Mech. Engg. Res. Bull.
Vol. 10, (1987), p p. 63—74

Mechanical Properties of Jute Reinforced Plastics

K. A. Kazim*
M. F. ILAHI*

Abstract

Jute Reinforced Plastics is finding wider application and for efficient use the mechanical properties should be known to the designers. Experimental values of tensile strength of the composite together with that for matrix and reinforcement and the fatigue properties as affected by the volume fraction are presented.

Introduction

Designers have succeded in selecting many new types of components for revolutionary machines and structures due to availability of composite materials. The composites have offered better properties in terms of strength, stiffness and specific weight. In this country jute fibre reinforced plastics have been used in some cases such as Silver Cans for Textile and Jute Industries, main container for milk vans, shuttering for concrete casting, some structure of slow moving transports etc. But systematic studies on different properties, economic viability of these materials have not been done. For useful and appropriate applications the mechanical properties of the materials should also be known to the designers. To attain this objective the effect of varying percentage of the fibre on tensile strength, flexural stiffness and fatigue of the composite material have been studied and presented in this paper.

Litterature Survey

Some experimental investigations (1-9) were carried out to study the failure characteristics of unifibre and multifibre, unilayer and multilayer specimens subjected to uniaxial tension in the direction of fibres only. Boue (10) studied the effect of fibre to matrix volume ratio on the failure mode of the composites. Tsai (11) made theoretical and experimental studies on composite materials and obtained good correlations for cross-ply and angle-ply laminations. Rosen (12), Pih et al (13) made experimental investigations using photoelastic methods to determine mode of failure, effect of fibre orientation, fibre and geometry of arrangement. Grinius (14) conducted experimental investigations on fibre reinforced composites subjected to tension, shear, bending and repeated loading in order to establish the effect of the matrix and the fibre orientation. Only two specimens were tested for each case. The observed mode of failure for tension was similar to that found by Boue (10) for low fibre-volume fraction specimens.

*M. E, Deptt. BIT, Khulna
*MCE Deptt., ICTVTR

Tsai (15) compared the uniaxial strength predicted by maximum stress, maximum strain, and maximum work theories, with the test data obtained from uniaxial tensile and compressive tests on a unidirectional E-glass-epoxy composite He found that the maximum work theory offered better agreement with experimental data than did the other theories.

Armenkas et al (16) investigated the strength characteristics of S-glass fibre bundles and composites subjected to quasi static loading. The specimens were observed photographically during deformation. Their experimental bundle strength compared well with that obtained on the basis of Daniel's theory (17). The mean experimental composite strength compared well with that obtained on the basis of rule of mixtures and Gucer-Gurland models (18-20).

Fariborg, Yang and Harlow (9) investigated the tensile behaviour of, Intraply Hybrid Composites. They modified the basic chain of bundles probability model. They used the Monte Carlo simulation technique for their method of analysis. They considered the effect of the volume ratio of the constituents and the degree of dispersion of the types of fibres. The existence of the 'Hybrid effect' for strain is shown along with its sensitivity of volume ratio and dispersion. The Weibull distribution function was shown to be a good representation for the hybrid breaking strain.

Most of the above investigations were involved with composites made of glass fibres. In Bangladesh Jute is finding wide application. No literature on the use of Jute as a reinforcing material in composites together with the mechanical properties is available as far as the knowledge of the authors are concerned.

The fibres of the fibre reinforced composite materials carry the bulk of the load whereas the resin binds the fibres together, to space them, to distribute the load to individual fibres, and to protect them from mechanical or chemical damage. The polyester resin is being widely used for this purpose as it satisfies the required characteristics and this resin has been selected for the present investigation.

Jute is abundantly grown throughout Bangladesh and is finding wide application. This fibre has different mechanical properties according to their grades, soil conditions, fertilization techniques and the climate. lu this study only one grade of fibre namely BTA grade have been used.

Experiment

Before carrying out the tests on Jute Reinforced plastics some tests were necesary to be carried out on Jute Fibres, Jute Fibre Bundles, Jute Yarn, Jute Yarn Bundles, Jute Mat and resin specimens to determine their strength characteristics. For the tests BTA grade jute was used.

i) Jute Fibres : BTA jute bales were selected and spread on the floor, Fifty tensile specimens were tested for each of three different gage lengths of 100 mm. 50 mm and 10 mm. The strain rates were 0.05, 0.1 and 0.5 per minute respectively.

ii) Jute Fibre Bundles : From a bale of jute ten reeds were taken at random. From these reeds forty fibres were taken at random. From these reeds forty fibres were taken for each specimen. Specimen length of 150 mm was selected and was tested at a cross head speed of 5 mm/min using a gage length of 100 mm.

iii) Jute Yarn : Samples with a length of 150 mm were perpared from reel of BTA grade jute. The samples were tested at a cross head speed of 50 mm/min using a gage length of 100 mm.

