EFFECT OF LOW VELOCITY IMPACT ON WOVEN GLASS FIBER / EPOXY POLYMER COMPOSITE LAMINATE

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ABSTRACT:

Composite materials have become viable alternative to metallic structures in aircrafts and automotive sectors. These structures prone to impact and fatigue loads. The objective of this paper is to investigate the effect of low velocity impact of woven glass fibre/epoxy polymer composite laminate. The specimens were subject to low-velocity impact at different energy levels. The thick laminates experienced higher deflection and the absorbed energy was low, when compared to other thick laminates.

KEYWORDS: *Composites, Fiber, Epoxy, Polymer, Low Velocity Impact,*

1. INTRODUCTION:

In the recent day's composite materials are widely used in all the fields like aerospace, automobile etc. because they have more strength to weight ratio. i.e. composite material has less weight and more strength compared to conventional materials like iron, steel, copper etc. these are more in weight compared to composites. A composite is a structural material which consists of combining two or more constituents. The constituents are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fibers, particles or flakes. The matrix phase material are generally continuous, example of composite system is epoxy reinforced with glass fibers. The use of composites has evolved to commonly incorporate a structural fiber and plastic, this is known as Fiber Reinforced Plastics (FRP). Fibers provide structure and strength to the composite, while a plastic polymers holds the fiber together, common types of fibers used in FRP composite includes: Glass fiber, Aramid fiber, Carbon fiber, Boron fiber, Basalt fiber, Natural fiber(wood, flax, hemp..) etc. In case of fiber glass, thousands of tiny glass fibers are compiled together and held rigidly in place by plastic polymer resin. Common plastic resins used in composites includes: Epoxy, Polyester, Vinyl ester, Polyurethane and Polypropylene etc. There are different types of manufacturing of composite laminates like Hand layup technique, Vacuum bag process, Compression moulding, Filament winding etc.

2. LITERATURE SURVEY:

Leonardo D. et.al [1] studied on "The Measurement Instrumentation for a Custom-Made Bi-Pendulum Impact Test Machine". Experimental investigations of structures under impact loads are normally carried out by means of drop-weight testing rigs, which are often tailor made, and require sensors for fast transient measurement of mechanical quantities. The Leonardo et al, a thorough study on the measurement instrumentation suitable to carry out reliable low-velocity impact tests by means of a custom-made by pendulum impact testing machine is presented. Attention has been focused on the choice of the quantities to be measured, on the measurement problem, on the calibration of the instrumentation, and on the mechanical characterization of the impact rig. Original transducers for the measurement of either the initial impact velocity or the impact force have been developed, and their uncertainty has been estimated.

Paolo Feraboli and Keith T. Kedward [2], they studied on the relative impact performance of composite structures from a force or an energy standpoint. These are peak and critical force; critical and dissipated energy; contact duration and coefficient of restitution (COR), which is direct indication of effective structural stiffness; and residual stiffness which yields a plot that bears a striking resemblance with the normalized Compression after Impact (CAI) strength. The determinate impactor/target system as baseline configuration, the program is applied toward the understanding of the role played in an impact event by fundamental impactor and target parameters. The equations previously derived for the prediction of the force–energy and residual stiffness curves are shown to apply to the configurations tested, thus confirming their general validity. A modification to the existing effective structural stiffness formulation, which does not account for impactor characteristics, is proposed, and it comprises the impactor material, size and mass characteristics.

A finite element model is proposed by Aminanda, Y. et.al, [3] to determine the residual print of sandwiches structures with Nomex honeycomb core and metallic skins indented by a spherical indenter and to simulate its behavior when this indented structure is subjected to lateral compressive loading (known as CAI/ Compression after impact). The particularities of this model rely on representing the honeycomb with a grid of non-linear springs which its behavior law is calibrated from uniform compression test. This simple model, after integrating the cycle behavior law of honeycomb, allow predicting the geometry of residual print with a good precision. This model is then developed to propose a complete computation from indentation, residual print geometry to lateral compressive loading after indentation (CAI). This model allows also predicting numerically the residual strength of structure in CAI and the elliptical evolution of residual print geometry during CAI loading. A good correlation with test results is obtained except for the very small residual print depth.

3. EXPERIMENTAL ANALYSIS:

In the first step, composite laminates are formed by placing woven glass fiber cloth is hand-laid up one ply at a time in the desired angles required. The desired composite thickness is built-up by placing successive layers of the fiber and resin mixture. The purpose of this step is to achieve the desired fiber architecture as dictated by the design requirements.

In the second step, fibers and resins were mixed together to form a lamina. In this, each fabric layer was wetted with resin mixture using a squeezing plate for proper impregnation. The squeezing plates were used to remove excess resin and air, which results in compaction of the plies.

