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Properties of 'Emu' Feather Fiber Composites

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ABSTRACT
A composite is usually made up of at least two materials out of which one is binding material called matrix and the other is a reinforcement material known as fiber. Many researchers are focusing on natural fiber composites. But, in the present work, composites were prepared with epoxy (Araldite LY-556) resin and 'emu' bird feathers as fiber. The composites were prepared by varying the weight percentage (P) of 'emu' fiber ranging from 1 to 5 and length (L) of feather fibers from 1 to 5 cm. The composite specimens were prepared and cured as per ASTM standards. Studies were carried out on various properties like mechanical properties, Thermal properties and Effect of atmosphere, Soil and certain Chemicals. An attempt is made to model the mechanical properties through response surface methodology (RSM). Analysis of Variance (ANOVA) is used to check the validity of the model. The results reveal that the developed models are suitable for prediction of mechanical properties of Epoxy 'Emu' Feather Fiber Composites.

Key words:- Emu bird feathers, Epoxy composites, Epoxy resin, Mechanical properties, Response Surface Methodology.

I. Introduction

Composite materials are produced by combining two dissimilar materials into a new material that may be better suited for a specific application than the individual material alone[1,2]. Important characteristics of composites are their strength, hardness, rigid, light in weight, environmental sustainability and biodegradability. The natural fiber reinforced polymer composites were used in several applications automotive, marine etc. The Studies reveals that the final properties of composites depend upon the properties of fiber and the interfacial bonding of fiber and matrix. The chemical bonding plays important role between the matrix and the fiber. Natural fibers become attractive to researchers due to their wide availability, low cost, lightweight and environmentally degradable [3,4,5]. Plant fibers consist of cellulose while animal fibers consist of proteins [6]. The chemical bonding plays important role between the matrix and the fiber. Reports on composites using bird feathers as reinforcing fibers are rare [7]. A notable disadvantage of natural fibers is their polarity which makes it incompatible with hydrophobic matrix [8]. Many physical and chemical methods were developed to improve the bonding between the natural animal feathers and matrix material. Chemical treatment method of natural fibers was explained by [9].These methods make the feathers free from moisture and impurities. These methods affect the bonding of fiber and matrix. The Emu (Dromaius novaehollandiae) is the largest bird native to Australia and the only extant member of the genus Dromaius. It is also the second-largest extant bird in the world by height, after its ratite relative, the ostrich. There are three extant subspecies of Emus in Australia. In the present work emu feathers were selected as fibers because, Emu Chicken feathers are waste products of the poultry industry. Billions of kilograms of waste feathers are generated each year by poultry processing plants, creating a serious solid waste problem. The objective of the study is to investigate the effect of length and percentage weight of feather on mechanical properties of epoxy polymer composites.

In the present work 'Emu' feathers were used as fibers because, 'Emu' Chicken feathers are waste products of the poultry industry. A study on mechanical properties of chicken feather composites [10] was carried by Jeffrey W.Kock. The Emu (Dromaius novaehollandiae) is the largest bird native to Australia and the only extant member of the genus Dromaius. The objective of the study is to investigate the effect of length and weight percentage of feather on the properties like Mechanical properties, Thermal properties and Effect of atmosphere, Soil and certain Chemicals.

II. Materials and Methodology

2.1. Extraction of fiber

The 'Emu' feather fiber collected from the local area, is washed several times with water then soaked in 5% of NaOH concentrated water for 30 minutes. The soaked feathers then washed with detergent water followed by pure water and then is dried in sun rays. A clean fiber free from dirt and impurities are obtained.

2.2. Preparation of composites

Laminates are prepared by hand layup technique. Composites are prepared from epoxy (Araldite LY-556) and hardener mixed in the ratio of 10:1 by weight [11] as recommended. To prepare the composite specimens, these fibers in pre determined weight proportion and length (maximum of 5% & 5 cm) are reinforced into the epoxy resin. Blocks of size (200mm x 20mm x 3mm) for tensile, (127mm x 13mm x 3mm) for flexural, (65mm x 13mm x 3mm) for impact test were cast with hand layup technique in a rubber mould. The control parameters used and their levels chosen are given in the below Table 1.

Table: 1 Control parameters and their levels.