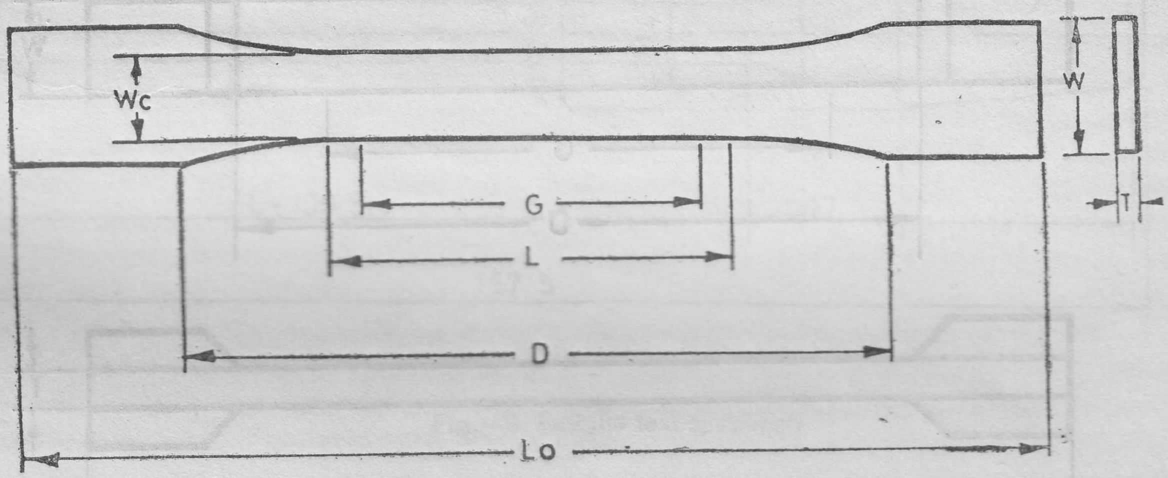
iv) Jute Yarn Bundles : Specimens each of 200 mm length and 27.5 mm width were cut from carpet backing cloth of BTA grade jute. There were ten longitudinal yarns in each sample. Pieces of 50 mmx 27.5 mm size were cut from glass mat. The matrix was then prepared by mixing 500 gm of Epolac G-774 TSY (unsaturated normal polyester resin), 15 gm of Cobalt Napthanate and 5 gm of methyl ethyl ketone peroxide. Glass mats were wetted with this liquid resin, placed on both side of the ends of the samples and cured slowly at room temperature. Transverse yarns were then isolated from the samples. The yarns were equally spaced in the sample. The test length of the samples were 100 mm and cross head speed of 50 mm/min was used.

v) Jute Mat : The procedure was similar to that for Jute Yarn Bundles except that the transverse yarns were not isolated from the specimens.

vi) Tensile Test of Polyester resin : A sheet of 200 X 200 X 6 mm of pure resin, according to the proportion shown in Table 1 was made. After curing at room temperature, specimens were cut from this sheet by a metallic die, according to the standard of ASTM D 638-77 a as shown in Figure 1. All the surfaces of the specimen were filed and finished with fine abrasive cloth. Tensile tests were conducted on ten specimens at the room temperature using Instron Testing Machine at a cross head speed of 50 mm/min.

vii) Tensile test of jute reinforced composite : Samples of 250 X 450 mm were cut from mat of BTA grade jute and weighed. The matrix polyester was prepared by mixing ingredients thoroughly in a container with a stick in the proportion as listed in Table 1, carefully avoiding the entrainment of excessive air.

