Effect of Water Immersion on Various Properties of Natural Fiber Reinforced Composite Materials

Channakeshava A[1], Dr. Maruthi B. H[2], Dr. K. Channakeshavalu[3]

[1]Research Scholar, Department of Mechanical Engineering, East West Institute of Technology, Bangalore, Karnataka, India
[2]Professor & Head, Department of Mechanical Engineering, East West Institute of Technology, Bangalore, Karnataka, India
[3]Principal, East West Institute of Technology, Bangalore, Karnataka, India

---

Abstract:- Effect of water immersion on sheep fiber reinforced with epoxy composites, were studied at different conditions. The present investigation is focused on the various fracture characterization of the sheep wool fiber-reinforced polymer-matrix composites. Result shows the effect of water immersion of woven sheep fiber composite of composition. The statistical method of Taguchi was used for experimental design. After water immersion, Edge Notched Tension (ENT) and Single Edge Notched Bend (SENB) test were conducted according to the ASTM E1922 and ASTM D5045 correspondingly. Main effect graphs are obtained to study the effect of a/w ratio, thickness and immersion time of composite on fracture constraints. The methodology of computing the percentage of impact of control variables was established using by analysis of variance (ANOVA). The influence of water immersion on fracture parameters of control factors can be analysed by using response surface graph (RSM) and linear regression method.

Keywords: Sheep wool, Polymer, Water immersion, ANNOVA, RSM

1. INTRODUCTION

Composites are blended with more than two materials in which one of the materials is reinforcing medium and the other is matrix medium. Composite materials are generally classified by the type of reinforcement such as polymer composites, cement and metal matrix composites [1]. The matrix phase plays an important role in the carrying out of polymer composites. In thermoset composites, component involved are such as base resin, hardeners. In this fiber loading can be high as 80% this is due to alignment of fibers. Properties of the fiber, aspect ratio of fiber- matrix interface governs the properties of composites. The surface attachment among the fibers and polymer plays a crucial part in the transmission of stresses from matrix to fiber and then contributing towards the completion of the composites [2]. Natural fibres are largely divided into three categories depending on their origin that includes mineral based, plant based, and animal based [2]. The physical and chemical characterization of the sheep woven fiber reinforced polymer composites. Hand lay-up technique is used for the preparation of the specimens, specimen preparation were carried out under ASTM standards. In this work, tensile and bending tests were carried out for different composition of composites. Resulting that (50-50) composition will give better result than (60-40) composition [3]. The fracture properties on glass fiber composite and its size effect, hand lay-up technique is used for preparing laminates [4]. The fracture mode of jute fiber reinforced composites, for various notch sizes. The obtained results are optimized by a method called Taguchi technique. The fracture toughness results were reported and analysed using Analysis of Variance (ANOVA) and Response Surface Analysis (RSM) is carried out to estimate the influencing factors [5]. The main aim of the present work is to proceed and characterize the new class of composites of sheep wool fiber reinforced composites. To study the effect of water immersion of specimen, it is treated with normal water, distilled water and sea water. Finally, determining the contribution of single parameter by using Taguchi method, ANOVA and RSM.

2.1 MATERIALS

The experiments are conducted for laminated composite material. The materials which are selected for this present work for preparation of composites are mentioned below: Reinforcing material as Sheep wool fiber and Matrix material as epoxy resin (L-12 and K-6). The considered volume fraction is shown in table 2.1.

Table 2.1 Percentage composition of materials in composites

Reinforcement	Matrix	Composition
60%	40%	100%
Sheep wool	Epoxy Resin	composite

Wool is a form of textile fiber, extracted from sheep and from other animals also. Wool is having some typical qualities that make difference it from hair or fur. Wool is crimped, it is elastic and it grows in bunch form. Hand layup process is considered for preparation of composites. Standard dimensions are considered as per ASTM standards.

3.1 EXPERIMENTATION

Water immersion test was conducted for ENT and SENB specimens. In this work the test specimens are soaked in different types of water they are normal water, distilled water and sea water. The ENT and SENB test specimens are soaked in these waters for four days. After four days the moisture absorption of sheep wool fabric composite will become constant [3].