Control parameters	Level 1	Level 2	Level 3	Level 4	Level 5
Percentage of fiber (P) %	1	2	3	4	5
Fiber length (L) in cm	1	2	3	4	5

The specimens were prepared by varying the fiber length from 1 to 5 cm and percentage weight of fiber (Fiber loading) from 1 to 5 percent. Specimens thus prepared were put under load for about 24 hours for proper curing at room temperature. After this, the specimens were removed from the moulds and cured further at a constant temperature of up to 70^{o}c for 3 hours.

III. Tests conducted on Mechanical properties

The following tests were conducted on the prepared emu feather fiber reinforced epoxy composites. In each case three samples were taken and the average values were considered.

The tensile test is performed on a flat specimens following ASTM test standard ASTMD 638 in the universal testing machine Instron. Flexural strength and Flexural Modulus were determined by the equipment as per ASTM D790 procedure. The load applied and the corresponding deflection, were recorded. Flexural strength is calculated. Impact strength of unnotched specimen was determined using charpy - impact tester according to ASTM D 256 standards.

IV. Test results

The mean values of Test results for the deferent combinations of Fiber loading and length of fiber are as presented in Table 2.

Table 2. Test results for various fiber loadings and lengths of fiber

Sl. No.	Fiber loading (%)	Length of fiber (cm)	Tensile strength (Mpa)	Impact strength (Joules/mm)	Flexural strength (Mpa)	Flexural Modulus (Mpa)
1	1	1	28.28	106.22	21.88	1335.70
2	1	2	27.37	112.78	21.27	1257.43
3	1	3	26.95	127.22	21.12	1182.20
4	1	4	26.11	136.11	21.30	1063.87
5	1	5	25.34	145.89	20.67	937.86
6	2	1	24.57	113.33	20.77	1175.96
7	2	2	24.65	120.67	19.71	1093.39
8	2	3	24.08	133.22	19.65	1028.39
9	2	4	23.94	149.67	19.35	947.72
10	2	5	23.81	174.44	18.79	848.03
11	3	1	23.64	116.89	19.48	1045.33
12	3	2	23.08	125.33	18.40	976.13
13	3	3	22.74	138.44	18.55	925.94
14	3	4	22.79	155.56	18.53	813.91
15	3	5	22.31	184.56	17.67	757.96
16	4	1	22.21	128.56	16.98	1010.85
17	4	2	21.81	142.00	16.72	929.83
18	4	3	21.63	171.00	15.99	852.60
19	4	4	21.53	194.67	17.12	778.05
20	4	5	21.40	203.56	16.48	701.46
21	5	1	21.00	135.89	15.87	913.82
22	5	2	20.63	159.33	15.66	832.03
23	5	3	20.28	187.89	14.63	795.26
24	5	4	19.64	210.67	14.74	735.49
25	5	5	19.30	221.44	14.03	645.02
26	Epoxy		29.72	106.22	21.88	1335.70

Graphical representation of the Tensile test results and Impact test results are shown in Fig. 3 and 4 respectively.

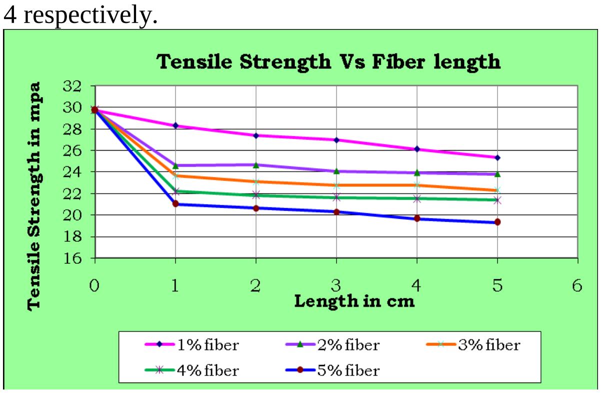

Fig. 3 Graphical representation of Tensile test results

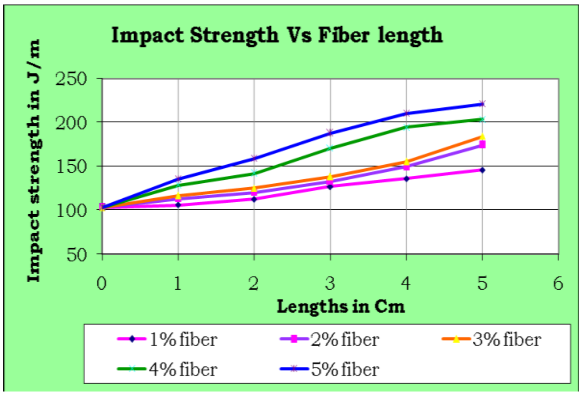

Fig. 4 Graphical representation of Impact test results

A graphical representation of the Flexural strength values and Flexural Modulus are shown in Fig. 5 and 6 respectively.

