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INVESTIGATION ON PERFORMANCE OF JUTE AND HYBRID (JUTE-GLASS) FIBER REINFORCED COMPOSITE PIPES

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ABSTRACT: The developed filament winding machine and modified lathe machine is used to fabricate cylindrical components. The components were developed using natural fiber (jute fiber) and natural-synthetic (jute-glass) fiber in epoxy matrix. Both machines consisting of wooden cylindrical mandrel over which resin impregnated fiber are wounded to obtain cylindrical components. For fabrication we used a raw material like, jute fiber of 0.5mm diameter, glass fiber 2400Tex and epoxy (LY 556) resign with hardener (HY951). Two experiments, three point bending and ring compression test were conducted to find the characteristics of composite pipes using ASTM standard. Different pipes were fabricated to conduct three point bending test using developed filament wing machines and for ring compression test specimen developed using modified lathe machine. Form the experiments it's observed that the drastic increases in strength of jute-glass/epoxy hybrid pipes when compared to the jute/epoxy pipes.

KEYWORDS: Jute Fiber, Hybrid pipe, Composites, Bending Strength, Effective modulus

I. INTRODUCTION

Composite cylindrical parts are used in a range of applications including pressure vessels, drive shafts, water lines and chilled water pipes, waste water and sewage systems, ventilation ducts and tubes, cooling water pipes, etc. If we use steel pipes for above application then cost involved in making and maintaining the pipes is huge because corrosion is the big drawback. Hence an alternative technique for fabrication of composite pipes is filament winding technique. If we use the composite pipes then we can overcome the above drawbacks. The main advantage of composite pipes is cost involved in making composite pie is less when compared to the metal pipes [1]. Enormous research has been performed on the efficiency of composite cylindrical parts reinforced by synthetic fiber.

Based on corrosion resistant polyester resin and wounded glass fibers at six different wind angles, biaxial pressure loading, hoop pressure loading and tensile loading, filament wound pipes were tested. For every pipe a stress/strain reaction was obtained and the findings compared to those expected by traditional lamination theory. The three separate loading cases obtained strong agreement between theory and experiment [2]. Research was carried out on the diffusion of water in the GRP pipe wall and its effect on the pipe properties. A model built from the Ficks law is used to predict the cycle of water diffusion that is in line with the experimental data [3]. The impact of hybridization of natural fiber with glass fibers for applications in the piping industry was examined. Hemp, flax and kenaf were the natural fibers examined [4]. Using standard bending testing procedure, determined the bending strength, bending module of elasticity and deflection of glass/polyester composite pipes [5, 7]

Theoretical, numerical and experimentally calculated the off axis bending strength of composite using four point bending test. The measurement of longitudinal bending compatibility was shown to be extreme by traditional test instruments [8]. The corrosion is the big problem in oil industries, the challenge face by oil industries to develop composite pipes which can fit for over 20 to 30 years [9]. In this research, the production of cylindrical component using natural fibers (jute fiber) and Hybrid or natural synthetic fibers (jute-glass fiber) is tried and their behavior under the bending and compression loading phase is investigated. Their usefulness is also examined.

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II. EXPERIMENTAL

2.1 Materials used

Table 1 shows the details about materials used for the fabrication of natural reinforced and hybrid composite pipes for testing three point bending and ring compression test.

Table 1 Materials Details used for Fabrication

Sl. No	Details	Material	Specification
1	**Reinforcement**	Jute fiber	Diameter of the yarn – 0.5 mm Density- 1.42 g/cm^3
		Glass Fiber	2400 Tex Density- 2.5 g/cm^3
2	**Matrix**	Epoxy	LY 556 Density- 1.22 g/cm^3
3	**Hardener**	Araldite	HY 951 Density- 0.98 g/cm^3

The resin system consists of epoxy and hardener in the ratio 1:0.10.