Table 3.1: Factors and level combination for ENT test specimen

Code	Control factors	Level 1	Level 2	Level 3
A	(a/w) ratio	0.4	0.5	0.6
B	Width in mm	20	25	30
C	Thickness in mm	7	10	12
D	Water	Sea	Normal	Distilled

Table 3.2: Factors and level combination for SENB test specimen

Code	Control factors	Level 1	Level 2	Level 3
A	(a/w) ratio	0.45	0.5	0.55
B	Width in mm	20	25	30
C	Thickness in mm	7	10	12
D	Water	Sea	Normal	Distilled

For water immersion test, the L9 orthogonal array has been changed, consisting of four control factors and three levels is as shown in table 3.1.

Table 3.1: Experimental design using L9 Orthogonal array

Trial	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

4. RESULTS AND DISCUSSION

Experiments were carried out to specify the failure load and fracture toughness of composite material in configuration of specimen, the analysis of the results and effect of process parameters on the mechanical properties were discussed.

4.1 Edge Notched Tension (ENT) test under water immersion

ENT test specimens are immersed in three different types of water they are distilled, normal and sea water in order to find out the damaze characterization properties of composite material. Experimental results are reported in table 4.1. During testingfailure load were recorded and for that corresponding fracture toughness is calculated by using formula.

Table 4.1 Experimental results of ENT based on Taguchi orhogonal array (L9)

SL No	a/w	Width (mm)	Thickness (mm)	Type of water	Failure load (N)	Fracture toughness (Mpa$\sqrt{m}$)
1	0.4	20	7	Distilled	155	34.93
2	0.4	25	10	Normal	185	26.26
3	0.4	30	12	Sea	235	25.53
4	0.5	20	10	Sea	185	38.93
5	0.5	25	12	Distilled	205	32.25
6	0.5	30	7	Normal	155	37.85
7	0.6	20	12	Normal	155	38.20
8	0.6	25	7	Sea	135	50.75
9	0.6	30	10	Distilled	185	44.91

4.1.1 Main effect plots for ENT test under water immersion:

4.1.1.1 Main effect plot for load carrying capacity (N):

The main effect plot of ENT test for Load carrying capacity under water immersion is represented in figure 4.1. Figure illustrates that as decrement in a/w ratio causes the increase in load carrying capacity this is due to the increase in crack depth, then the critical stresses are decreases in terms reduces the load carrying capacity [4]. Sea water degradation can cause plasticisation, swelling and also debonding in the fiber matrix interface and those causes reduce in the mechanical properties.

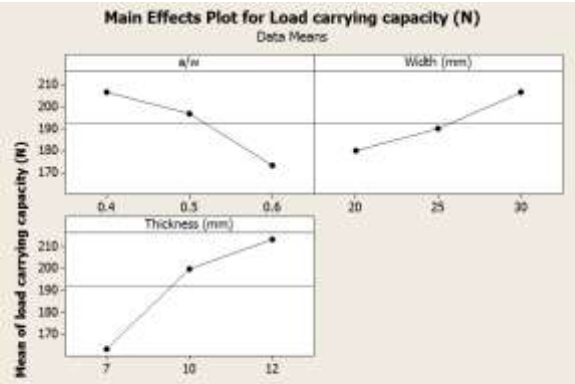

Fig 4.1: Main effect plot for load carrying capacity (N)

4.1.1.2 Main effect plot for Fracture toughness (Mpa$\sqrt{m}$):

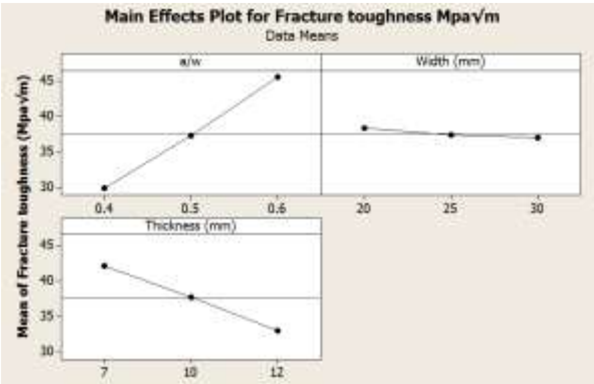

Fig 4.2: Main effect plot for Fracture toughness (Mpa$\sqrt{m}$)

Main effect plot for fracture toughness under water immersion is as shown in figure 4.2. Fracture toughness will increases with increasing in a/w ratio due to plastic zone size will increase with increasing in crack length. A thicker material having high plastic zone hence toughness decreases in increasing of thickness of material.