The third step involves creating intimate contact between each layer of the lamina. This step ensures that all the entrapped air is removed between layers during processing. Consolidation is a very important step in obtaining a good quality part. Poorly consolidated parts will have voids and dry spots. The bagged part was then placed in an oven and cured under the specified time, temperature and pressure. The vacuum bag was evacuated to remove the air and the autoclave supplied gas pressure to the part. The vessel contains a heating system and a blower which circulate the hot gas.

The final step is solidification, which may take up to 120 min for thermo sets. Vacuum and pressure was maintained during this period. In thermoset composites, the rate of solidification depends on the resin formulation and cure kinetics.

4. EXPERIMENTAL INVESTIGATION

The impact tests on composite laminates could be performed in various test methods. Now a day's different types of impact testing equipment's are available, it is capable of measuring the force during an impact. However, the most widely used among these are,

a. Drop/falling weight test method.

b. Penetrating impact test method using pneumatic guns.

The tests were performed using an instrumented falling weight testing machine with no energy storage device and is primarily used to investigate the impact behavior under lower acceleration. This type of impact test helps to understand the behavior of materials when they are subjected to impact loads. Falling weight impact testing unit enables to simulate a wide variety of real-world impact conditions and collect detailed performance data. The penetrating test involves higher impact velocities.

In accordance with ASTM D 3029 standard a batch of square, thin (150 × 50 × 4mm) specimens was clamped on a fixture with a rectangular slot. The dart had a hemispherical head of 5mm radius; the piezoelectric load cell is placed at the other extremity of the calibrated cylindrical rod that constitutes the dart, at which the pushing mass was connected. Fig. 4.3 shows the specimen clamping apparatus, specifically designed in order to assure the constancy of the clamping force, through the pre-loading of four helical springs.

Below diagram of the dart and the specimen mounted on the base plate. Specimens of three thicknesses were used in this investigation 4 mm. A fixed impactor mass of 15.69 N with the dart was released from varying heights of 0.5, 1, 1.5 m. The vertical guides of the impact tower were lubricated frequently to minimize any friction generated during the descent of the impactor.

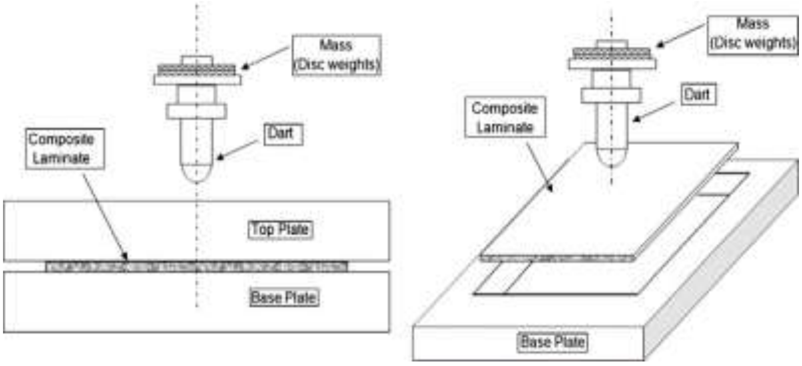


Figure 1. Schematic Diagram of Specimen Being Impacted

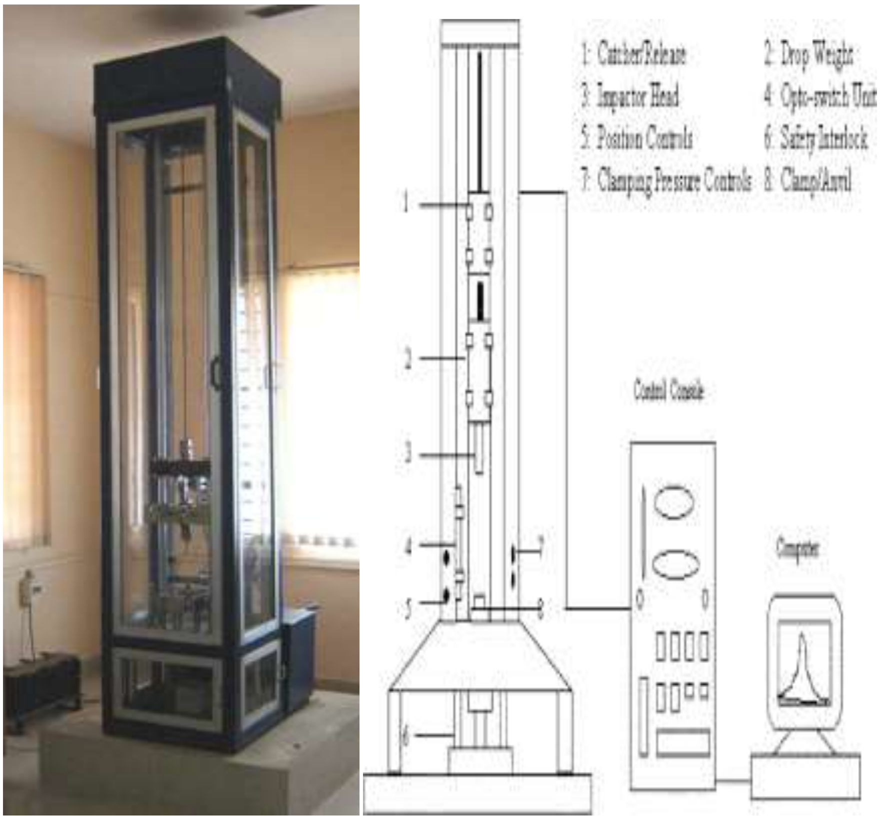


Figure 2. Falling Weight Impact Test Equipment Setup.