2.2 Fabrication of pipes and preparation of specimens

Figure 1 (a) is used to fabricate composite pipe of diameter 60mm and 70mm used in three point bending test and Figure 1(b) is used to fabricate a composite pipe of diameter more than 200mm diameter. The reason of Fig 1(b) is mandrel weight for more diameter composite pipes.

The filament winding machine shown in Fig 1(a) consists of a carriage, mandrel, and direction reversing/switch mechanism, transmission mechanism and resin bath. The fiber yarns are guided to pass through the resin bath where it gets impregnated with the resin system. The impregnated fiber yarns then pass through the carriage on to the mandrel for winding. Provision is made in the machine to vary the speed of rotation of the mandrel and carriage to obtain different winding angles and pitch. Relay switches are used to reverse the direction of movement of the carriage. Provision is also made in the machine to control the tension in the fiber yarn and to squeeze and collect the excess resin.

Higher diameter (>200 mm) are needed for ring compression test is fabricated using modified lathe machine shown in Fig 1(b). Because of the limitation of filament winding that the maximum diameter of the pipe that can be cast is limited to 150mm, the different samples for ring compression test are fabricated using modified lathe.

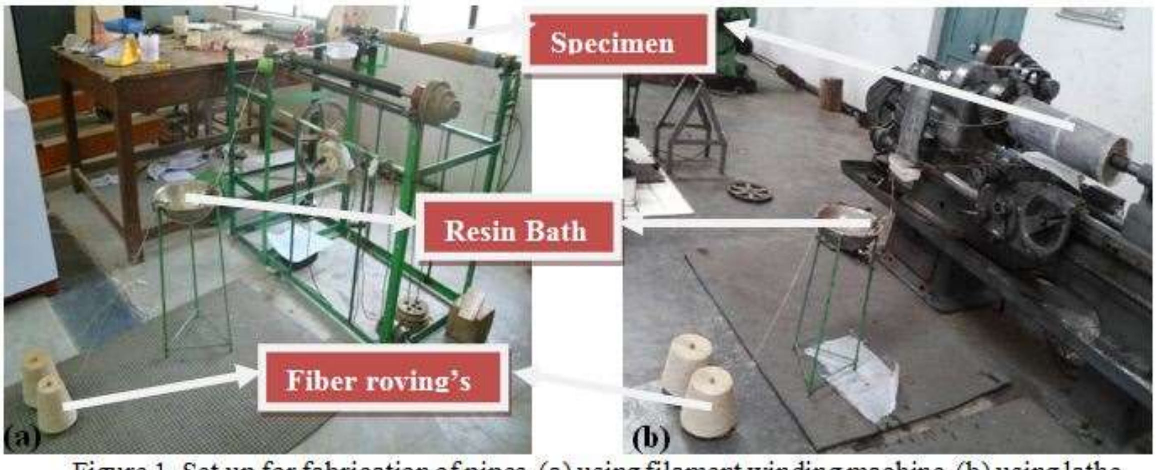

Figure 1. Set up for fabrication of pipes, (a) using filament winding machine, (b) using lathe.

The Fig 2 (a) shows the jute fiber reinforced composite specimen fabricated using developed filament winding machine and Fig 2(b) is hybrid composite pipe fabricated for three point bending test. Figure 2 (c) is jute fiber reinforced composite pipe fabricated using modified lathe machine the specimen used for ring compression test.

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Figure 2. Pipes fabricated, (a) and (b) Using filament winding machine, (c) Using lathe.

Table 2 presents the detailed specification of the component fabricated using Filament winding machine and modified lathe these components are used in three point bending and ring compression tests.

