

Mechanical Properties of Kevlar/Jute Reinforced Epoxy Composite

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ABSTRACT: In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturers in the present scenario. Weight reduction can be achieved primarily by the introduction of low density materials. So the Industry has shown increase interest for replacement of steel material with that of composite material. The aim of this work was to determine the tensile strength, Modulus of elasticity, flexural strength, impact strength, weight and cost of Kevlar-Jute composite. Epoxy SE 70 matrix was used for the composite of Kevlar and Jute. Test samples were prepared using compression moulding. This is a well-known technique to fabricate composite products. Analytically, the volume fraction and weight fraction, tensile strength, modulus of elasticity, weight and cost of composite specimen was calculated. Experimental test conducted on specimen using Universal Testing Machine (UTM). The results indicated that the properties of Kevlar-Jute composites can be considerably improved by incorporation of Kevlar in jute fibre composites enhancing the properties of resulting hybrid composites. Stacking sequence (altering the position of Kevlar plies) significantly affects the flexural strength. For the same relative weight fraction of Kevlar and Jute fibre, layering sequence has little effect on tensile properties. The Kevlar to jute ratio increases the tensile, flexural strength, impact energy, strain energy and reduces the weight of specimen. More the Kevlar percentage lowers the epoxy percentage so the cost is reduced of specimen.

KEYWORDS: Kevlar, Woven Jute, Epoxy, Compression moulding, Charpy impact tester

I. INTRODUCTION

In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturers in the present scenario. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The introduction of composite materials made it possible to reduce the weight of component without any reduction on load carrying capacity and stiffness. The composite materials have more elastic strain energy storage capacity and high strength to weight ratio. The composite material offer opportunities for substantial weight saving but not always are cost-effective over their steel counter parts. A composite material is a material in which two or more distinct materials are combined together but remain uniquely identifiable in the mixture. The most common example is, perhaps, fiber-glass, in which glass fibers are mixed with a polymeric resin. If we break the composite, the fibers and resin would be easily distinguished.

II. LITERATURE SURVEY

Girisha et al. [1] worked on E-glass, Jute and epoxy and found that the mechanical properties are higher in the 90 degree oriented hybrid composite than in 45 degree and 30 degree orientation. There were indications that by the incorporation of both fibres the polyester resin stabilized mechanical properties than epoxy resin. Braga et al. [2] worked on E-glass, Jute and epoxy and found that the impact strength, tensile strength and thermal properties were more of E64-J18-V19 sample specimen but flexural strength did not have significantly increased. Margoto et al. [3] worked on polypropylene (PP) and Jute and found that the tensile and flexural tests showed increase in some mechanical properties of the composite, such as strength values, maximum tension and deformation, mainly for composites PP matrix with two layers of fabric jute in flexural tests as compared to PP matrix without fabric jute. Sanjay et al. [4] worked on E-glass, Jute and epoxy and found that the impact, flexure, and laminar shear strength of the specimen L4 are more than the L1, L2 and L3 specimen. Ahmeda et al. [5] worked on E-glass, jute and polyester and found that the properties of jute composites can be considerably improved by incorporation of glass fibre as extreme glass plies. The layer sequence has greater effect on flexural and inter laminar shear properties than the tensile properties. An overall comparison between

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the properties of all the laminates revealed that the hybrid laminate with two extreme glass plies on either side is the optimum combination with a good balance between the properties and cost.

III. DETERMINATION OF COMPOSITE PROPERTIES USING ANALYTICAL TECHNIQUE

Three samples were prepared with different percentage of composites. Natural fiber (Jute) woven mat of 0.4 mm thickness was purchased from local market. Synthetic fibers (Carbon fiber, Kevlar and E-glass) were purchased from A1 Corporation, Ambad MIDC, Nashik. TABLE I mentioned the physical properties of epoxy resin, Kevlar and jute fiber.

