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Impact Analysis of Carbon/Glass/Epoxy Hybrid Composite Pipes

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Abstract: ***Filament winded composite pipes are used in various environments conditions for different applications. In this study filament winded hybrid (Glass/Carbon/Epoxy) composite pipes with interwoven (CG90/CG60) orientation were tested under various low velocity impact conditions for two different thickness. Internal diameter as 50 mm with various thicknesses such as 4 mm, 6mm are used to study the effect of impact. The impact test conducted at three different energy levels as 20 J, 25 J and 30 J. Effect of impact on these pipes were measured by the comparison of energy absorption, force and deformation values. The results shows that increasing thickness of specimens increase maximum load carrying capacity and reduces the energy absorption and deformation of impacted specimens***

Keywords: ***Hybrid composite pipes,Impact behavior, Carbon/Glass/Epoxy hybrid composite, Filament winding technique***

I. INTRODUCTION

Composite materials are made by combing two or more different constituent materialsto obtain desired properties.Their advantageous material properties like strength to weight ratio, high corrosion resistance property and good fatigue strength, forever the use of composite pipes in many piping due to and auto mobile industries.In some situations, composite pipes are subjected to low velocity impacts due to sudden drops of loads like tool drops during maintenance or some fitting operations, which can reduce the strength of the fiber composites but not showing any visual damage on impacted the surface. The effect of impact depends upon the material characteristics and impact parameters such as impact energy mass, plunger diameter, and material thickness and diameter of materials.A study of the behavior of impact on composites is important to understand the initial failure of fibers at the time of the impact. Doyum and Atlay [1] studied the impact damage in glass/epoxy cylindrical tubes with various energy levels for two different orientations of composites and found this was due to the large elastic deformation of this walls parallel running circumferential cracks developed at the lateral sides with respect to the impact point at high energy level.

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The effect of sea water effect on impact behavior of glass-epoxy composite pipes was studied by Mehmet EminDeniz and RamazanKarakuzu [2],They found the absorption of sea waterreducing the strength of specimens and a decrease in the failure area

with increasing pipe diameter. Khalili et al. [3] studied the finite element modeling of low velocity impact on laminated composite plates and cylindrical shells by using the ABAQUS software to model the composites.CelalEvci et al. [4] made experimental investigation on the impact response of composite materials under various impact energy levels and found plain weave E-glass composite exceeding 43% than unidirectional E-glass fiber composite in hertzian failure and maximum force. Minak, Abrate et al. [5] made an analytical and experimental study of low velocity impact on carbon/epoxy tubes subjected to torque and found delamination initiation is not affected by the torsional preload. Saud Aldajah et al [6] studied the impact of sea and tap water exposure on the durability of GFRP laminates and found laminates lost their strength when exposed to sea water and tap water environments. Satoshi Kobayashi and Mari Kawahara [7] studied the effects of stacking thickness on the damage behavior in CFRP composite cylinders subjected to out-of-plane loading and found that a thicker CFRP improved the stiffness of the cylinder and decreased the resultant plastic deformation due to indentation. Giovanni Belingardi and Roberto Vadori [8] studied the low velocity impact test on glass fiber epoxy composites with three different orientations.Murat Sari [9] studied the behaviour of impact in different energy levels and impacted and non-impacted specimens were used in the study of the fatigue life of specimens which were subjected internal pressure.A.S. Kaddour, M.J. Hinton and P.D. Soden [10] studied the behaviour of GRP filament wounded pipes under uniaxial tension and compression loading for various wall thicknesses. MesutUyaner, Memduh Kara and AykutS_ahin [11] burst strength and fatigue life of the impacted and non-impacted specimens of E-glass/epoxy fibre composite tubes. Memduh Kara, MesutUyaner, AhmetAvci, and AhmetAkdemir [12] made study on studied the effect of low velocity impact on pre stressed e-glass fibre composite tubes and the changes in diameter due to internal pressure were observed. Lokman GEMİ, Memduh KARA and Ahmet AVCI [13] foundhybrid composite pipes with various internal pressure were subjected to impact test and burst strength of the impacted specimens.M. Kathiresan, K. Manisekar [14] reported the effect of low velocity axial impact loading in frusta and values validated by FEA (ABAQUS).