Table 2 Detailed specifications of fabricated specimens

Sample details	Bending test				Ring compression test			
	Sample code				Sample with code			
	Jute/epoxy		Jute-Glass/epoxy (Hybrid)		Jute/epoxy		Jute-Glass/epoxy (Hybrid)	
	B60J	B70J	B60H	B70H	C20J	C40J	C20H	C40H
Inner dia, mm	60	70	60	70	200	200	200	200
Thickness, mm	5	5	5	5	5	5	5	5
Length, mm	478	478	478	478	20	40	20	40
Helix angle, Deg.	66	66	66	66	90	90	90	90

2.3 Three point bending test

The developed 60mm and 70mm diameter composite pipe of both natural and hybrid pipes were tested using three point bending. Experiments were conducted using computer interfaced universal testing machine TUE-C-400 as per ASTM D 790. The span length of 300mm is maintained during test and the loading rate was 5mm/min. The Fig 3 shows the bending test configuration for one of the sample (jute-glass epoxy). Using the equation (1) the average bending stress of the reinforced pipe in the outer layer is calculated when the pipe fails [5].

Figure 3. Bending test configuration

$$\sigma_f = \frac{P_{max} L D_o}{2 I_{xx}}$$

(1)

Where,

P= Maximum applied load on specimen (N)

L= Support length (mm)

D_o =Outer diameter of the reinforced pipe (mm)

D_i=Inner diameter of the reinforced pipe (mm)

I = Moment of inertia (mm^4)

σ_f =Maximum bending stress (MPa)

The moment of inertia I is calculated using the equation (2).

$$Ixx = \pi \frac{(D_o^4 - D_i^4)}{64}$$

(2)

2.4 Ring Compression test

Ring compression test was conducted in UTM with 200kN capacity according to ASTM D2410 to determine the compressive stiffness of the fiber reinforced composites pipes. The developed composite pipe is held between two steel plates. The bottom plate is stationary and top plate is subjected to gradually applied load. During the experiment the load applied and deflection is noted. The loading rate during experiment was maintained to be v=8mm/min. The experimental setup is shown in Figure 4.

Figure 4. Ring compression test configuration

The effective elastic modulii of composite material is estimated using equation (3) [6]

$$Eeff = 0.223 \frac{Dn^3}{S^3 L} \mathrm{X} \frac{\Delta F}{\Delta f}$$

(3)

Where,

L = Length of the ring specimen (mm)

S= Wall thickness (mm)

Do = Di+S is the outer diameter (mm)

($\Delta F/\Delta f$) is the slope from load-deformation plot.

III. RESULTS AND DISCUSSION

3.1 Bending test results

Load-deflection plot for three point bending test on 70mm diameter specimen is shown in Fig 5 from the plot it is observed that hybrid reinforced pipe with stand to a maximum load when compared to the natural fiber reinforced pipe.

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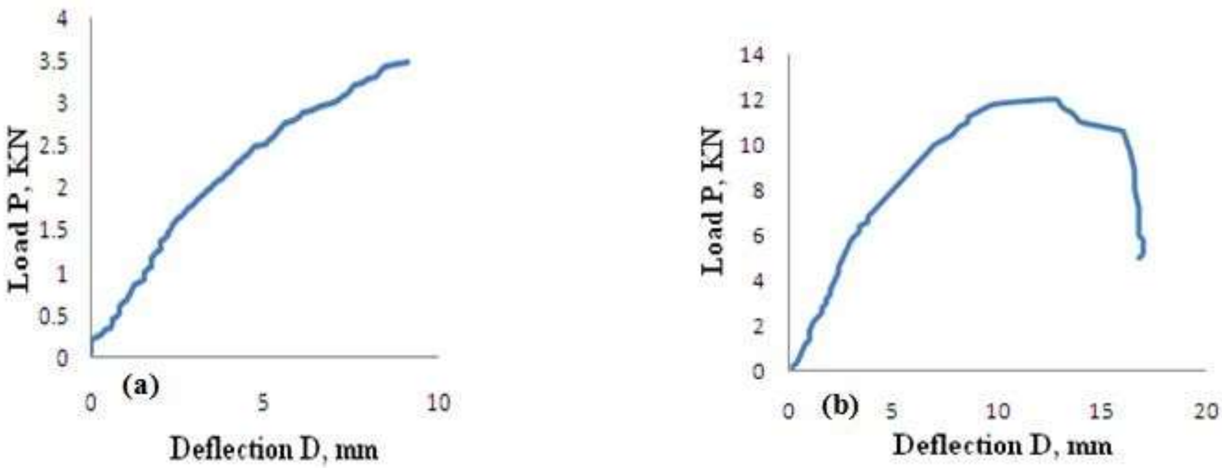