Unilayer and multilayer of jute mat reinforced plastics were made by hand lay-up method. These were cured slowly at room temperature. These composite sheets were weighed. Specimens with a length of 250 mm and width of 27.6 mm were cut from these sheets. All surfaces and edges of these were filed and smoothened by abrasive paper. A ten layer of glass mat reinforced composite sheet was made by hand



W—Width, overall	19mm
Wc—Width of narrow section	$13_{\pm}$ 0.5mm
G—Gage length	50mm
L—Length of narrow section	$57_{\mp}$ 0·5mm
D—Distance between grips	$102_{\pm}$ 0 5mm
Lo—Length overall	152mm
T—Thickness	$6_{\pm}$0 5mm

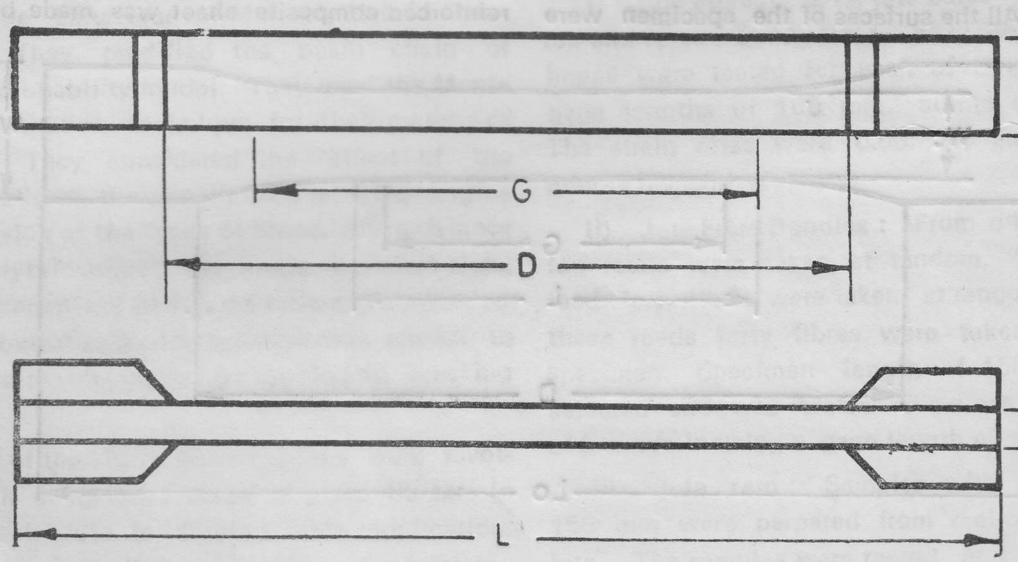
Fig. 1 —Polyester resin specimen for tensile test.

Table 1
Matrix polyester molding compound formula

Name	gm	%
Emolac G-240 Fx (Unsat. flexible polyester resin)	6,000	72.82
Epolac G-774 TSY (Unsat. normal polyester resin)	2,000	24.27
Cobalt Nepthanate	160	1.94
Methyl Ethyl Ketone Peroxide	80	0.97
Total	8,240	100.0

lay-up method, cured to make 38 × 25.4 × 5 mm tabse used for attaching by Aica adhesives to the ends of specimens (Figure 2) for gripping according to the standard of ASTM D3039-76.

Tensile tests were carried out by using Instron Testing Machine at a cross head speed of 50 mm/min. Tensile specimens were tested at different volume fraction of jute.



L – Overall length 254mm
D – Distance between grips 177·8mm
G – Gage length 127mm
W – Width 25·4mm
T – Thickness vary from 0·1 – 6·5mm

Fig.–2 Jute reinforced composite specimen for tensile test

viii) Fatigue test of jute reinforced composite : A glass mat reinforced mold was prepared for the purpose of makihg test specimens according to dimensions and shape (Figure 3) required for the Terco MT 205 Testing Machine. A random sample 200 mm long, 0. 752 mm mean dia of BTA grade jute yarn was placed in the bottom half of the mold and the yarns were subjected to tension. The top of the mold was then placed above the prepared. The details of the test have been described elsewhere (21). Five similar specimens with pure matrix were also made. The specimens were tested in the fatigue testing machine as cantilever beams with a load of 5 N. The effective span length was 100.5 mm. The life of the test specimen was expressed in number of loading cycles, recorded by the counte automatically.