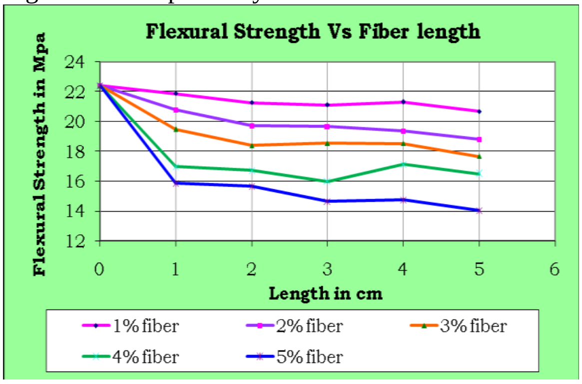

Fig. 5 Graphical representation of Flexural strength

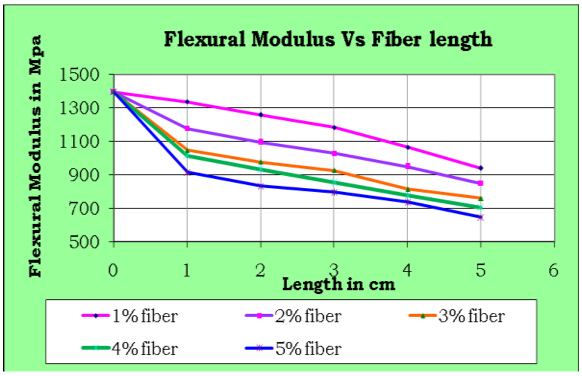

Fig. 6 Graphical representation of Flexural Modulus

V. 5. Response surface methodology (RSM)

RSM is a collection of mathematical and statistical techniques that are useful for modeling, analysis and optimizing the process in which response of interest is influenced by several variables. RSM uses quantitative data from appropriate experiments to determine and simultaneously solve multi variant equations. The RSM comprises regression surface fitting to obtain approximate responses, design of experiments to obtain minimum variances of the responses and optimizations using the approximated responses.

The experimental results are modeled using RSM and empirical model has been developed. Summary of models for the four responses are shown in the Table 3.

Table.3 Model Summary Results

Test	Model expression	R^2	Adj R^2
TS	TS =3.0102 -0.2632 P -0.0612 L+ 0.0154 P^2 + 0.0014 L^2 + 0.0054 PL	97.8	97.2
FS	FS = 23.4204 - 0.9843 P - 0.5453 L - 0.0883 P^2 + 0.04871 L^2 - 0.024 PL	97.4	96.7
FM	FM = 1586.03 - 189.911P - 81.1457L + 12.9806 P^2 - 3.01 L^2+ 6.5727 PL	99.1	98.9
IS	IS =99.3239 -4.0691 P +4.7991 L+ 1.6314 P^2 + 0.5604 L^2 + 2.9099 PL	97.5	96.8

The statistical testing of the developed models was done by Fisher's statistical test for the analysis of variance (ANOVA). The results of ANOVA at 95% confidence interval are presented in table 4 and it is found that the developed mathematical models are significant at 95% confidence interval as F - ratio of all three models is greater than 143.

The Fig. 7 to 10 shows comparison between experimental values and RSM predicted values of mechanical properties.