Figure 5. Load – deflection plots for 70 mm diameter pipes, (a) Jute/Epoxy, (b) Jute-Glass/Epoxy

The bending strength of the natural reinforced pipe and hybrid reinforced pipe is compred which is shown in Fig 6. It can be shown from the statistics that the bending capacity of the hybrid composite pipe is stronger that of only natural fiber by more that 200%. This is because of the strong strength and rigidity of glass fibers relative to jute fibers. The bending strength is also affected by the geometry of the specimen. Obviously, for the same material, lower diameter pipes exhibited higher bending strength.

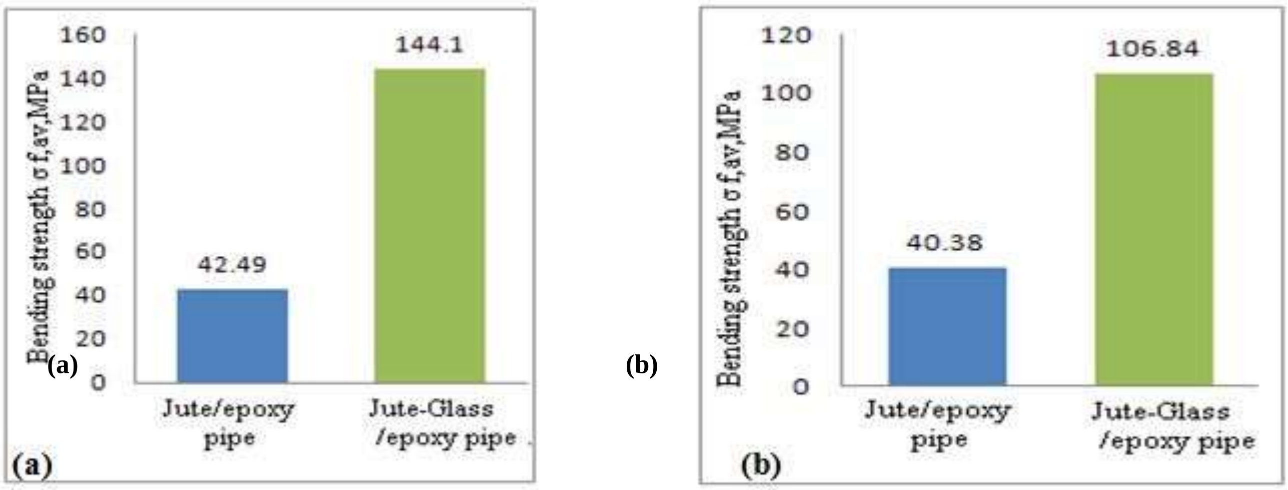

Figure 6. Bending strength of the pipes (a) Pipe of φ60mm, (b) Pipe of φ70mm

3.2 Ring Compression test results

Load-deformation plot obtained during ring compression experiments is shown in Fig 7. From fig it is observed that the load with standing capacity is more in hybrid composite pipe.