4.1.2 Analysis of Variance (ANOVA) for ENT test under water immersion

Table 4.2 ANOVA for Load carrying capacity (N)

Source	DF	SS	MS	F	P	%of confid ence level
a/w ratio	2	1755.6	877.8	2.55	0.282	23.24
Width (mm)	2	1088.9	544.4	1.58	0.387	14.41
Thickness (mm)	2	4022.2	2011.1	5.84	0.146	53.23
Error	2	688.9	344.4			9.11
Total	8	7555.6				100

ANOVA for load carrying capacity under water immersion treatment is shown in table 4.2. The percentage of confidence level of each factor is listed in table. Thickness gives amajor contribution is about 53.23% the percentage contribution of a/w ratio is about 23.24% and width is having lesser contribution that is 14.41%. Finally conclude that the composite material couldn't cause any sever damage to the material.

Table 4.3 ANOVA for Fracture toughness (Mpa$\sqrt{m}$)

Source	DF	SS	MS	F	P	%of confid ence level
a/w ratio	2	370.72	185.36	12.28	0.075	69.95
Width (mm)	2	2.55	1.28	0.08	0.922	0.48
Thickness (mm)	2	126.53	63.26	4.19	0.193	23.87
Error	2	30.20	15.10			5.7
Total	8	530.00				100

ANOVA for Fracture toughness under water immersion treatment is shown in table 4.3. The percentage of confidence level of each factor is listed in table. a/w ratio gives a major contribution is about 69.95% the percentage contribution of Thickness ratio is about 23.87% and width is having lesser contribution that is 0.48%.

4.1.3 Response Surface Methodology

Surfce plot of load carrying capacity v/s thickness, a/w ratio is shown in figure 4.15. Figure illustrates that increase of load carrying capacity with increase in thickness and it decreases with the decreaes in a/w ratio. For highest value of load carrying capacity is found at 12 mm thikness specimen. Surface plot of load carrying capacity v/s width, a/w ratio is shown in figure 4.16. Figure illustrates that increase of load carrying capacity with increase in width and it increaes with the decreaes in a/w ratio. For highest value of load carrying capacity is found at 30 mm width of specimen.

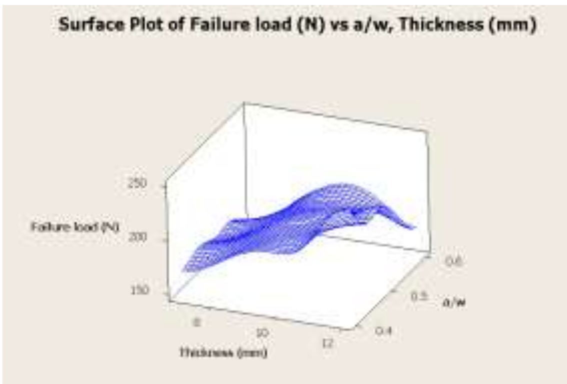

Fig 4.3: Surface plot for Load carrying capacity (N)

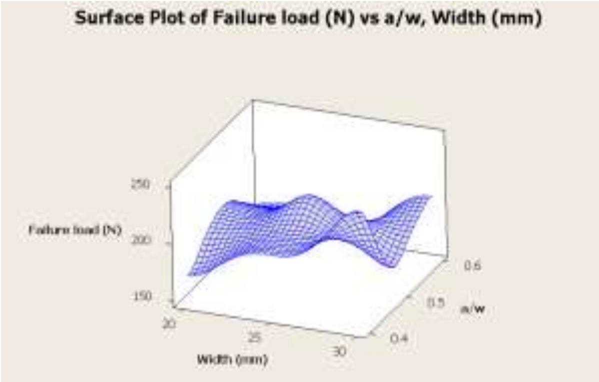

Fig 4.4: surface plot for Load carrying capacity (N)

Surface plot of fracture toughness v/s thickness, a/w ratio is shown in figure 4.5. Figure illustrates that increase in fracture toughness with decrease in thickness and increase in a/w ratio. As the crack depth value increases toughness will increase.