A. Materials and its properties

The two specimen strips of following dimension were selected for the test. The sample (Woven Jute) of dimension (1.7 mm thick, 60 mm width and 200 mm long) as shown in Fig.1 and the sample (Kevlar) of dimension (0.44 mm thick, 60 mm width and 200 mm long) as shown in Fig. 2;



Fig.1. Woven jute strip



Fig.2. Kevlar strip

The mechanical properties of the specimen strips were find out by conducting the test on UTM.

The tension test conducted on Jute specimen strips and Kevlar specimen strips are shown in Figs.3 and 4 respectively and results are mention in TABLE I.



Fig.3. Tensile test on Jute specimen strips



Fig.4. Tensile test on Kevlar specimen strips

B. Weight fraction calculation

Weight fraction expresses the concentration of a component in a mixture or an element in a compound.

Weight fraction can be calculated using the following formula;

$$W_F = \frac{\text{Weight of fiber}}{\text{Total weight of composite}} * 100$$

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The weight fractions of composite are shown in TABLE II.

TABLE I

MECHANICAL PROPERTIES OF SPECIMEN STRIPS

S. No.	Materials	Mechanical properties		
		Density	Tensile strength	Young's Modulus
		g/cm ³	MPa	GPa
1	Epoxy(E)	1.3	54	3.61
2	Kevlar (K)	1.47	378.78	60
3	Jute (J)	1.4	59.80	30

TABLE II

WEIGHT FRACTION OF COMPOSITE

Comp.	Weighti n	Weight of			Total
		J	K	E	
		W _J	W _K	W _E	W _J +W _K +W _E
K15J85	%	33	6%	61	100%
	gram	108	20	199	327
K33J67	%	38	19	43	100%
	gram	81	40	91	212
K75J25	%	18	53	29	100%
	gram	27	80	44	151

Where; K15J85 is 15% Kevlar and 85 % Jute, K33J67 is 33 % Kevlar and 67 % Jute, K75J25 is 75% of Kevlar and 25 % of Jute. J, K, E are Jute,Kevlar, Epoxy respectively. W_J, W_Kand W_E are the weight of Jute,weight of Kevlar and weight of Epoxy respectively.

C. Volume fraction calculation

Volume fraction is the percentage of fiber volume in the entire volume of a fiber-reinforced composite material. When manufacturing the polymer composites, fibers are impregnated with resin. Volume fraction can be calculated using the following formula;

Volume fraction of Composite;

$$V_F = \frac{\frac{W_J}{\rho_J} + \frac{W_{CF}}{\rho_{CF}}}{\frac{W_J}{\rho_J} + \frac{W_{CF}}{\rho_{CF}} + \frac{W_E}{\rho_E}}$$

The volume fractions of composite are shown in TABLE IV.

D. Elastic of modulus of composite

Two mathematical expressions have been formulated for the dependence of the elastic modulus on the volume fraction of the constituent phases for a two phase composite. These rule of mixtures predict that the elastic modulus should fall between an upper bound and lower bound represented by

For upper limit;

$$E_C(u) = E_J V_J + E_K V_K + E_E V_E$$

For lower limit;

$$E_C(l) = \frac{(E_J V_J + E_K V_K) E_E}{(V_J + V_K) E_E + V_E (E_J + E_K)}$$

In these expressions E and V denote the elastic modulus and volume fraction, respectively, whereas the subscript C, J, K and E represents composite, Jute, Kevlar and Epoxy respectively. The moduli of elasticity of composites are tabulated in TABLE V [7].

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TABLE IV
VOLUME FRACTION OF COMPOSITE

Comp.	Volume fraction			
	V _E	V _K	V _J	V _C
K15J85	0.583	0.082	0.335	37.218
K33J67	0.267	0.28	0.453	54.859
K75J25	0.02	0.617	0.363	68.531

Where V_E, V_K, V_J, V_C are the volume fraction of epoxy, Kevlar, jute and composite respectively

E. Tensile strength of composite

The tensile strength of composite can be calculated using the relation between the volume fraction and the individual tensile strength of the matrix and reinforcement. Following are the relation to calculate the tensile strength of the composite,

Tensile strength of the composite;

$$\sigma_c = \sigma_J V_J + \sigma_K V_K + \sigma_E V_E$$

F. Strain of composite

The fiber matrix interfacial bond is very good, that deformation of both matrix and fibers is same. Under these condition

$$\epsilon_c = \epsilon_J = \epsilon_K = \epsilon_E$$

Where, $\epsilon_c, \epsilon_J, \epsilon_K, \epsilon_E$ are the deformation of composite, Jute, Kevlar and Epoxy respectively. The elongations of composite are tabulated in TABLE VII.

