Impact Analysis of Density Graded E-Glass Composite Laminate

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Abstract - *E-Glass/Polyester composite laminates are subjected to low velocity impact and their behavior is analyzed. To investigate the impact strength, the laminate is fabricated by hand-layup process. E-glass fiber mats of different densities are used in the fabrication. Due to the cost and complexity related to impact experiments it is not optimal to base all impact related studies on laboratory tests alone. Therefore, to reduce the experimentation cost few samples are fabricated and tested in laboratory using drop weight impact tester, further numerical simulation of impact on composite laminate is investigated using 3-D dynamic explicit finite element code. ANSYS/AUTODYN which is general purpose non-linear dynamic modeling and simulation software. Trial simulations are conducted and results are validated.*

Key Words: **Impact, E-Glass/Polyester, Density Grading, Deformation, Energy Absorption.**

1. INTRODUCTION

A composite is a material consisting of two or more distinctive materials which acts as isotropic materials on a macroscopic level but has anisotropic properties at microscopic level. They are designed and fabricated to be superior to those of the constituent materials acting independently. Composite materials have significant design advantages in the aerospace industry. The combined properties such as light weight and high strength are the most attractive feature for the aerospace and aircraft designs. Composite materials are formed when two or more chemically distinct materials are combined in such a way that a distinct interface separates the components (as opposed to alloys). Each of the constituent materials has its own specific physical and chemical properties, thus resulting in composite which has different properties from each material alone. The composite for the impact protection is generally fibrous or continuous fiber reinforced. This type consists of one phase, which is usually much stronger i.e. fiber, than the other phase i.e. matrix. This unique mixture leads to anisotropic properties for the composite which provide the specific characteristic of obtaining high strength in one critical direction.

2. PROBLEM DESCRIPTION

The density graded E-glass composite laminate was investigated on low velocity impact using experimental setup and finite element analysis software. The finite element software used in this study was Ansys Autodyn. The complicated response of composite laminate along with the high cost of fabrication limits the number of laminates considered for experimentation. In order to overcome this issue, finite element analysis can be used to find out the responses for a number of density graded laminates, and to obtain the various information on the parameters that affects the impact phenomena.

2.1 Objectives of the Research

The main focus of this research is to study the response of density graded E-glass composite laminate when subjected to low velocity impact using both experimental and finite element analysis.

The objectives of this research are:

- To determine the effects of low velocity impact on density graded E-glass composite laminate.
- Linear and Symmetric density grading is tested to find low velocity impact behavior on their structures.
- To analyze the deformation, stress and the strain energy distribution of the laminates when struck by an indenter at low velocity.

3. EXPERIMENTAL DETAILS

For conducting the low velocity impact test, the drop weight impact test is used shown in figure 1. The testing is done under low acceleration falling weight of 6.3kg from a height of 1m having a velocity of 4.429m/s at the time of impact. The indenter is cylinder of diameter 10mm and has a conical front with a cone angle of 90^0. This closely simulates a real world impact conditions and the required data is obtained from the Data Acquisition System present along with the experimental setup.

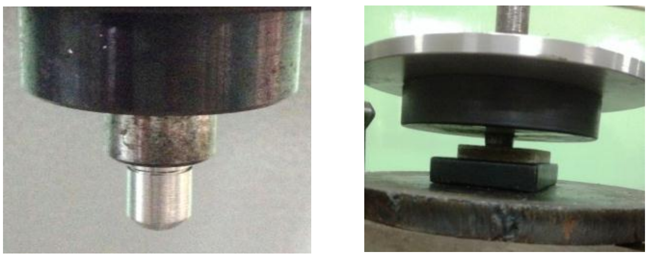

Fig -1: Conical indenter on impact over specimen

In this study, specimens are prepared by hand layup process. The various materials used in the experiment and their properties are given in table I. E-glass fiber mats of densities $225g/m^2$, $300g/m^2$ and $600g/m^2$ are used. Six different samples of 50mm X 50mm cross section area of varying density arrangements were fabricated the arrangements of the mats are shown in table II

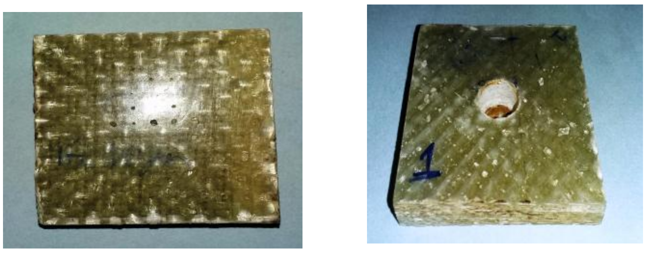

Fig -2: Specimen before and after impact

Table -1: Material Property

Material	**Density (Kg/m^3)**	**Young's Modulus (N/m^2)**	**Poisson's Ratio**
E-glass	2550	76e9	0.21
Polyester	1120	2.1e9	0.37
Structural Steel	7850	2e11	0.3

Table -2: Arrangement of Fiber Mat

Specimen	**Stacking Sequence**
1	$225g/m^2\ [0^0_{15}]$
2	$300g/m^2\ [0^0_{15}]$
3	$600g/m^2\ [0^0_{15}]$
4	$[c0^0_2/b45^0_3/a45^0_2/a45^0_1]_{sym}$
5	$[c0^0_2/b90^0_3/a90^0_2/a90^0_1]_{sym}$
6	$[c0^0_2/b45^0_3/a45^0_2]_2$

Where a represents the fiber mat density of $225g/m^2$, b represents density $300g/m^2$, and c represents density $600g/m^2$ in the above stacking sequence table 2.