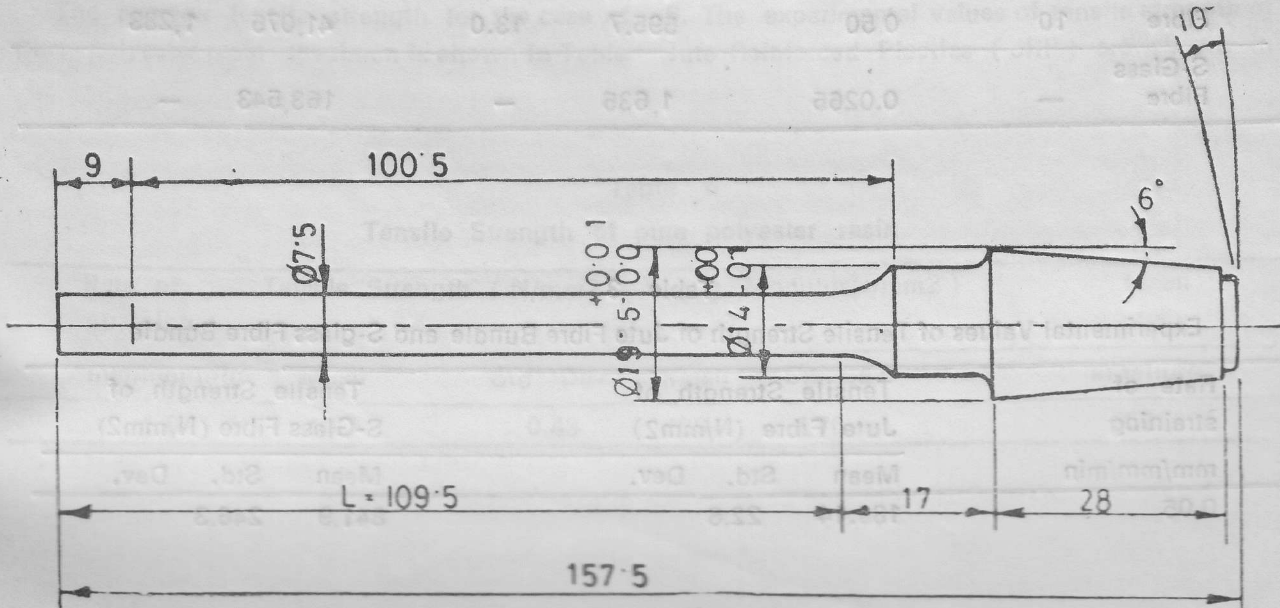


Fig.—3 Fatigue test specimen

bottom and the two sections were clamped. Prior to placement of yarns, the mold had been cleaned thoroughly and subsequentlys its surface were evenly coated with a thin coat of Mold Release Wax. The matrix polyester was then prepared by mixing thoroughly in a container with a wooden stick, while carefully avoiding the entrainment of Cobalt excessive air, 25 gm of Epolac G. 774 TSY, 0.5 gm of Cobalt Nepthante and 0.25 gm of Methyl Ethyl Ketone Peroxide, The resin was then injected into the mold. The mold was cured at room temperature for two hours and then opened to remove the specimen carefully. The composite specimen was placed in air for post curing for a period of two days. For each fraction of jute five specimens were

Results and Discussion

The mean values of tensile strength, modulus of elasticity for the jute fibres are shown in Table 2 together with the values for S-glass fibre (16).

Table 2

Experimental Values of Tensile Strength, Young's Modulus of Jute Fibres

Specimen	Gage Length mm	Rate of straining mm/mm/min	Tensile Strength N/mm2		Young's Modulus N/mm2	
			Mean	Std Dev.	Mean	Std Dev.
Jute Fibre	100	0.05	360.9	58,5	37,916	3,624
	50	0.10	406.2	65.4	40,979	3,561
	10	0.50	595.7	13.0	41,075	1,283
S-Glass Fibre	—	0.0265	1,635	—	163,543	—

Table 3

Experimental Values of Tensile Strength of Jute Fibre Bundle and S-glass Fibre Bundle

Rate of straining mm/mm/min	Tensile Strength of Jute Fibre (N/mm2)		Tensile Strength of S-Glass Fibre (N/mm2)	
	Mean	Std. Dev.	Mean	Std. Dev.
0.05	189.14	22.8	841.9	246.3

The average tensile strength of jute bundle together with S-glass fibre bundle (16) are shown in Table 3. Experimental values for the case of jute yarn, jute yarn bundle and jute matsare shown in Tables 4 and Table 5.

Table 4

Experimetal Values of Tensile Strength and Young's Modulus of Jute Yarn

Rate of straining mm/mm/min	Tensile Strength (N/mm2)		Young's Modulus (N/mm2)	
	Mean	Std. Dev.	Mean	Std. Dev.
0.5	141.4	42.4	5,993	113

Table 5

Experimental Values of Tensile Strength of Jute Yarn Bundle and Jute Mat

Specimen	Rate of Straining mm/mm/min	Tensile Strength (N/mmZ)	
		Mean	Std. Deviation
Jute Yarn Bundle	0.5	102.5	15.2
Jute Mat	0.5	146.6	18.6

The average tensile strength for the case of pure polyester resin specimen is shown in Table 6. The experimental values of tensile strength of Jute Reinforced Plastics (JRP) are shown in

