Impact Response of Basalt Composite Pipe Using Filament Winding

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Abstract: The aim of this work was to study the energy absorption of composite pipes under different level of low velocity impact test. The basalt fiber is used for making filament wound composite pipe. Because it offer more strength and a reduction in density when compared to existing fibres such as glass fibres, carbon fibre and etc... Moreover the fibre has higher breaking strength compare to other fibre. The basalt composite pipe is manufactured under filament winding process with the help of epoxy resin and undergoes impact tests. The pipe is manufactured with 100mm diameter, 6mm thickness and filament winding angle is set as 55degree. In this pipes are tested under drop weight low velocity impact machine and strength of the pipe was examined in different energy level. Impact force, displacement, energy absorption were measured.

Key words: Filament winding; composite pipe; impact response; basalt fibre;

1. Introduction:
Fiber reinforced polymer composites materials are used in many more engineering applications areas such as aircraft, marine, automobile and building construction, etc... Many more fibers are used for fabrication of polymer composites materials. The reinforcement fibers as synthetic (glass, carbon, Kevlar , aramid, nylon, etc..) or natural fibers (sisal, banana, flax, jute, hemp,etc..) are used. For biodegradable applications natural fibers are mostly preferred. Basalt fiber is extracted from lava of volcano and its one of natural fiber and more strength than glass fiber. Basalt fiber composite can overcomes mechanical properties of the widely used glass fiber composites[1]. Basalt composite cylinders are widely used, for fluid transport, storage system, cooling systems, and pipe lining in underwater applications[2]. Abdalla et al. Investigated on filament wound composites structures for low cost applications. They have used the basalt roving and dipped in epoxy resin and then filament wound on a mandrel rotating a constant speed of 13.6 revolutions per minute (rpm) while the speed of screw of delivery unit varies from 0 rpm to a maximum of 250 rpm[3]. Filament wound composites pipes are widely used due to more advantages over metal pipes, and also the weight ratio, and resistance against frost, corrosion and heat[4]. Composite pipes require minimal maintenance to ensure they are safe [5]. The composites are tested with different applied load, this will affect the inner layer of the composite that will not visible to our naked eyes the results will gives the life time details of the composite pipes[6]. Hawa et.al. studied the impact test on a composite pipe, the indenter is subjected to the centre of the testing pipe so that impact load will correctly distributed to body of the composite[7]. Low velocity impact testing gives the graphical represents oscillations which are primarily the result of failures formed in the specimens such as matrix cracks and delamination due to impact loading[8]. Hosur et.al. found the failure on composites pipe under low velocity impact test depends on the hammer falling height and geometric properties of the indenter.
[9]. Tarakcioglu et.al. studied the filament winding angle effect on composites pipe. They fabricate the composite pipe with various angles are used (±45°, ±55°, ±65°, ±75°) but they found better properties on ±55° angle orientation and good fatigue performance [10]. The composites are sealed together with an adhesive for bonding this will seal the layer and give the strong bonding this also helps to transfer the load by using a epoxy resin as a matrix [11]. The epoxy resin has low viscosity (0.70 Pas) due to this property they are suitable for wet filament this is known after lot of mechanical test done on the resin [12-13].

2. Materials and Experimental Methods

2.1 Materials
Basalt fibre (Figure 1) was brought from Aerotex, basalt roving Pvt.ltd, located in Mumbai, India. The epoxy resin is used for impregnate the material for control the quality of fabrication. The density of the basalt material is 2.7g/cm³ and the density of epoxy resin is 1.15g/cm³. The modulus of elasticity for epoxy resin (E) is 3.4GPa. Tensile strength of the resin is 79MPa and the Poisson ratio is 0.35. The modulus of elasticity for basalt fibre is 12,500-13,000GPa and the tensile strength is 400-695MPa.

![Figure 1. Basalt Material](image)

The lava from volcano is used for making basalt filament. Initially the crushed basalt lava raw material is required for making the filament. It is a continuous fibre produced through igneous basalt rock melts drawing at about 2,700°F. Though the temperature required producing fibre from basalt is higher than glass. It is reported by some researchers that production of fibres made from basalt requires less energy by due to the uniformity of its heating.

2.2 Polymer Composites pipe fabrication

![Figure 2. Filament winding process](image)

Figure 2 shows the process of filament winding machine. The filament winding method is used for fabrication of basalt fibre reinforced composites pipe structures. The winding angle is set as constant of 55°. The set of seven basalt reel is placed on a machine. Then the single filament is taken from each basalt reel then it is passed through resin bath way. Each seven filament is immersed in epoxy.
resin after that it is wound in a mandrel through guide way. The filament is wound on a mandrel until obtain a designed material thickness then the mandrel is kept in a hot air oven for post curing. After post curing then the pipe is machined using lathe machine for removing unwanted materials and obtained smoothness on a surface of materials.