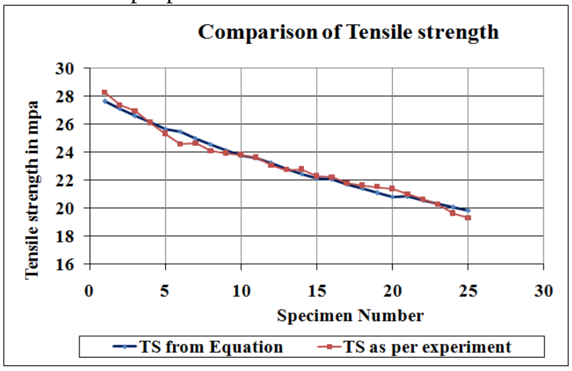

Fig.7 Comparison of experimental values with predicted values for Tensile strength (TS)

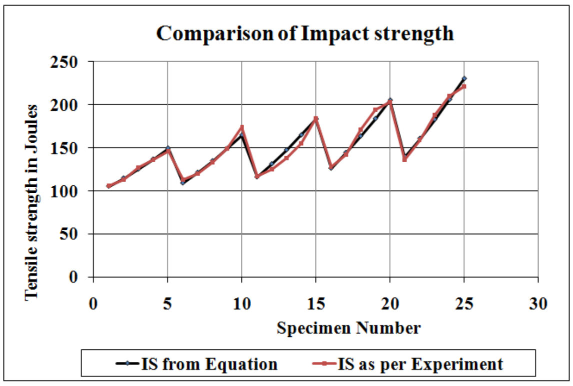

Fig. 8 Comparison of experimental values with predicted values for Impact strength (IS)

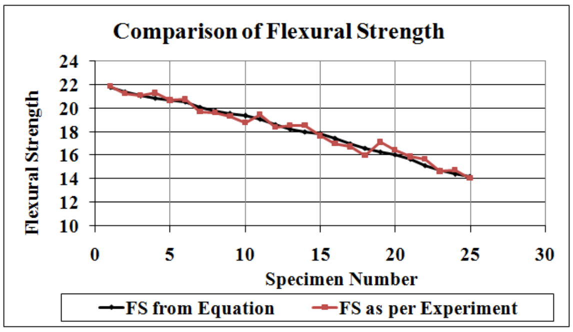

Fig. 9 Comparison of experimental values with predicted values for Flexural strength (FS)

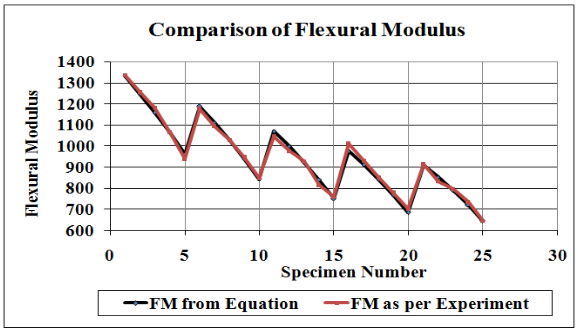

Fig. 10 Comparison of experimental values with predicted values for Flexural Modulus (FM)

ANOVA results for Mechanical properties of composite material, viz., Tensile strength, Flexural strength, Flexural modulus and Impact strength are presented in Table 4.

Table 4. ANOVA results for Mechanical properties of composite material

Response	Sum of squares		Degree of freedom		Mean squares		F - Ratio
	Regression	Residual	Regression	Residual	Regression	Residual	
TS	1.27794	0.02893	5	19	0.2555	0.00152	167.88
FS	131.820	3.502	5	19	26.364	0.184	143.06
FM	758716	6673	5	19	151743	351	432.08
IS	25760	671.4	5	19	5152	35.3	145.80

1. The mechanical properties viz., Tensile strength (TS), Flexural strength (FS), Flexural modulus (FM) and Impact strength (IS) of the 'Emu' feather fiber epoxy composite material is greatly influenced by fiber length and as well as fiber loading.
2. Tensile strength, Flexural strength, Flexural modulus decreases with increase in the % of fiber and with increase in the fiber length.
3. Impact strength increases with increase in % of fiber and increases with increase in fiber length.
4. Developed RSM models can be used to predict the mechanical properties of 'Emu' feather fiber epoxy composite materials at 95% confidence level.
5. Accuracy of the model can be improved by including more number of parameters and levels.

VI. Thermal properties

The 'Emu' feather fiber epoxy composites (with various percentage weights and lengths of fiber) were subjected to TGA, DSC and DTG tests and the results observed are shown in Tables 5 and 6.