Table 6

Tensile Strength of pure polyester resin

Rate of straining	Tensile Strength (N/mm2)		Young ModulusN/mm2)		Mean strain
mm/mm/min	Mean	Std Dev	Mean	Std Dev	at failure
1.0	10.7	0.43	150	4.76	59

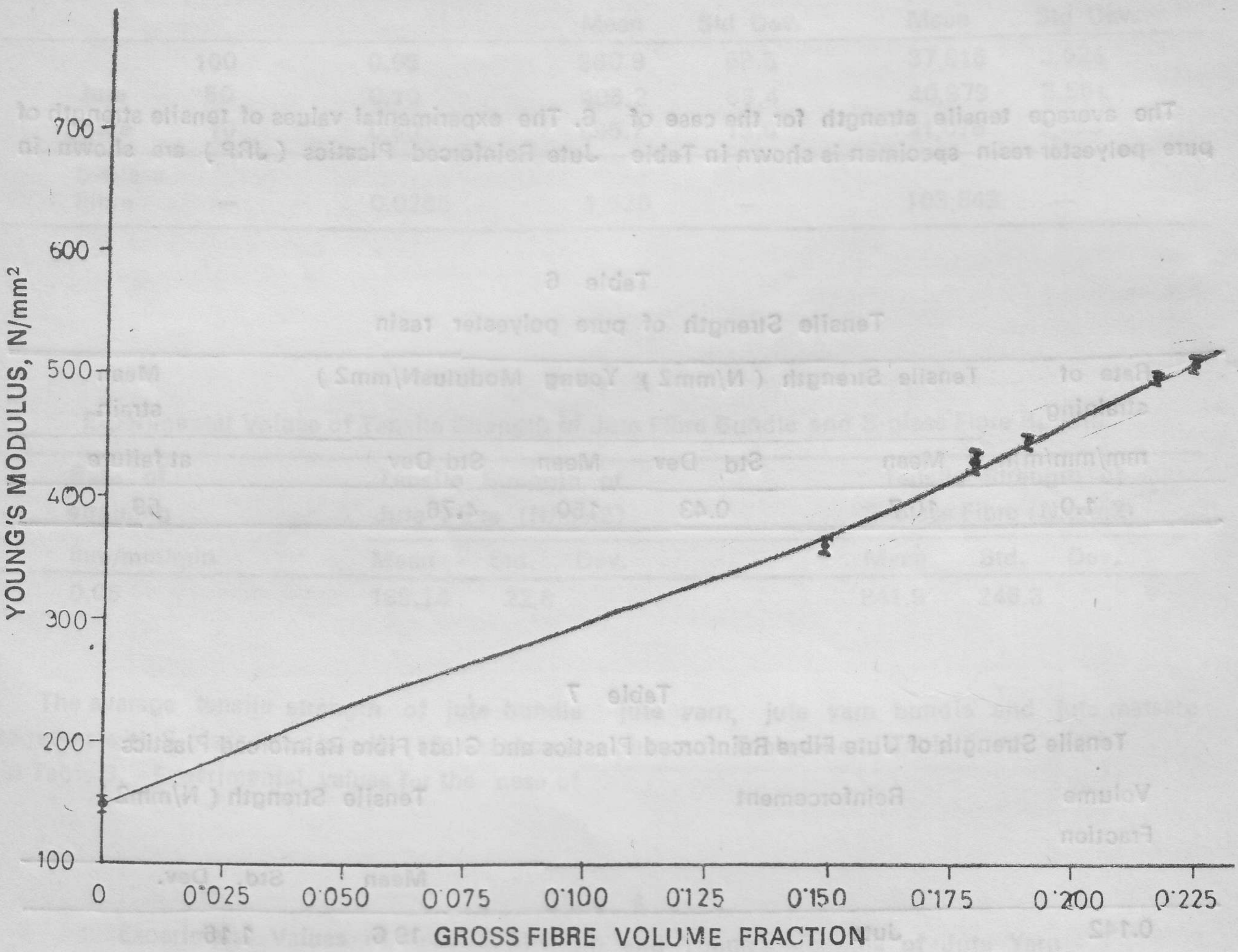
Table 7

Tensile Strength of Jute Fibre Reinforced Plastics and Glass Fibre Reinforced Plastics

Volume Fraction	Reinforcement	Tensile Strength (N/mm2)	
		Mean	Std. Dev.
0.142	Jute	19 6	1.16
0.168	Jute	23.4	1.26
0.178	Jute	24.98	0.372
0.202	Jute	28.5	0.62
0.208	Jute	28.4	0.93
0.0895	Glass	1925	268 4

Table 7. These values have been compared with the values for a typical Glass Reinforced Plastics (GRP). The values for JRP are very low compared to that for GRP. By referring the strength of the two fibres of Table 3 it may be noted that the strength of JRP do not increase like that of GRP due to reinforcement. The effect of volume fraction however indicates that with the increase in volume fraction the strength increases.