TABLE VI
TENSILE STRENGTH OF COMPOSITE

Compo.	Tensile strengt h of Epoxy	Tensile strengt h of Kevlar	Tensile strengt h of Jute	Total tensile strength of composite
	MPa	MPa	MPa	MPa
	σ_E	σ_K	σ_J	σ_C
K15J85	54	378.78	59.80	82.58
K33J67	54	378.78	59.80	147.57
K75J25	54	378.78	59.80	256.5

Where, $\sigma_E, \sigma_K, \sigma_J, \sigma_C$ are the tensile strength of Epoxy, Kevlar, Jute and composite respectively.

G. Load on composite

The elastic behaviour of a continuous and oriented fibrous composite was loaded in the direction of fiber alignment. First, it was assumed that the fiber-matrix interfacial bond is very good, that deformation of both matrix and fibers is the same. Under these conditions, the total load sustained by the composite F_C is equal to the sum of the loads carried by the matrix phase F_M and fiber phase F_R.

So, Total load on composite can be calculated by;

$$F_c = A_c \times \sigma_c$$

TABLE V
MODULUS OF ELASTICITY OF COMPOSITE

Compo	Modulus of elasticity of composite in MPa	
	Upper bound	Lower bound
	E _{c(u)}	E _{c(l)}
K15J85	17074.63	6019.412
K33J67	31353.87	12179.43
K75J25	47982.2	60867.77

Where, u and l indicates the upper bound and lower bound respectively.

TABLE VII
ELONGATION OF COMPOSITE

Comp.	Total Elongation of comp.
K15J85	0.0049
K33J67	0.0048
K75J25	0.0054

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Force ratio of reinforcement and matrix;

$$\frac{F_R}{F_M} = \frac{E_R V_R}{E_M V_M}$$

So, Force on each particulate can be calculated by;

$$F_C = F_M + F_R$$

The tensile loads on composite are tabulated in TABLE VIII [7].

H. Strain energy of composite

The strain energy stored in an elastic material upon deformation was calculated as shown below for a number of different geometries and loading conditions. The work done is stored as elastic strain energy U and it is calculated by;

$$U = \frac{P^2 L}{2EA}$$

Where, P, L, A, E are the load, length, area and young's modulus of specimen.

The strain energy of test specimen is tabulated in TABLE IX.

TABLE VIII
TENSILE LOAD ON COMPOSITE

Compo.	Area	Total Load	Load on each		
	mm ²	N	N	N	N
	A _C	F _C	F _E	F _K	F _J
K15J85	238.92	19.74	2.44	5.71	11.66
K33J67	153.45	22.65	0.7	12.21	9.87
K75J25	106.92	27.43	0.05	25.64	7.55

TABLE IX
STRAIN ENERGY OF COMPOSITE

Compo.	Area	Total Load	Modulus of elasticity	Strain Energy
	mm ²	N	MPa	mJ
	A _C	F _C	E	U
K15J85	238.92	21480	17074.63	9.56
K33J67	153.45	22990	31353.87	10.67
K75J25	106.92	27430	47982.2	14.67

Where, A_C, F_C, F_E, F_K, F_J are the area of composite, Load on composite, Epoxy, Kevlar and Jute respectively.