Figure 3. Specimen Clamping Apparatus.

5. RESULTS AND DISCUSSION

A number of tests were performed under varied impact energies ranging from approximately7.85–23.54 J. Therefore, in the following, energy profile of the woven composite, the load–deflection curves and the images of some damaged specimens are discussed.

The mechanical system consists of the free falling dart and the constrained specimen. The energy balance equation of the system consists of six terms: three of them refer to the falling dart (kinetic, elastic and gravitational terms) and other to the specimen and its constraint device (kinetic, elastic and gravitational terms). In order to deal with this energy balance equation, the following approximation can be made:

(1) The dart can be considered as a rigid body, so its elastic energy is set to zero;

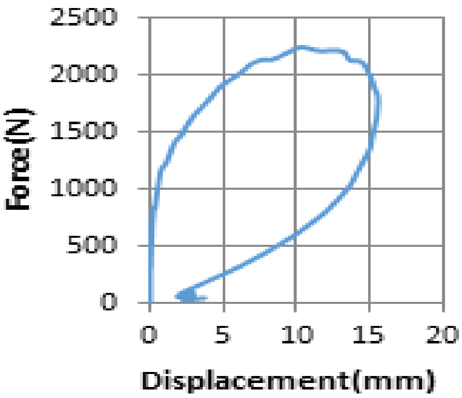
(2) The specimen mass is negligible, if compared with the impactor mass, so its gravitational and kinetic energy variation can be considered negligible.

Graph represents the histories of force and deformation energy. Impact energy (E_i) and absorbed energy (E_a) are the two main parameters that are used to assess the damage process in composite structures after an impact event. Impact energy is the kinetic energy of the impactor right before contact-impact takes place while absorbed energy is the amount of energy absorbed by the composite specimen at the end of an impact event. Absorbed energy is calculated from force-displacement curves.

The experimental tests were performed on three specimens for thickness of 4mm. Tests were performed two times at three energy levels determined by the falling height, namely 500, 1000 and 1500 mm. The corresponding values of the nominal impact velocities are 3.132, 4.429 and 5.425 m/s.

Figure 4 shows six curves of force versus displacement and force versus time of the dart at various levels of impact energy. This figure allows us to clearly detect the transition from rebound to perforation, in the perforation cases the curve ''folds'' onto itself toward decreasing displacement, while in the rebound cases the displacement is monotonically increasing. The transition case is shown by the fifth curve (corresponding to 1000 mm of falling height and 5.125 m/s of nominal impact velocity) that evidences very little rebound of the dart after the maximum penetration has been reached.

Furthermore it must be noted that the curves are well superimposed upon each other up to the point where the energy initially supplied to the dart is completely transferred to the plate (rebound cases) or the perforation takes place. Specimens have been examined after the impact test with the aim of establishing a correlation between the test conditions and the plate damage.



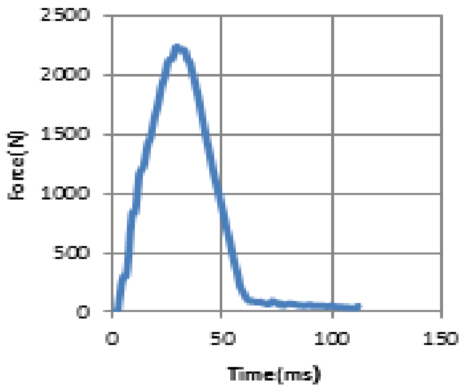


Figure 4. Curves of force versus displacement and force versus time

Table 1. Summary of the calculated impact energy

Specimen no.	Thickness, mm	Mass, kg	Height of fall, m	Impact velocity m/s	Impact energy, joules	Max load, N	Energy at max load joules
1	4	15.69	0.5	3.132	7.85	2245.5	7.729
2	4	15.69	1.0	4.429	15.7	3550.5	15.547
3	4	15.69	1.5	5.425	23.54	4113	23.352

6. CONCLUSIONS:

The investigation of the effect of low velocity impact and tension-tension type fatigue on woven glass fiber/epoxy polymer composite laminate has led to the following conclusions:

1) These impact tests have shown that the dynamic response of the laminates depends on the elastic properties of the fiber material.

2) The force versus displacement and the time versus force curves for each case have been drawn.

5) At low velocity impact damage (3.132 m/s) less effect on the fatigue life compared to other velocities & it is so in the log of no. of cycle's v/s impact velocity curves.

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