Table. 5 Temperature corresponding to various percentages of degradation

Sl No.	Percentage Degradation	Temperature in ^{o}C					
		Epoxy	1% of Fiber	2% of Fiber	3% of Fiber	4% of Fiber	5% of Fiber
1	5%	200	250	250	250	250	250
2	10%	290	325	325	325	325	325
3	15%	320	340	340	340	340	340

Table. 6 Temperature corresponding to Maximum degradation for various fiber loadings.

Sl No.	Percentage Degradation	Temperature in ^{o}C for degradation for					
		Epoxy	1% of Fiber	2% of Fiber	3% of Fiber	4% of Fiber	5% of Fiber
1	Starting	280	300	300	300	300	300
2	Ending	410	450	450	450	450	450

VII. Effect of Atmosphere and Soil on Composites

The effect of atmosphere and soil on the composites was studied. For the above purpose, the composite specimens were exposed to atmosphere at three different locations ie., Anantapur, Nandyal and Hyderabad. Similarly, the specimens are buried under earth at the above three locations. In each case, three pre weighed samples were exposed to atmosphere as well as three pre weighed samples were buried under earth. At the end of the month, specimens were cleaned thoroughly with distilled water and dried by pressing them on both sides by filter papers. The final weight of the samples and % weight loss or gain was determined.

The experiments were conducted for various fiber loadings and fiber lengths.

The degradation process of poultry feathers was studied in detail by Vijay Kumar et al. [12].

7.1 Effect of Atmosphere

In general, the effect of Atmosphere and soil on all the samples including pure epoxy is negligible. It was observed that maximum 1.0% of weight loss was noticed when the 5% fiber loading composite samples were exposed to atmosphere at Anantapur. Maximum of 0.58% loss in thickness was observed for the composite samples when exposed to atmosphere at Anantapur. The effect of atmosphere on the 'Emu' feather fiber reinforced epoxy composite have been presented in the Table. 7.

Table 7. Variation in weight and thickness of samples on exposure to atmosphere

Sl. No	On exposure to atmosphere	%Variation in weight		% Variation in thickness	
		5% fiber loading	Pure epoxy	5% fiber loading	Pure epoxy
1	At Anantapur	-1.00	-0.37	-0.58	-0.23
2	At Hyderabad	-0.82	-0.48	-0.52	-0.18
3	At Nandyal	-0.82	-0.39	-0.50	-0.31

Note : "-ve" sign indicates Weight loss or decrease in thickness

Graphical representation of the above values has been presented in Fig. 11.

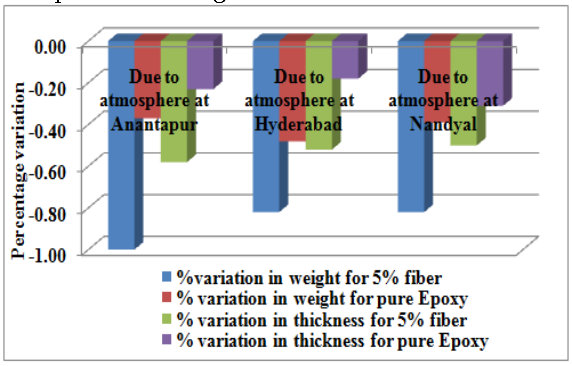

Fig. 11 Graphical representation of the effect of atmosphere on the composites

The moisture or volatile fluids present in the voids of the prepared emu feather fiber reinforced epoxy composites gets evaporated due to atmospheric conditions like wind, sunshine etc, when exposed to atmosphere for long periods. Due to this effect there is decrease in weight and thickness of the samples.

7.2 Effect of Soil

Maximum of 1.38% weight gain and 0.64% gain in thickness were observed for 5% fiber loading composites when buried in soil at Nandyal and Hyderabad. When the samples were buried in the soil under earth, there might be absorption of moisture by the samples and as a result, their weights might have been increased. The details of % variation in weight and thickness of the samples of various fiber loading and fiber length due to soil have been presented in Table 8.

Table 8. Variation in weight and thickness of samples due to soil

Sl. No	Effect of Soil	%Variation in weight		% Variation in thickness	
		5% fiber loading	Pure epoxy	5% fiber loading	Pure epoxy
1	At Anantapur	1.07	0.44	0.59	0.28
2	At Hyderabad	1.33	0.48	0.64	0.30
3	At Nandyal	1.38	0.50	0.60	0.26

The effect of soil on the 'Emu' feather fiber reinforced epoxy composite have been presented in the Fig. 12.