The values of Young's Modulus and percent of elongation at fracture as affected by volume fraction are shown in Figures 4 and 5. It is apparent



Fig—4 Young's modulus of composite Vs gross fibre volume traction

Gross fibte volume fraction, v_f

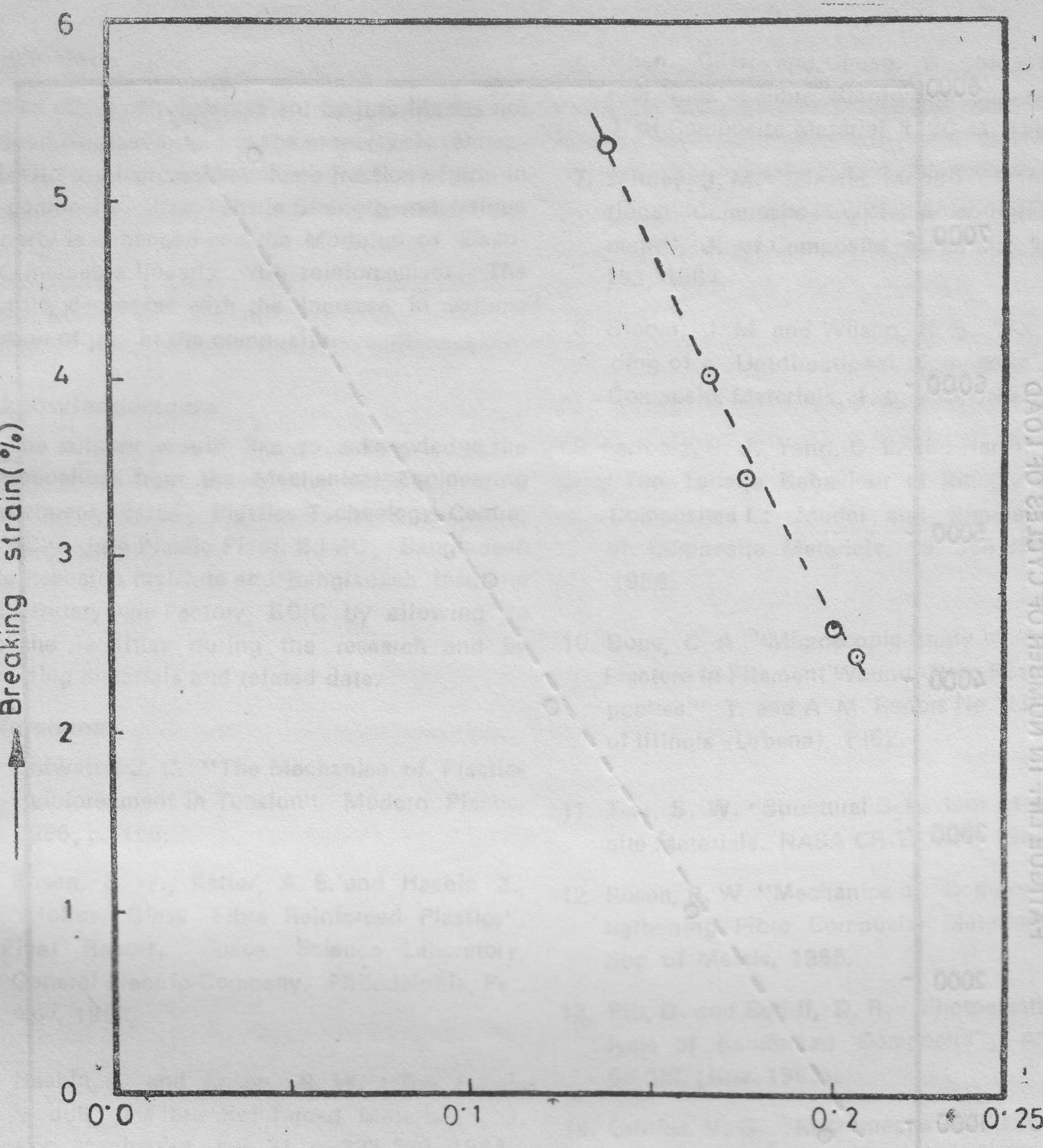


Fig.—5 Mean breaking strain of composite, in percentaqe Vs gross fibre volume fraction

that the value of E increases and percent elongation at fracture decreases with the increase in volume fraction of jute.