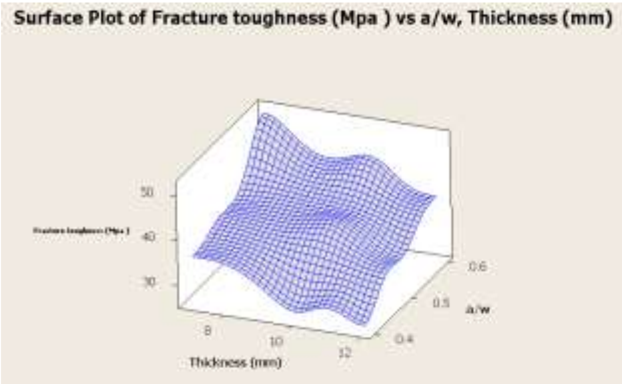

Fig 4.5: Surface plot of Fracture toughness (Mpa$\sqrt{m}$)

Surface plot of fracture toughness v/s width, a/w ratio is shown in figure 4.6. Figure indicates that increase of fracture toughness with decreasing in width and increasing in an a/w ratio.

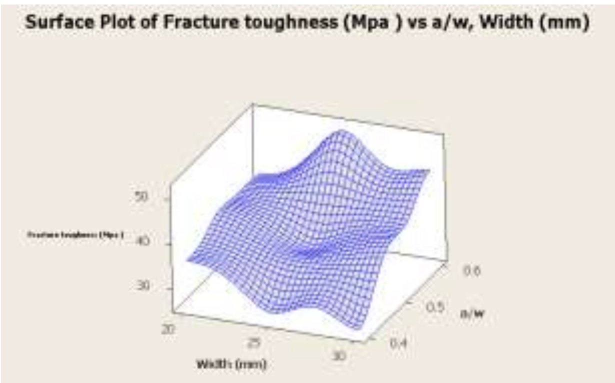

Fig 4.6: Surface plot of Fracture toughness (Mpa$\sqrt{m}$)

4.2 Single Edge Notched Bend (SENB) test under water Immersion

The bending test were carried out for different specimen configurations such as a/w ratio, width and thickness and immersed in water. Experimental results of failure load for each specimen is recorded in table 4.10 and corresponding fracture toughness is calculated by using suitable formula. Main effects plots are plotted using ANOVA. Response surface analysis is done and surface plot are plotted.

Table 4.4 Experimental results of SENB test based on Taguchi orthogonal array (L9)

SL No	a/w	Width (mm)	Thick ness (mm)	Type of water	Failure load (N)	Fracture toughness (Mpa$\sqrt{m}$)
1	0.45	20	7	Distilled	235	67.21
2	0.45	25	10	Normal	305	54.90
3	0.45	30	12	Sea	355	48.73
4	0.50	20	10	Sea	305	71.49
5	0.50	25	12	Distilled	325	56.85
6	0.50	30	7	Normal	235	63.94
7	0.55	20	12	Normal	305	70.32
8	0.55	25	7	Sea	255	89.84
9	0.55	30	10	Distilled	305	68.90

4.2.1Main effect plots for SENB test under water immersion

4.2.1.1 Main effect plot for load carrying capacity (N):

The main effect plot for load carrying capacity for SENB test specimens under water immersion is shown in figure 4.7. Composite material failure occurs by bending load causes the delamination; it is due to water absorption by the specimen. The figure illustrates that load carrying capacity decreases with increasing in a/w ratio. Load carrying capacity increases with increase in both thickness and width.

The main effect plot of fracture toughness for SENB specimens under water immersion is shown in figure 4.8. Figure illustrates fracture toughness increases with increasing in a/w ratio. The large amount of energy is required for failure of material. As thickness increases the fracture toughness will decreases due to water absorption may be in small quantity due to presence of any voids and cracks in the specimen.