QiaoguoWu, Xuedong Chen,ZhichaoFan, Yong Jiang and DefuNie [15] studied the effect of impact with different types of impactors on carbon wrapped composite cylinders.

The main objective of this study is to understand the behaviour of different thickness hybrid composite pipes with different energy levels.

II. EXPRIMENTAL

A.Specimen preparation

Figure 1 shows the filament winding machine, which was used for manual winding of the composite pipes. Interwoven Carbon and Glass fibers were wound using the filament winding method with different layers of 6 and 8 as orientation shown in table 1. The internal diameter of composite pipe was 50 mm with varying thicknesses such as 4 mm, 6 mm. The mandrel was coated with wax and covered with a Teflon sheet for easy removal of composite pipes after getting cured, Resin coated roving E-glass and carbon fibers were wound around the rotating mandrel. The orientation of specimen was varied with the help of the movement of horizontal a carriage.The entire curing process was carried out at room temperature for 24 hours while the mandrel was rotating. The cured composite pipe was pulled out and cut into 100 mm length with two thicknesses and diameters.

Figure 2 (a) shows the hybrid composite pipes which were wound by a filament winding machine and (b), (c) are specimens of composite pipes with 4 and 6 mm thickness and cut using the water jet cutting machining process. Fibers and matrix are separated from the composite sample using acid dilution method and using nitric acid.The composite and fibers were weighed before and after processing.

Weight of the composite (sample) = 2.6902 g

Weight of the fibers (Carbon & Glass) = 1.762 g

Weight of the epoxy = 0.9282 g

Density of carbon fiber = 1.8 g / cm3

Density of Glass fibers = 2.58 g / cm3

Density of epoxy = 1.15 g / cm3

By calculations, fiber and matrix volume fraction find out.

Carbon = 20 % Glass = 56 % Epoxy = 23 %

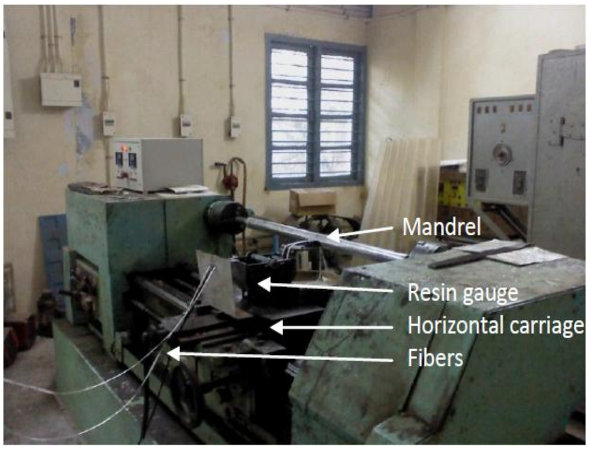
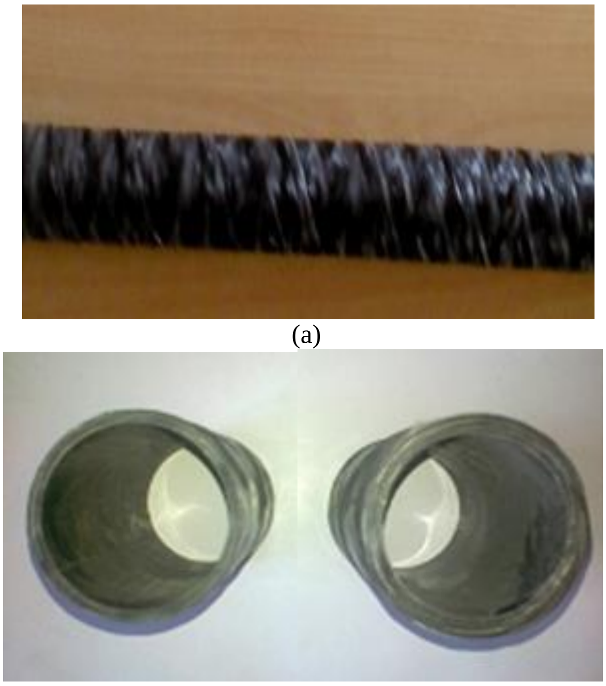