The values of fatigue strength of JRP as affected by volume fraction are represented in Figure

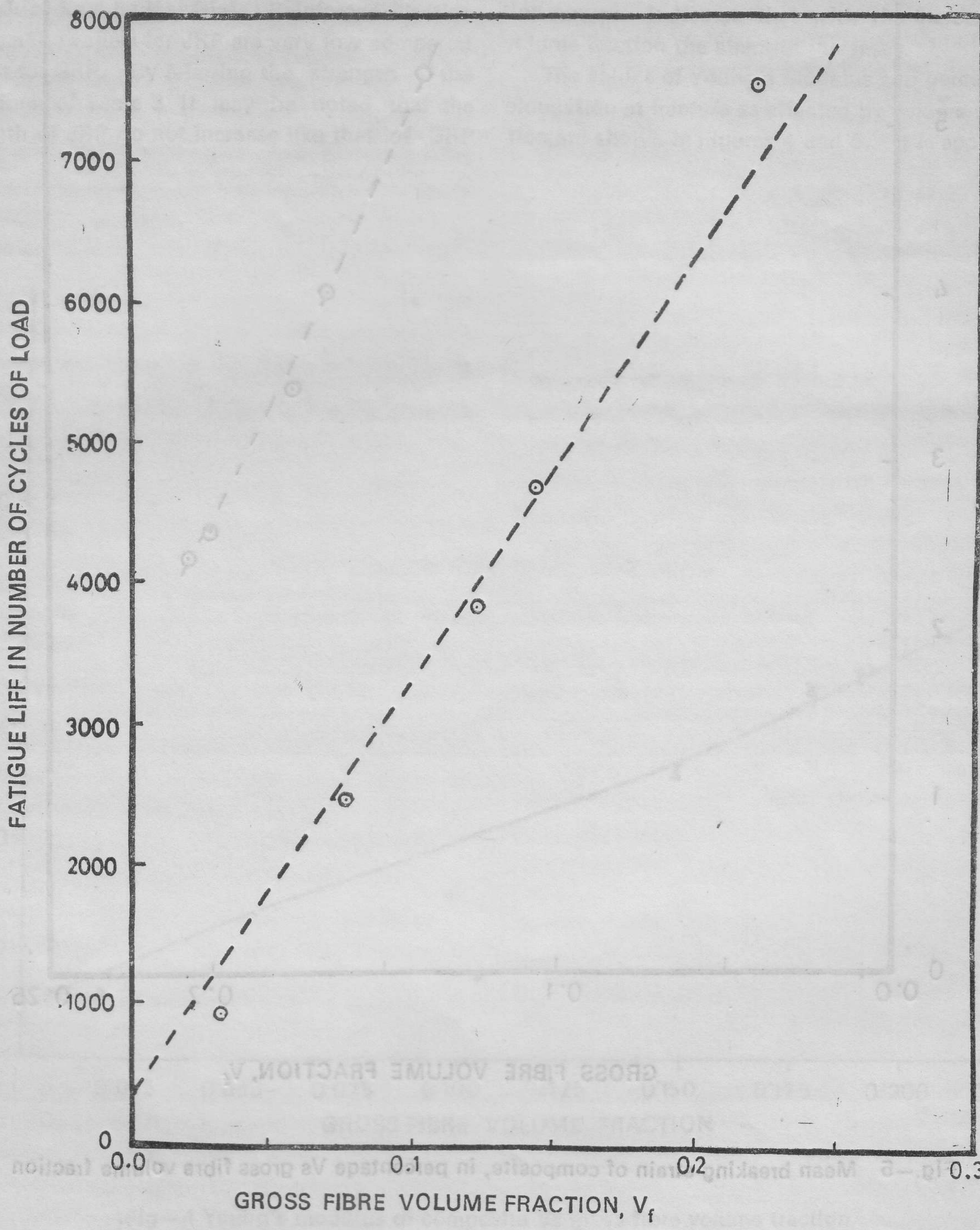


Fig.—6 Fatigue life, in cycles of loading Vs gross fibre volume fraction, at load of 5 Newtons

6 which shows that with the increase in volume fraction the fatigue strength is improved almost in a linear fashion.