2.3 Impact Test analysis

![Low Velocity Impact Testing Machine](image)

**Figure 3. Low Velocity Impact Testing Machine**

The energy absorbed and computer based impact testing machine was used. The impact test is conducted in University Putra Malaysia (UPM). The height of the impact hammer is adjustable one for applying different impact energy on the material. Fig 3 shows the low velocity impact testing machine. In this machine the pipe is placed on a V shape fixture for avoiding rolling of specimens during impacting. The spherical shape impact hammer is used for hitting on the materials. The impact hammer is attached to data acquisition of computer system. During impact test the specimen displacement, contact force, absorbed energy, hitting velocity and time were recorded by software. The figure 4 shows the composites pipe specimen placed on a fixture and after impact test the impression of hammer on materials is shown by circle.

![Tested specimen under impact testing](image)

**Figure 4. Tested specimen under impact testing**
3. Results and discussion

![Force vs. Displacement](image1)

**Figure 5. A typical force displacement curve for basalt fibre composite**

The low velocity impact property of basalt fiber reinforced polymer composites pipe structure is listed on table 1. It is shown that, the altitude height of hitting impact is increased then the impact energy of the materials also increased (i.e.) The impact force is increased as the level of impact energy is increased. When the impact energy was sufficient high, the most extreme force appeared to have a similar impact value. This esteem was named as the impact force of the composite pipe covers under the particular focal point. The force displacement curve for basalt pipe structure is as shown in figure 5. In this figure shown that a rebound of displacement is noted after hitting of pipe structure. This rebound is created for main reason is the material try to retain is deformation to original position after hitting. The same trend is observed on Kevlar/epoxy, graphite/epoxy [14], glass/vinylester composites pipe [15]

![Energy, Force Vs Time response](image2)

**Figure 6. Energy, Force Vs Time response of basalt composites pipe for 1.0m distance**

Figure 6 shows the energy absorption behaviour of basalt fibre reinforced polymer composites pipe. The pipe structure is absorbed the energy upto 48J after that the curve is slightly decline and then it should be a straight line with respect to time. The same trend is happen on glass fibre reinforced vinylester composites pipe by Khan et al [15]. They have fabricated the composites pipe for 150mm diameter and 6mm thickness. They conducted the low velocity impact test with various distance and obtained different energy absorption for the same pipe. At the same time they observed that the peak load is increased with respect to impact energy. The Moreover the energy and force are decline the same time on figure 6.
Table 1. Low velocity Impact property of basalt fibre at different height

| Type of pipe materials | Impact distance [m] | Peak force [KN] | Impact energy [J] | Peak deformation [mm] | Absorbed energy [J] | Energy to peak deformation [J] |
|------------------------|---------------------|-----------------|------------------|-----------------------|---------------------|-----------------------------|
| Basalt                 | 1.0                 | 5.25            | 48.09            | 21.87                 | 48.21               | 48.46                       |
|                        | 1.25                | 4.3             | 59.83            | 31.37                 | 59.59               | 59.5                        |

Figure 7. A typical measurement of impression(damaged) zone area on basalt fiber reinforced polymer pipe structure using Image J software.

The image J software is used for measuring the area of low velocity impact impression (damage zone) on basalt pipe structures is as shown in figure 7. It was noted that the impact altitude is increased the area of impacted impression also increased. Moreover, the inner surfaces of basalt pipe structure are deformed due to high altitude and this stage goes to failure condition on pipe. At low altitude of 1 m, the impact hammer is produced the low deformation on a materials. When material absorbed energy level is exceeded then materials goes to catastrophic failure conditions.

4. Conclusions
The following conclusions were obtained from experimental results
- The basalt fiber filament is used as reinforced to making of pipe structure for replacing of harmful glass fiber
- The pipe structure is successfully fabricated using filament winding machine with epoxy as matrix materials
- In low velocity impact test, the fabricated basalt fiber reinforced pipe structure absorbed the maximum impact energy is measured as 60.42J at 1.25 meter attitude hit of impactor. After that composite is broken completely.
- The energy absorption and hitting forces is increased when the loading point is increased upto a particular distance. After that the pipe structure is more damaged.
- The impact damage zone area is increased with increasing loading distance.
- Based on the experimental results, the basalt fiber is better alternative materials for replacement of conventional material pipe.
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