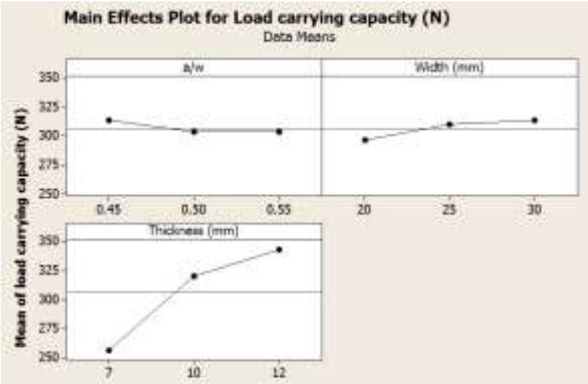

Fig 4.7: Main effect plot for load carrying capacity (N)

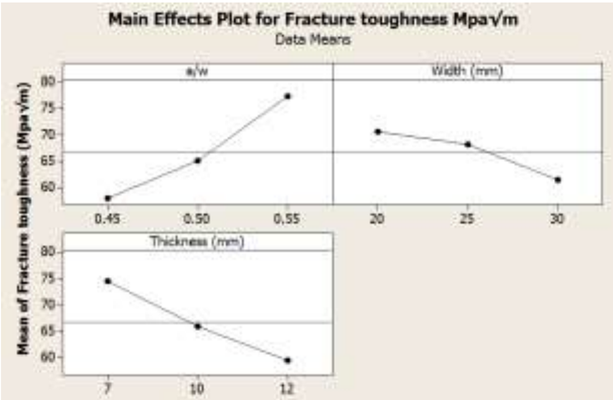

Fig 4.8: Main effect plot for Fracture toughness (Mpa$\sqrt{m}$)

4.2.2 Analysis of Variance (ANOVA) for SENB test under water immersion

Table 4.5 ANOVA for Load carrying capacity (N)

Source	DF	SS	MS	F	P	%of confidence level
a/w ratio	2	200	100	0.23	0.813	1.47
Width (mm)	2	466.7	233.3	0.54	0.650	3.43
Thickness (mm)	2	12066.7	6033.3	13.92	0.067	88.73
Error	2	866.7	433.3			6.37
Total	8	13600				100

ANOVA for load carrying capacity of SENB test under water immersion is listed in table 4.5. It shows that percentage of contribution of each factor on load carrying capacity. The major contribution is from thickness it is about 88.73%, due to larger surface area is exposed to the load.

Table 4.6 ANOVA for Fracture toughness (Mpa$\sqrt{m}$)

Source	DF	SS	MS	F	P	%of confidence level
a/w ratio	2	578	298.0	7	0.125	50.87
Width (mm)	2	134.39	67.19	1.63	0.381	11.83
Thicknesss (mm)	2	341.06	170.53	4.13	0.195	30.02
Error	2	82.63	41.31			7.27
Total	8	1136.08				100

ANOVA for fracture toughness for SENB specimens is listed in table 4.6. The main factor influencing on toughness is a/w ratio it is about 50.87% it is due to decrement of load carrying capacity.

4.2.3 Response Surface Methodology (RSM):

Surface plot of load carrying capacity v/s thickness, a/w ratio is shown in figure 4.9. Figure illustrates that increase of load carrying capacity with increase in thickness and it decreases with the decreaes in a/w ratio. For highest value of load carrying capacity is found at 12 mm thikness specimen. Surface plot of load carrying capacity v/s width, a/w ratio is shown in figure 4.10. Figure illustrates that increase of load carrying capacity with increase in width and it increaes with the decreaes in a/w ratio. For highest value of load carrying capacity is found at 30 mm width of specimen.

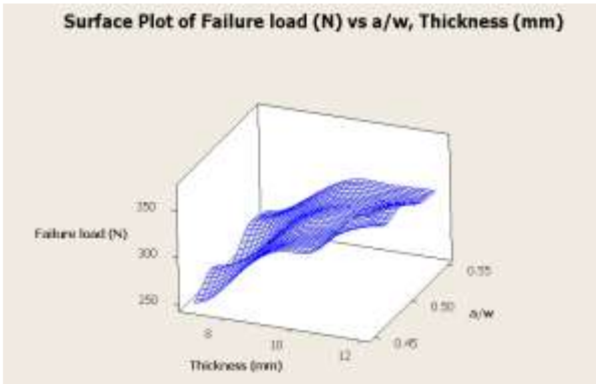

Fig 4.9: Surface plot for Load carrying capacity (N)