IV. DETERMINATION OF COMPOSITE PROPERTIES USING EXPERIMENTAL TECHNIQUE

A. Laminate fabrication:

Hybrid laminates of woven jute and Kevlar mat were prepared by compression moulding at temperature 114⁰C and pressure 20 Kg/cm². PVA release agent was applied to the surfaces of the mold. Jute and Kevlar fabrics were pre-impregnated with the matrix material consisting of epoxy SE-70. The impregnated layers were placed one over the other in the mold (300 mm×250 mm) and pressed for 2h before removal. Provision was made in the mold to allow the hot gases to escape. Uniform thickness was achieved by using spacers of desired thickness between the moldplates. After 2h, the laminate was removed from the mold and cured at room temperature for 24 h. All the laminates were made with total 05 layers by varying the number and position of Kevlar layers to obtain various stacking sequences tabulated in Table III [4].

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TABLE III
LAMINATE STACKING SEQUENCE

Symbol	Stacking Sequence	Weight of Fiber in gm		Thickness in mm
		Jute	Kevlar	
K15J85	J-J-K-J-J	108	20	7.24
K33J67	K-J-K-J-K	81	40	4.72
K75J25	K-K-J-K-K	27	80	3.46

B. Sample Preparation:

Compression moulding is a well-known technique to develop variety of composite products. It is a closed moulding process with high pressure application. In this method, three samples were prepared with different composite percentage. Two matched metal moulds were used to fabricate composite product. In compression moulding; base plate is stationary while upper plate is movable.

For sample I (size 250 mm X 300 mm) as shown in Fig.5, 108 gram of woven Jute mat, 20 gram of Kevlar and 800 gram of Epoxy were placed in the metallic mould and the whole assembly were kept in between the compression moulder. Temperature of 114⁰ C and 20 Kg/cm² pressure was applied for two hours.

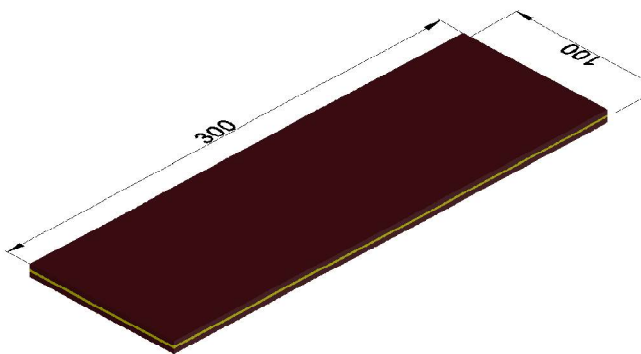


Fig.5. K15J85 layer orientation

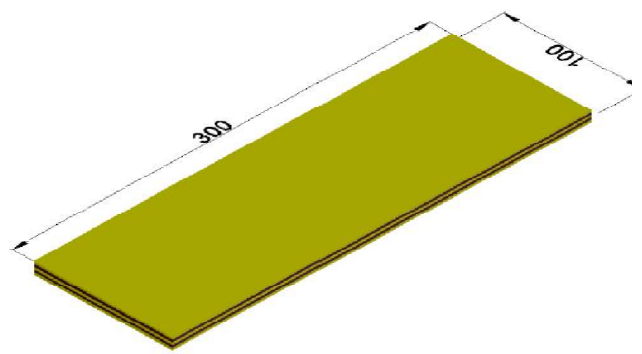


Fig.6. K33J67 layer orientation

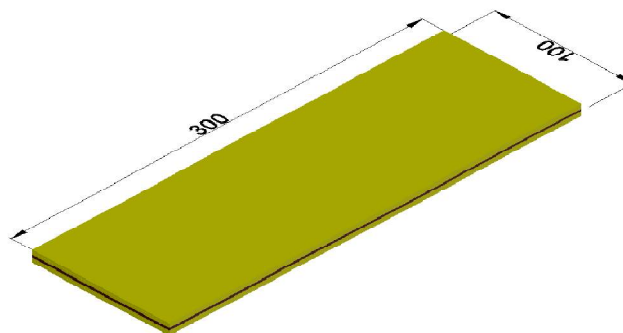


Fig.7. K75J25 layer orientation

For sample II (size 250 mm X 300 mm) as shown in Fig.6, 81 gram of woven Jute mat, 40 gram of Kevlar (Aramid LM) and 510 gram of Epoxy were placed in the metallic mould and the whole assembly was kept in between the compression moulder. Temperature of 114⁰ C and 20 Kg/cm² pressure was applied for two hours.