Fig.1. Filament winding machine



(a)

(b) (c)

Fig. 2. Hybrid composite pipe and specimens (a) Hybrid Composite Pipe with internal diameter 50 mm (b) 6 Layer Specimen (c) 8 Layer specimen

Table-I: Orientations for 6 and 8 layer specimens

Number of layers	Orientation	Thickness in mm
6	$(CG_{90}/CG_{60})_3$	4
8	$(CG_{90}/CG_{60})_4$	6

B.Impact test

Low velocity impact analysis was done using a bi-axial drop weight (Fractovis plus) machine, this is shown in Figure 3. Specimens were tested in accordance with ASTM D5628 standard. The V-block fixture was used for holding the testing specimens, this is shown in Figure 4. Compressed air was used for clamping the specimens. The projectile has a hemispherical head of 12.7 mm radius.The piezoelectric load cell was placed at the other extremity of the calibrated cylindrical rod that constituted the projectile, to which the pushing mass was connected with cross head. The mass of the projectile was 2 kg, an additional mass 2 kg attached to the projectile. Impact energy range varied as 20 J, 25 J and 30 J. Four specimens with each thickness were tested to determine the impact response of Glass/Carbon hybrid composite pipes for the sequence considered. Mixed mass used for getting the impact effect. Impact energy and height were also varied with respect to velocity and mass. Velocity values were calculated from the impact energy.

Table – II mpact velocity at different energy level

Impact Energy (J)	Velocity (m/s)
20	3.191
25	3.569
30	3.91

Fig.3. Impact test machine

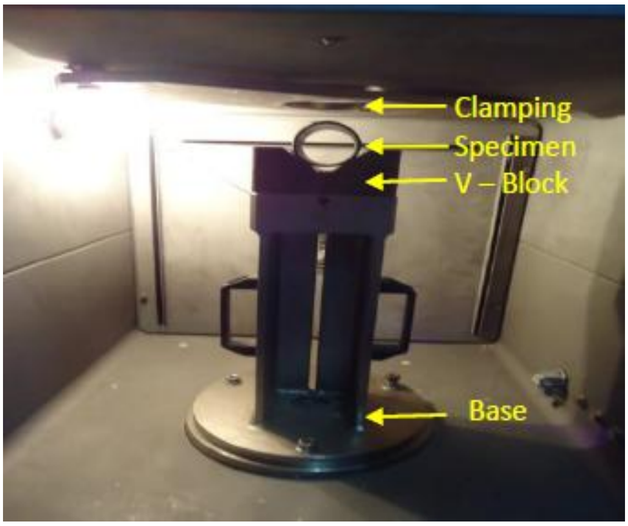


Fig.4. V-Black fixture with specimen

III. RESULTS AND DISCUSSION

The results seen from the impact analysis using the experimental method are given below.Orientation of the specimens- (CG90 / CG60)3 four specimens were tested under each condition.

Table – III mpact test results for 4 mm and 6 mmthickness specimen with various impact energy levels

Energy level	Maximum deformation (mm)	Maximum energy (J)	Maximum force (KN)
4 mm thickness			
20 J	3.109	15.637	3.781
25 J	3.709	21.377	4.062
30 J	4.709	26.522	4.358
6 mm thickness			
20 J	1.635	14.290	6.206
25 J	2.127	19.721	6.535
30 J	2.585	24.611	6.935

Table 3 shows the impact test results for one of the orientations (CG90 /CG60)3 with 4 mm and 6 mm thickness specimens, at varying impact energy levels namely, 20 J, 25 J and 30 J. Deformation of specimens at the time of impact, maximum absorption energy of the specimen by impact and maximum contact force at the time of impact are shown.