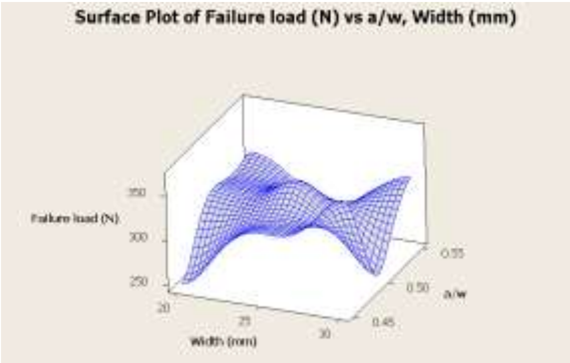

Fig 4.10: Surface plot for Load carrying capacity (N)

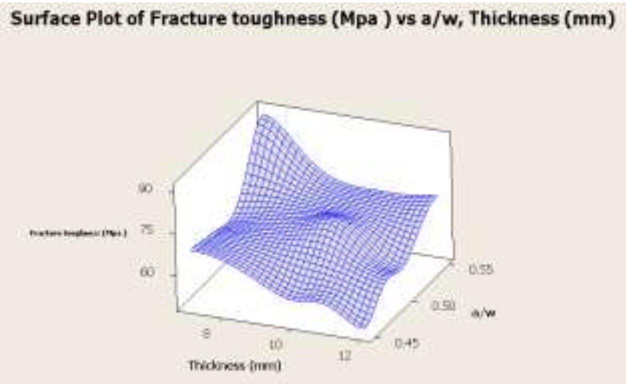

Fig 4.11: Surface plot of Fracture toughness (Mpa$\sqrt{m}$)

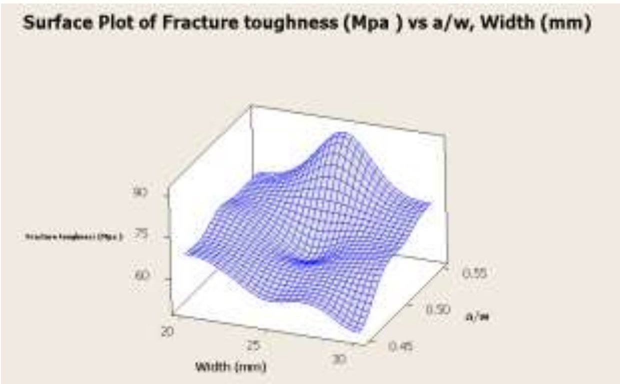

Fig 4.12: Surface plot of Fracture toughness (Mpa$\sqrt{m}$)

Surface plot of fracture toughness v/s thickness, a/w ratio is shown in figure 4.11. Figure illustrates that increase in fracture toughness with decrease in thickness and increase in a/w ratio. As the crack depth value increases toughness will increase. Surface plot of fracture toughness v/s width, a/w ratio is shown in figure 4.12. Figure indicates that increase of fracture toughness with decreasing in width and increasing in an a/w ratio.

5. LINEAR REGRESSIONS

To obtain the relationship between the load carrying capacity / fracture toughness and different parameters such as a/w ratio, width, thickness, diameter of hole, eccentric distance and crack length for these all a mathematical equations were developed.

5.1 Mathematical Equations

5.1.1 For ENT under water immersion test:

Load carrying capacity (N): 90.5 – 167(A) + 2.67(B) + 10.2(C)…………..5.1

Fracture toughness (Mpa$\sqrt{m}$): 17.9 + 78.6(A) – 0.126(B) – 1.81(C)………...5.2

5.1.2 For SENB under water immersion test:

Load carrying capacity (N): 125 – 100(A) + 1.67(B) + 17.6(C)…………...5.3

Fracture toughness (Mpa$\sqrt{m}$): 20.5 + 194(A) – 0.915(B) – 2.99(C)…………5.4

Where,

A = a/w ratio

B = width in mm

C = thickness in mm

5.2 Experimental validation for ENT test under water immersion:

Table 5.1 Confirmation test table for load carrying capacity (N)