For sample III (size 250 mm X 300 mm) as shown in Fig.7, 27 gram of woven Jute mat, 80 gram of Kevlar and 275 gram of Epoxy were placed in the metallic mould and the whole assembly was kept in between the compression moulder. Temperature of 114⁰ C and 20 Kg/cm² pressure was applied for two hours.

The material placed in between the moulding plates surge due to application of pressure and heat and acquires the shape of the mould cavity with high dimensional accuracy which depends upon mould design. Curing of the composite

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was carried out at room temperature for two hours. After curing, mould was opened and composite product was removed and trimmed with exact dimension for further processing.



Fig.8. Tensile test specimen (K15J85)



Fig.9. Tensile test specimen (K33J67)



Fig.10. Tensile Test Specimen (K75J25)



Fig.11. Tensile Test on UTM

C. Sample Tensile Test

The tensile test was done by cutting the composite specimen as per ASTM: D3039 standards.

Sample I (K13J87) dimension is (200 X 29.17 X 8.67 mm³) as shown in Fig. 4. Sample II (K43J57) dimension is (200 X 33 X 4.65 mm³) as shown Fig. 7; Sample III (K67J33) dimension is (200 X 33 X 3.24 mm³) as shown in Fig. 8;

A universal testing machine (UTM) was used for testing with a maximum load rating of 400 KN. Composite with different fiber combinations were tested, which are shown in Fig.11. In each case, two samples were tested and the average were determined and noted. The load was applied until the specimen break and break load, ultimate tensile strengths were noted.

The composites specimens K15J85, K33J67 and K75J25 were tested for tensile properties in UTM and obtained tensile properties are as shown in Table X.

TABLE X
ULTIMATE LOAD AND THE ULTIMATE TENSILE STRENGTH OF COMPOSITE MATERIAL

Comp.	Size (mm)	Area (mm ²)	Ultimate Load (KN)	Tensile Strength (MPa)
K15J85	33X 7.24	238.92	18.42	77.1
K33J67	33X 4.65	153.45	19.98	130.21
K75J25	33X 3.24	106.92	29.01	271.33

TABLE XI
STRAIN AND THE MODULUS OF ELASTICITY OF COMPOSITE MATERIAL

Comp.	Gauge Length (mm)	Elongation (mm)	Strain	Modulus of Elasticity
K15J85	80	0.334	0.0042	17342.86
K33J67	50	0.266	0.0054	24112.97
K75J25	50	0.261	0.0053	51194.34

The composites specimens K15J85, K33J67 and K75J25 were tested for tensile properties in UTM and the values obtained tensile properties are shown in table. Strain and the modulus of elasticity are shown in TABLE XI.

D. Sample Impact Test

Charpy impact testing has been used for many years to test the impact toughness of various metals. The composite properties depend on their orientation. Consequently, new test methods had to be found to accurately test the directionally dependent impact resistance of composite materials. Since Charpy impact testing is both cheap and fast, its use was extended to composites. A Charpy impact test machine is shown in the Fig. 12.



Fig.12. Charpy impact tester

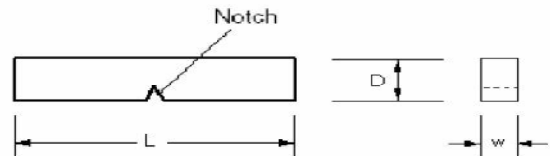


Fig.13. Charpy impact specimen

The specimen that fits into the Charpy impact tester is rectangular with a notch cut in one side. The notch allows for a predetermined crack initiation location. Many composite Charpy impact tests were performed without the notch cut into the specimen. A typical Charpy impact specimen is shown in the Fig. 13.