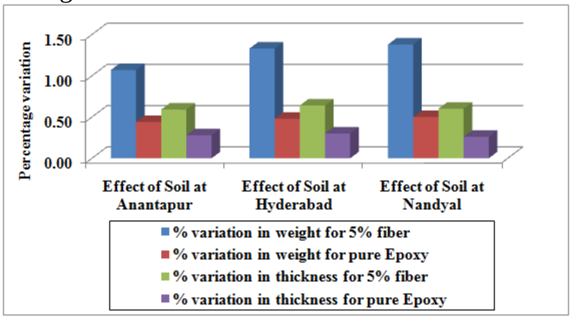

Fig. 12 Graphical representation of the effect of Soil on the composites

VIII. Chemical Resistance Tests for Composites

The chemical resistance of the composite was studied as per ASTM D 543-87 method. For chemical resistance test, the acids namely concentrated hydrochloric acid (10%), concentrated nitric acid (40%) and glacial Acetic acid (8%), the alkalis namely aqueous solutions of Sodium hydroxide (10%), Ammonium hydroxide (10%) and Sodium carbonate (20%) and the solvents –Benzene, Carbon tetra chloride and Toluene were selected. In each case, three pre weighed samples were dipped in the respective chemicals under study for 24 hours, removed and immediately washed thoroughly with distilled water and dried by pressing them on both sides by filter papers. Weight and thickness of the specimens were measured. The % variation in weight and thickness were determined.

The chemical resistance tests were conducted for various fiber loadings of epoxy 'Emu' fiber composites with various chemicals. The effect of acids, alkalis, and solvents like acetic acid, nitric acid, hydrochloric acid, sodium hydroxide, sodium carbonate, ammonium hydroxide, benzene, toluene, and carbon tetra chloride on 'Emu' fiber epoxy composites were studied.

In general, all the samples including pure epoxy are getting reacted for all the chemicals. It is clearly evident that the weight gain was observed when treated with acids and bases irrespective of their concentration. But weight loss was observed for the composite specimens when treated with solvents like Toulen, Benzene and Carbon tetra chloride. The percentage variation in weight is getting increased with increase in percentage fiber in the composites. But loss in weight of the 'Emu' feather fiber epoxy composites when treated with toluene, benzene and carbon tetra chloride is also increasing with increase in fiber loading. The details of % variation in weight and thickness of 5%fiber loading composites and epoxy samples when treated with chemicals are presented in Table 9.

Table 9. % variation in weight and thickness of samples subjected to chemicals

Sl. No.	Name of the Chemical	% Variation in weight		% Variation in thickness	
		5% fiber loading	Pure epoxy	5% fiber loading	Pure epoxy
1	Acetic acid	4.00	1.80	1.96	1.01
2	Hydrochloric acid	3.80	1.50	1.80	0.80
3	Nitric acid	3.20	0.70	1.90	0.70
4	Sodium hydroxide	3.90	2.03	1.10	0.30
5	Sodium carbonate	5.50	1.80	2.60	0.60
6	Ammonium hydroxide	2.30	0.70	1.70	0.30
7	Benzene	-0.83	-0.26	-0.62	-0.24
8	Toulen	-1.07	-0.34	-0.70	-0.26
9	Carbon tetra chloride	-0.70	-0.22	-0.70	-0.33
10	Water	0.95	0.52	0.82	0.35

Graphical representation of the above values has been presented in Fig. 13.

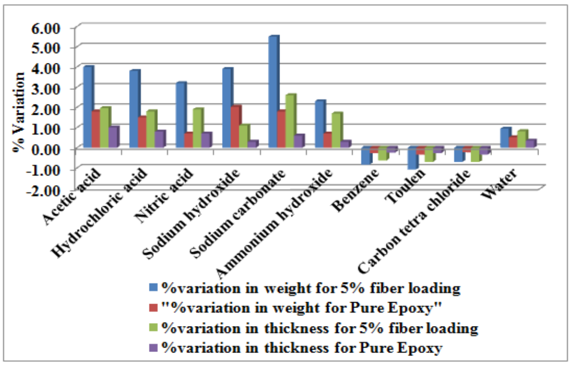

Fig:13 Graphical representation of Chemical effect on the composites

IX. Scanning Electron Microscopy (SEM)

The Scanning Electron Microscope is one of the most versatile instruments available for the examination and analysis of the microscope, morphology and chemical composition. Some of the Photographs obtained by SEM are shown in Fig 14 and 15.