Factor combination (a/w, width, thickness)	Experimental load (N)	Predicted load (N)	% Error
0.4, 20, 7	168.33	148.5	11.780
0.5, 25, 10	180.55	175.75	0.026
0.6, 30, 12	182.77	192.8	5.202

Table 5.2 Confirmation test table for Fracture toughness (Mpa$\sqrt{m}$)

Factor combination (a/w, width, thickness)	Experimental Fracture toughness (Mpa$\sqrt{m}$)	Predicted Fracture toughness (Mpa$\sqrt{m}$)	% Error
0.4, 20, 7	35.80	34.15	4.60
0.5, 25, 10	36.48	35.95	1.45
0.6, 30, 12	37.56	39.56	5.05

5.5 Experimental validation for SENB test under water immersion:

Table 5.3 Confirmation test table for load carrying capacity (N)

Factor combination (a/w, width, thickness)	Experimental load (N)	Predicted load (N)	% Error
0.45, 20, 7	273.88	236.6	13.62
0.50, 25, 10	296.11	292.75	0.12
0.55, 30, 12	304.99	331.3	7.94

Table 5.4 Confirmation test table for Fracture toughness (Mpa$\sqrt{m}$)

Factor combination (a/w, width, thickness)	Experimental Fracture toughness (Mpa$\sqrt{m}$)	Predicted Fracture toughness (Mpa$\sqrt{m}$)	% Error
0.45, 20, 7	66.75	68.57	2.65
0.50, 25, 10	65.45	64.73	1.10
0.55, 30, 12	65.16	63.87	1.98

The table 5.1 shows for ENT test under water immersion for load carrying capacity the deviation in error change from 0.026 to 11.780% and for fracture toughness varies from 1.45 to 5.05% as shown in table 5.6. The table 5.3 represents for SENB test under water immersion for load carrying capacity the deviation in error varies from 0.12 to 13.62% and for fracture toughness error varies from 1.10 to 2.65% as shown in table 5.8.

CONCLUSION

The sheep wool fiber reinforced epoxy polymer composite have been studied and analysed various fracture behaviours and also calculated for several factors. And can be concluded as the percentage of contribution of thickness is more on load carrying capacity and a/w is more on fracture toughness. Thickness is the major contribution on load carrying capacity is major contribution on fracture toughness.

References

[1] M.P. Westmen, L.S Fifield, K.L. Simmons, S.G. Laddha and T.A. Kafentzis. Natural fiber composites: A Review U.S. department of energy March 2010 PNNL-19220.

[2] D. Chandramohan and K.Marimuthu, A Review of natural fibers. IJRRAS August 2011: Vol 8,ISSUE 2, IJRRAS.

[3] K.N. Bharath, Mudasar Pasha and B.A. Nizamuddin. Characterization of natural fiber (Sheep wool) – reinforced polymer – matrix composites at different operating conditions, Journal of industrial textiles, 2014, 1-22.

[4] Y. Mohammed, Mohamed k. Hassan, Abu El-Ainin H, A.M. Hashem. Fracture properties of glass fiber composite laminates and size effect, SJET Sch. J. Eng. Tech., 2013; 1(1): 13-26.

[5] Sandip kumar Bhagat, Sandesh patil, Nilesh Dhavaleand Akash Mohanty. Estimation and comparison of Stress intensity factor in epoxy resin components with Eccentric V-notches, International Journal of Applied Engineering Research Vol.8, No.19 (2013) ISSN 0973 –4562.

[6]G. B. Manjunath, T.N. Vijaykumar and K.N. Bharath, Optimization of Notch Parameter on Fracture toughness of Natural Fiber Reinforced Composites Using Taguchi Method. Journal of Materials Science & Surface Engineering Vol. 3(2) 2015 99 244 – 248.

[7] Omar suliman Zaroog, Mahmoud Ahmed Mohamed Zein, Abreeza Noorlina Abd. Manap. Fracture Toughness of Composite Materials. International Journal of Science and Research (IJSR). ISSN : 2319-7064.

[8] Krishankant, Jatin Taneja, Mohit Bector, Rajesh Kumar. Application of Taguchi Method for Optimizing Turning Process by the Effects of Machining parameters. International Journal of Engineering and Advanced Technology (IJEAT) Volume 2, 2012 ISSN: 2249-8958.