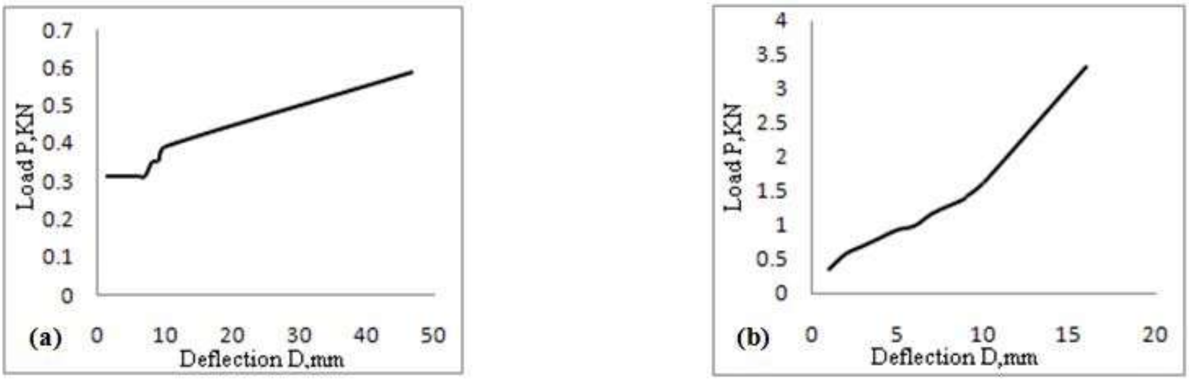

Figure 7. Load – deflection plots for Jute/Epoxy and Jute-Glass/Epoxy, (a) Jute/Epoxy, (b) Jute-Glass/Epoxy

Figure 8 contrasts the maximum effective elasticiy modulus for jute/epoxy, and jute-glass/epoxy applications. It can be seen from the figure that, relative to only jute composite pipes, the efficient module of the hybrid composite pipe is dramatically incresed. The effective compressive modulii is also affected by the geometry of the specimen and behaviour of the material under radial compressive load(slope of load-deformation plot). The samples with lower length depicted higher modulus.

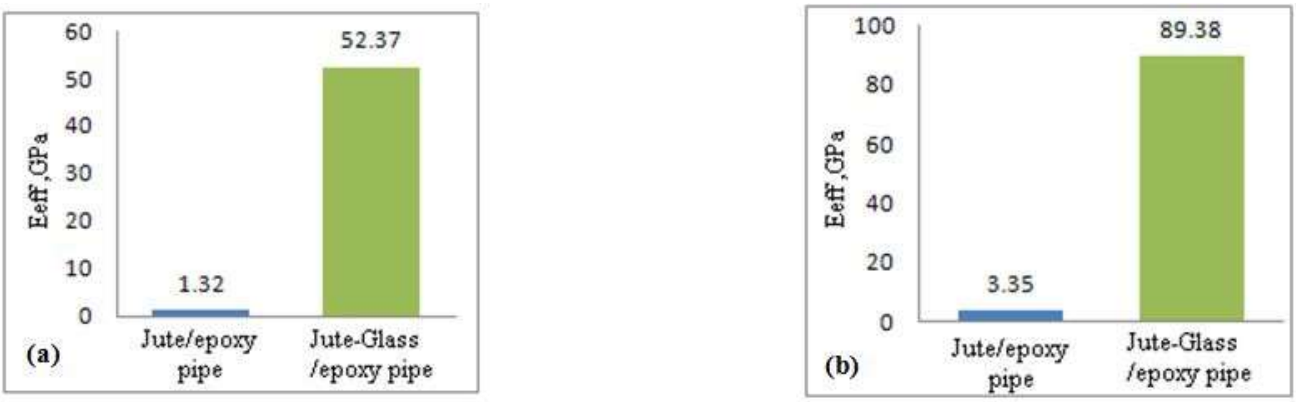

Figure 8. Effective modulus values for jute/epoxy and Jute-glass/Epoxy pipes, (a) Jute/Epoxy, (b) Jute-Glass/Epoxy

IV. CONCLUSIONS

From the research findings it can be argued that, addition of glass fibers to jute fibers significantly increases the bending strength and effective radial compressive modulus of the resulting hybrid composite pipes. The geometry of the test specimen (diameter in case of bending and length in case of ring compression) has significant effect on the properties. Hybrid composite pipes can be used for the air ducting, roof drains, ventilation, plant piping, corrosive pipe line etc as they display propertis higher than those found in the litrature on the glass/polyester composite pipes.

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