Maximum force values were seen increasing with the values of increasing impact energy and the number of layers. But the deformation values and the maximum energy values were decreasing with respect to increasing the number of layers. It shows the damage area of specimen can be reduced by increasing the number of layers. This way due to increasing stiffness of specimens while increasing the number of layers

In force- deformation graphs all curves look.like similarly for three impact energy levels. But the maximum force and deformation values were changing depending upon the impact energy. The area under the curve represents deformation energy, which is transferred from theimpactor to the specimen. The maximum energy absorption of material can be evaluated at this time.

Start with material damage and Maximum force value were identified using the force-deformation graph.Force versus deformation graphs clearly show for increasing impact energy force and deformation values also with increase in various impact energy levels. The deformations of the laminates werereduced to nearly half of the maximum deformation when rebound occurred.Figures 7 and 8 show the initial fiber failure values and maximum load carrying capacity with respect to load and time. In 6 layers and 8 layer specimens for 30 J impact energy initialfailure occurred at 3425 N and

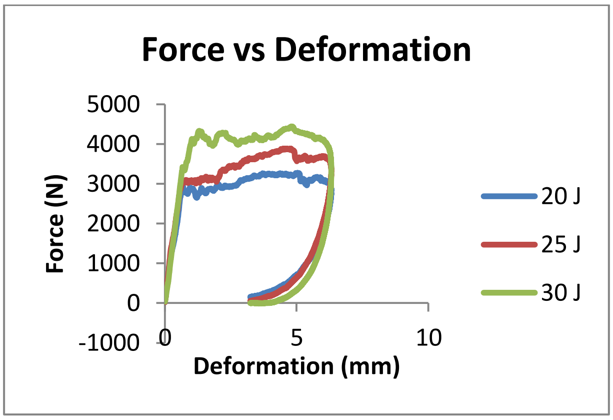


Fig.5.Force – Deformation curvefor 4 mm thickness specimen with 3 different energy level

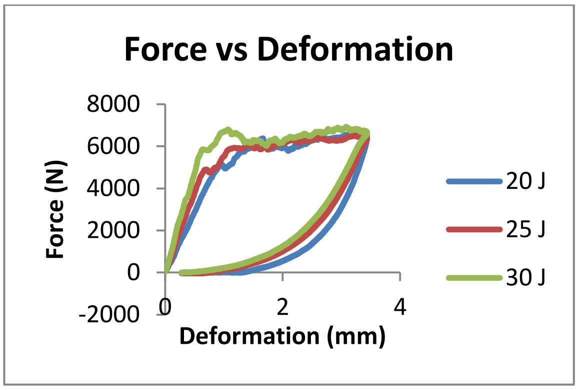


Fig.6. Force – Deformation curve for 6 mm thickness specimen with 3 different energy level

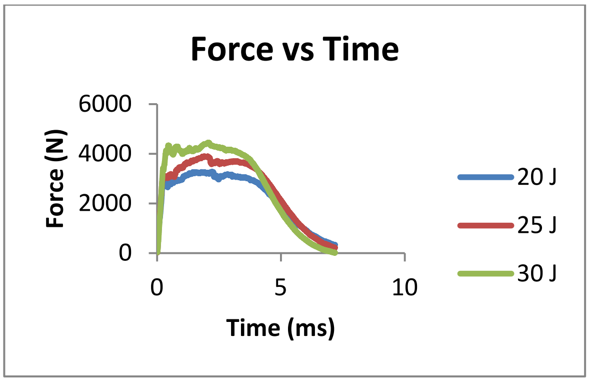


Fig.7. Force – Time curve for 4 mm thickness specimenwith 3 different energy level

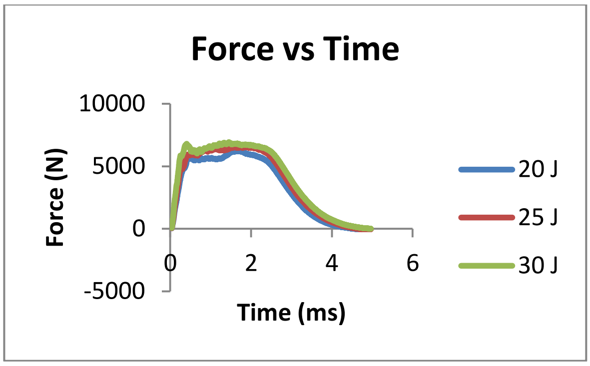


Fig.8. Force – Time curve for 6 mm thickness specimenwith 3 different energy level