One of the sample images of pure epoxy obtained from 'SEM' has been presented in figure 14. Chemical bonding in pure epoxy is good which can be seen in the Plate 14. Hence, the Tensile strength, Flexural strength and flexural modulus are good. As there is no fiber in Pure Epoxy to oppose the sudden loading, the Impact strength of the specimen found to be low.

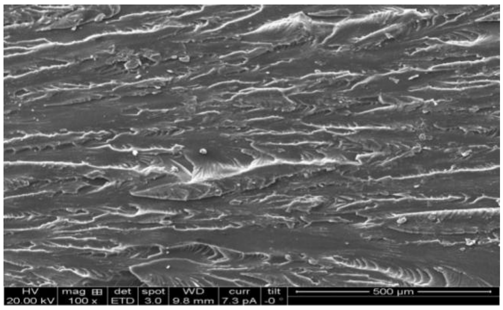

Fig: 14 SEM image of Pure Epoxy Specimen

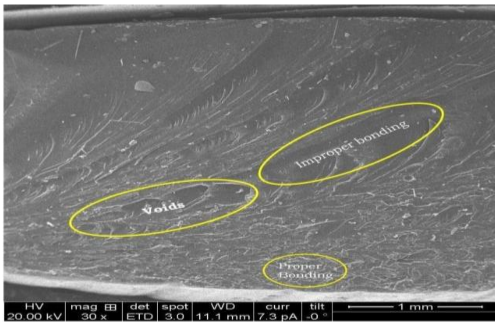

Fig. 15 SEM image of with 1% fiber loading and 1cm fiber length

When a little amount of fiber is added, the chemical bonding is disturbed and not homogeneous in the matrix. Improper bonding in epoxy can be observed along with small void as shown in Fig. 15. This results in reduction in Tensile strength, Flexural strength and flexural modulus. The fiber which is present tries to resists the sudden loads, as a result the impact strength found to be increased to some extent.

A sample ‘SEM’ image of composite specimen with 2% of fiber loading with 4 cm fiber length and 3% of fiber loading with 5 cm fiber length has been presented in have been presented in Fig.16 and 17.

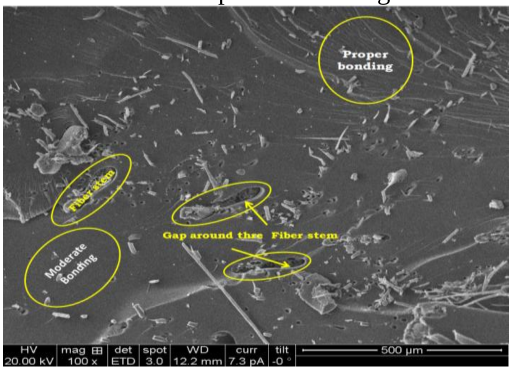

Fig. 16 SEM image of Specimen with 2% fiber loading and 4 cm fiber length

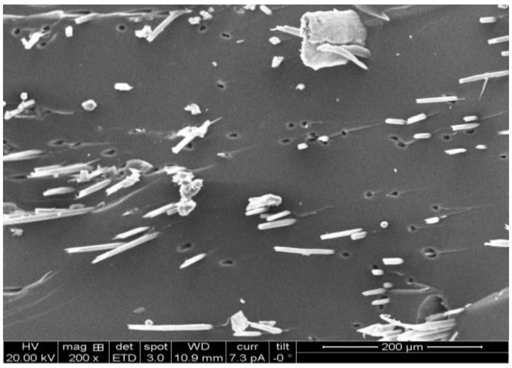

Fig. 17 SEM image of with 3% fiber loading and 5 cm fiber length

From the plate 16, it can be observed that the bonding between the matrix and fiber is moderate. Gap can be observed around the fiber stem, which leads to reduction in Tensile strength, Flexural strength and flexural modulus. Uniform distribution of fiber can also be seen in the image of the composite sample due to which, the Impact strength increases. From the SEM image shown in Plate 17, voids can be observed in the matrix, which indicate the improper bonding between fiber and matrix.

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