabulated and following graphs, anova table, least square means were obtained as follows.

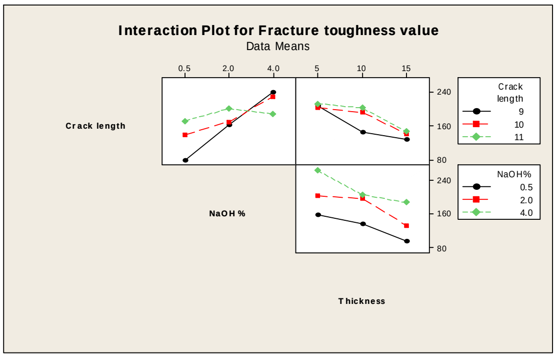


Fig 10 Interaction plot

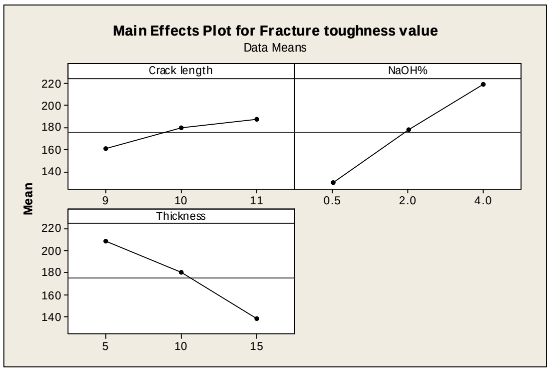


Fig 11 Main Effect plot

After performing the analysis using MINITAB software, the interaction plot is obtained and following interpretations can be made

- Factors crack length and thickness show severe interaction between 5mm to 15mm thickness and as crack length increases the load decreases.
- Crack length of 9mm and 10mm increases from 0.5% to 4% NaOH but 11mm crack length decreases as NaOH percentages increases and there is interaction between 9mm and 10mm crack length at 4% NaOH and they have high fracture toughness value hence their combined effect is more.
- As NaOH percentages increases there is decrease in fracture toughness value and also thickness increases, fracture toughness value decreased.

After studying the individual effects using main effects plot, following interpretations can be made.

- As crack length increases from 9 mm to 11mm the fracture toughness value increases, hence at 11mm crack length the fracture toughness value is high and at 9mm crack length fracture toughness value is less.
- As NaOH% increases from to 0.5% to 4% NaOH the fracture toughness value increases, hence at 4% NaOH the fracture toughness value is high and at 0.55 NaOH fracture toughness value is less.

As thickness of specimens increases from 5mm to 15mm thickness the fracture toughness value decreases, hence at 5mm thickness the fracture toughness value is high and at 15mm thickness fracture toughness value is less.

General Linear Model: Fracture tou versus Crack length, NaOH%, Thickness

Factor	Type	Levels	Values
Crack length	fixed	3	9, 10, 11
NaOH%	fixed	3	0.5, 2.0, 4.0
Thickness	fixed	3	5, 10, 15

Analysis of Variance for Fracture toughness value, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Crack length	2	3498	3498	1749	1.02	0.377
NaOH%	2	35759	35759	17879	10.46	0.001
Thickness	2	21954	21954	10977	6.42	0.007
Error	20	34183	34183	1709		
Total	26	95394				

S = 41.3420 R-Sq = 64.17% R-Sq(adj) = 53.42%

Fig 12 Anova Results

From the anova table above, we observe the P-value (probability value) is less than the confidence level (0.05) and hence we can conclude that all the two factors have significant effect on the Fracture toughness value.

V. CONCLUSION

Alkaline treatment of hemp fibre reduces its weight. This is due to removal of moisture contain from the fibre. The alkaline treatment of hemp fibre increased the tensile strength of hemp/epoxy composites, indicating that interfacial bonding improved after alkaline treatment. The best tensile strength of the hemp reinforced epoxy composites were achieved with the 2% alkali chemical treatment. Meanwhile, the tensile strength of the 4% NaOH-treated fibre composite was lower than those of the 2% and 0.5 % NaOH-treated composites.

Fracture study deals with study of cracks created in materials due to load applied. It is cleared observed that as the thickness of the material increases the fracture toughness value is decreeing. But the variation in crack length causes it to increase as the length changes from 9 mm to 11 mm.

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