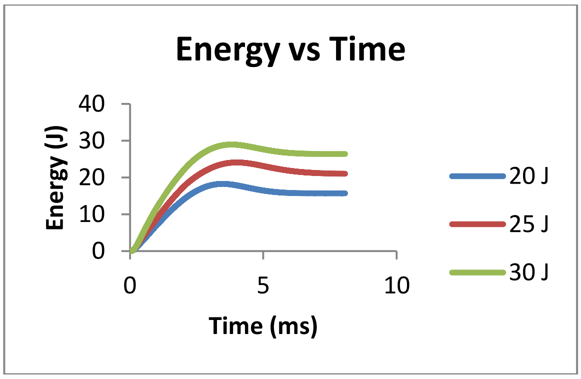


Fig.9. Energy – Time curve for 4 mm thickness specimenwith 3 different energy level

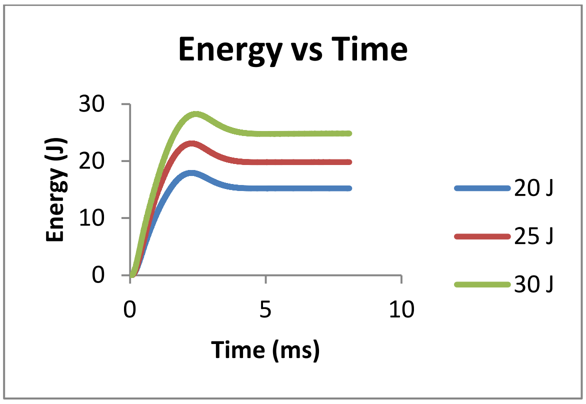
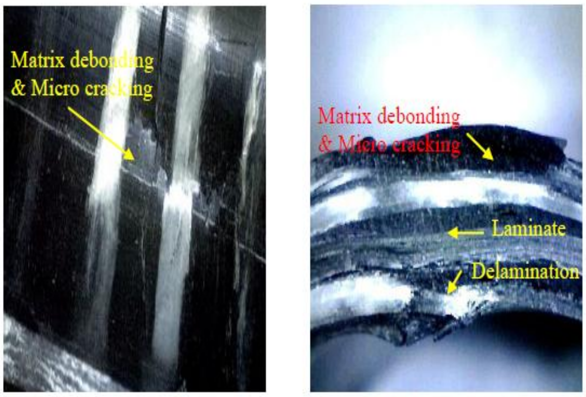


Fig. 10. Energy – Time curve for 6 mm thickness specimenwith 3 different energy level



(a) (b)

Fig. 11. Impacted specimen (a) back side view (b) Along Thickness

IV. FAILURE ANALYSIS

Figure 11 shows the impacted 4 mm thickness specimen. This was taken using USB micro viewer with the 20x magnification factor. Fiber failure was found at the impacted place. Matrix de-bonding and delamination failure was found along the longitudinal direction in the rear view of the impacted specimen. Figure 11 (b) shows delamination failures along the thickness of the specimen. The top layer of the specimen was subjected to compressive load and so delamination was not found in this layer but matrix de-bonding and micro cracking in laminate occurred. The last layer of the specimen was subjected to tensile load at the time of impact, Delamination and matrix de-bonding, micro cracking failures occurred in this layer at the time of impact.

V. CONCLUSION

In this study, carbon/glass/epoxy hybrid composite pipes were tested using the free fall impact test. Details of the impact behavior of material at various energy levels were obtained in terms of maximum force, maximum deformation and energy absorption for both the layers. These showed that the maximum force and energy absorption of material could be increased with decreased deformation by increasing the number of layers.

The damage to material at the time of impact can be reduced through increasing the number of layers, and impacted specimens failed due to matrix de-bonding and micro cracking and delamination on surfaces and along the thickness.

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