Conclusions

The effect of reinforcement by jute fibre is not as good as glass fibre but the property is enhanced with the increase in volume fraction of jute in the composite. The Tensile Strength and fatigue property is enhanced and the Modulus of Elasticity increases linearly with reinforcement. The ductility decreases with the increase in volume fraction of jute in the composite.

Acknowledgements

The authors would like to acknowledge the help received from the Mechanical Engineering Department, BUET; Plastics Technology Centre, BITAC; Jute Plastic Plant, BJMC; Bangladesh Jute Research Institute and Bangladesh Insulator and Sanitaryware Factory, BCIC by allowing to use the facilities during the research and by providing materials and related data.

References

1. Outwater, J. C. "The Mechanics of Plastics Reinforcement in Tension", Modern Plastic, 1956, p. 156.
2. Rosen, B. W., Ketler, A. E. and Hashin Z., "Hollow Glass Fibre Reinforced Plastics", Final Report, Space Science Laboratory, General Electric Company, Philadelphia, Pa., Nov. 1962.
3. Hashin, Z. and Rosen, B. W. "The Elastic Moduli of Fibre Reinforced Materials", J. App. Mechanics, vol. 31, p. 223-232, 1964.
4. Shaffer, B. W. "Stress Strain Relations of Reinforced Plastics Parallel and Normal to their Internal Filaments", AIAA Journal, p. 348 352, 1964.
5. Whitney, J. M. and Riley, M B., "Elastic Stress-Strain properties of Fibre-Reinforced Composite Materials", Air Force Materials Laboratory Report AFML TR 65-238, Dec. 1965.
6. Chen, C. H. and Cheng, S., "Mechanical Properties of Fibre Reinforced Composites", J. of Composite Material 1, 30-41, 1967.
7. Witney, J. M. "Elastic Moduli of Unidirectional Composites with Anisotropic Fiacl-ment", J. of Composite Materials, 1, 188-193, 1967.
8. Bloom, J. M and Wilson, H. B. "Axial Loading of a Unidirectional Composite". J. of Composite Materials, 1, p. 268, 1967.
9. Fariborz, S. J., Yang, C. L. and Harlow, D. G. "The Tensile Behaviour of Intraply Hybrid Composites I: Model and Simulation" J. of Composite Materials, 19, 334-354, July 1985.
10. Boue, C A. "Microscopic Study of Mode of Fracture in Filament Wound Glass-Resin Composites." T. and A. M. Report No. 234, Univ. of Illinois (Urbana), 1962.
11. Tsai, S. W. "Structural Behaviour of Composite Materials. NASA CR-71, July 1964.
12. Rosen, B. W. "Mechanics of Composite Strengthening Fibre Composite Materials", Am. Soc. of Metals, 1965.
13. Pih, D. and Sutliff, D. R. "Photoelastiy Analysis of Reinforced Composite", AFMI TR 68-380 (Nov. 1968).
14. Grinius, V. G. "Micromechanics-Failure Mechanism Studies", TR-AFML-66-177, Aug. 1968.
15. Tsai, S. W. "Strength of Theories of Filamentary Structures, in Fundamental Aspects of Fibre Reinforced Composites", ed. Schwartz, R. T. and Schwartz, H. S. Interscience, New York, 1968, p. 3-11.
16. Armenkas, A. E., Garg, S. K., Sciammarella, C. A. and Svalbox, V.

"Experimental Study of the Failure Mecheanism and Strength Characteristics of Eibre Bundles and Composites", Experimental Mechanics, 12, 1-10, 1972.

17. Daniels, H. E. "The Statistical Theory of the Strength of Bundles of Thread-I", Proc. Royal Society (London), Ser. A, 183, 405-435 1945.

18. Gucer, D. E. and Gurland, J. "Comparison of the Statistics of Two Fracture Models", J. Mech. Physics of Solids, 10, 365-373, 1962.

19. Arridge, R. G. C. "Orientation Effects in Fibre-Reinforced Composites where the Modulus of the Fibres is No More Than an order of Magnitude Greater than that of the Matrix," Presented at 18th Ann, Meeting of Reinforced Plastics Div. of Soc. of Plastics Industry, 1963.

20. Gordon, J. E. "On the present and potential efficiency of structural plastics", J. of Royal Aero. Soc., 66. 704-728, 1952.

21. Kazim, K. A. "Study of Mechanical Behaviour of Jute Fibre Reinforced Plastics," M. Sc. Engg. Thesis, Mech Engg. Deptt., BUET, Dhaka, 1986.