Fig.15. Impact Test Specimen (K33J67)



Fig.14. Impact Test Specimen (K15J85)

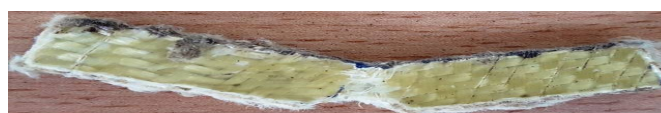


Fig.16. Impact Test Specimen (K75J25)

The impact test was done by cutting the composite specimen as per ASTM: D3763 standards and notch was 2 mm in depth.

Sample I (K15J85) dimension is (55 X 10 X 7.24 mm³) as shown in Fig. 13; Sample II (K33J67) dimension is (55 X 10 X 4.65 mm³) as shown in Fig. 14; Sample III (K75J25) dimension is (55 X 10 X 3.24 mm³) as shown in Fig. 15;

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A Charpy Impact tester was used having maximum capacity of 300 J. Composite with different percentage of fiber combinations was tested, which are shown in Fig. 14, 15 and 16. In each case, two samples were tested and the average were determined and noted. The loss of energy during impact was the energy absorbed by the specimen during impact. The values are tabulated in TABLE XII.

E. Sample Flexural Test

The flexural test was done in a three point flexural setup as per ASTM: D790 standard when a load is applied at the middle of the specimen, it bends and fractures as shown in Figure 17, 18 and 19. This test was carried out on the UTM from which the breaking load was recorded flexural strength was calculated. Flexural strength can be calculated by;

$$f = \frac{P^2L}{bt^2}$$

Where; f, P, L, b and t are the flexural strength, breaking load, length, width and thickness of specimen.

TABLE XII
IMPACT TEST RESULT OF COMPOSITE
MATERIAL

Comp.	Size (mm ³)	Impact energy absorbed in (J)
K15J85	55 X 10 X 7.24	3
K33J67	55 X 10 X 4.65	4
K75J25	55 X 10 X 3.24	5



Fig.17. Flexural test on sample K15J85



Fig.18. Flexural test on sample K33J67



Fig.19. Flexural test on sample K75J25

The flexural strength of the specimen which has having a length of 180 mm for K15J85, K67J33 and K75J25 were tabulated in TABLE XIII [5].

F. Weight Estimation

The weight of specimen was calculated by calculating the volume and the density of material and results were tabulated in TABLE XIV.

G. Cost Estimation

The cost of specimen was estimated by calculating the volume and material percentage in specimen. Cost of Kevlar was Rs. 3800 per Sq. Mt. and Cost of Jute was Rs. 25 per Kg. and epoxy was Rs. 632 per kg. So considering this factor and fabrication cost and labour cost the cost of specimen were tabulated in TABLE XV.

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TABLE XIII
FLEXURAL STRENGTH RESULT OF COMPOSITE MATERIAL

Comp.	Load	Width	Thickness	Flexural Strength
	P	b	t	f
	N	mm	mm	MPa
K15J85	4600	33	7.24	478.68
K33J67	2200	33	4.65	554.98
K75J25	1158	33	3.24	601.7

TABLE XIV
WEIGHT ESTIMATION OF COMPOSITE MATERIAL

Comp.	Sample Size (l X b X t)	Volume in mm ³	Density in g/mm ³	Weight of sample in gram
K15J85	100 X 300 X 7.24	260100	1.4093	365.5445
K33J67	100 X 300 X 4.65	139500	1.4012	195.4674
K75J25	100 X 300 X 3.24	97200	1.4012	136.1966

TABLE XV
COST ESTIMATION OF COMPOSITE MATERIAL

Comp.	Cost in Rs.			
	Material	Processing	Labour	Total
K15J85	804.6	200	300	1304.6
K33J67	689.32	200	300	1189.32
K75J25	654.8	200	300	1154.8

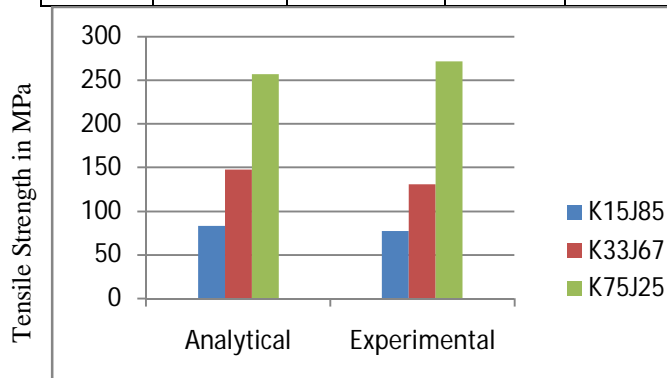


Fig.20. Tensile strength of laminates

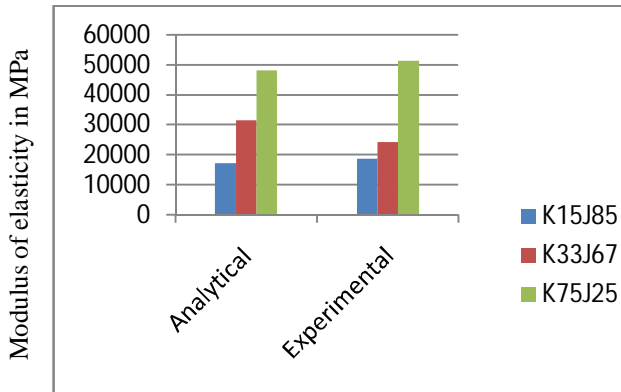


Fig.21. Modulus of elasticity of laminates

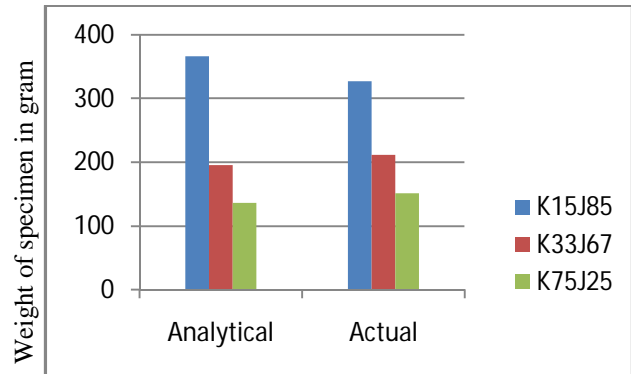


Fig.22. Weight of laminates

V. RESULT AND DISCUSSION

The experimental results showed that;

1. Tensile strength of composite K75J25 was 72 % more than K15J85 and 43 % more than K33J67 as shown in Fig. 20.
2. The Modulus of elasticity of composite K75J25 was 65 % more than K15J85 and 53 % more than K33J67 as shown in Fig. 21.
3. Flexural strength of K75J25 was 20.45 % more than K15J85 and 7.77 % more than K33J67.
4. The Impact energy stored in K75J25 was 40 % more than K15J85 and 20 % more than K33J67.
5. Strain Energy of K75J25 was 35 % more than K15J85 and 28 % more than K33J67.
6. The weight of K75J25 was 173 % less than K15J85 and 77 % less than K33J67 as shown in Fig. 22.
7. The cost of K75J25 was 13 % less than K15J85 and 03 % less than K33J67.

VI. CONCLUSION

Effect of stacking sequence on tensile, modulus of elasticity, and flexural properties of Kevlar-Jute fabric reinforced epoxy composites, have been analytically calculated and experimentally evaluated. From the results of this study, the following conclusions are drawn.

1. Incorporation of Kevlar in jute fibre composites enhances the properties of resulting hybrid composites.
2. Stacking sequence (altering the position of Kevlar plies) significantly affects the flexural strength.
3. For the same relative weight fraction of Kevlar and Jute fibre, layering sequence has little effect on tensile properties.
4. The Kevlar to jute ration increases the tensile, flexural strength, impact energy, strain energy and reduces the weight of specimen.
5. More the Kevlar percentage lower the epoxy percentage so the cost of specimenis reduced.

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