3.1 Experimental Results

Table -3: Deformation and Load at Impact

Specimen	**Total Deformation (mm)**	**Peak Load Measured (N)**
1	9	5239
2	9	4953
3	8.2	5821
4	6.4	7354
5	5.1	10532
6	6.1	9841

The load versus deformation curve is obtained in real time using the Data Acquisition System which is integrated along with the Drop weight impact tester, the curve is shown in figure 3.

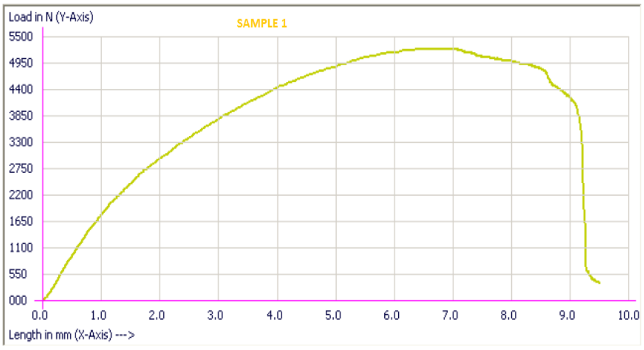

Fig -3: Load vs. Deformation of specimen 1

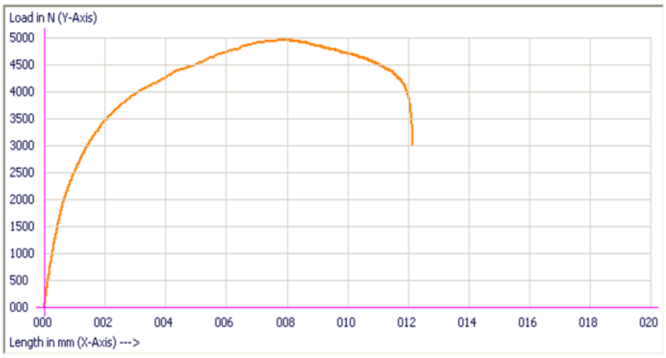

Fig -4: Load vs. Deformation of specimen 2

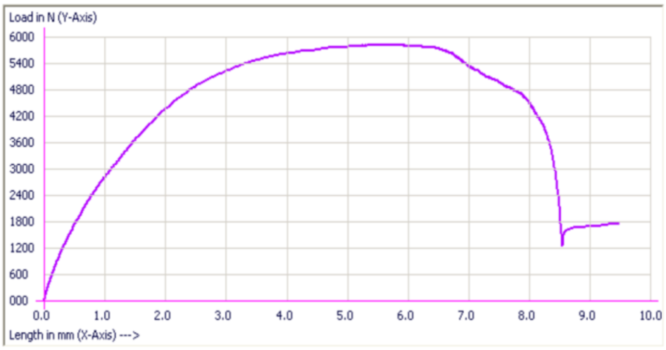

Fig -5: Load vs. Deformation of specimen 3

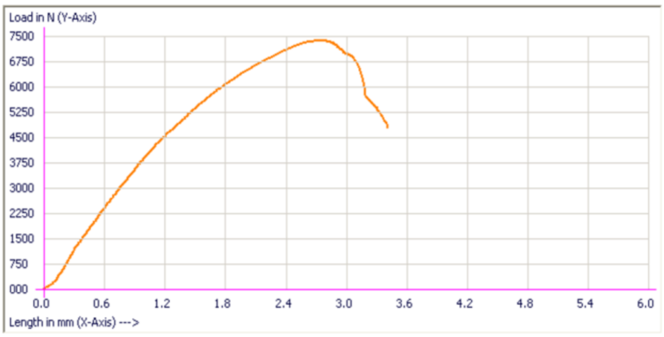

Fig -6: Load vs. Deformation of specimen 4

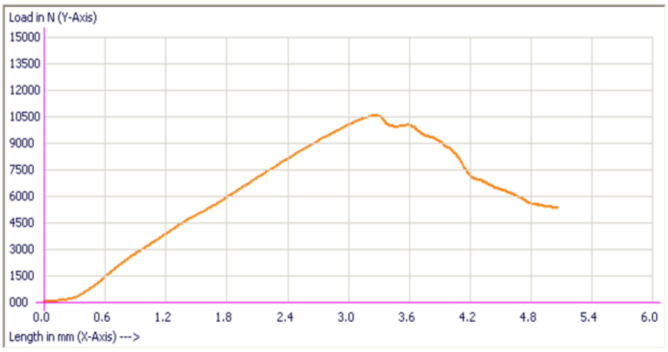

Fig -7: Load vs. Deformation of specimen 5

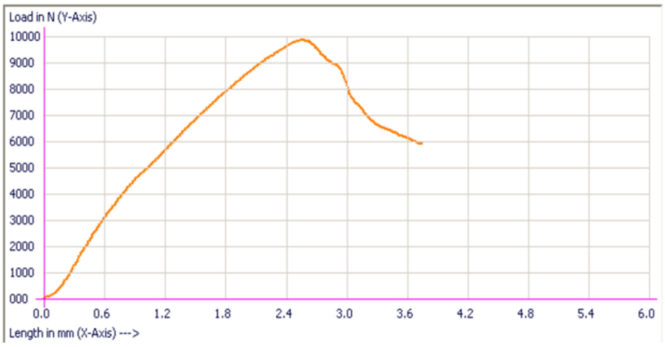

Fig -8: Load vs. Deformation of specimen 6

4. FEM DETAILS

In this study test laminate materials are density graded E-glass fiber reinforced in polyester resin and the projectile material is structural steel. The test plate is a square laminate of 50mm X 50mm and 9mm thickness and the impact indenter is conical. Modeling is done in Catia. The boundary conditions used for low velocity impact on the laminate has less effect on the final results, so reduction in the test laminate size is not affecting the FEM results thus user can reduce computational time. Finite element analysis is done in Ansys 15 Explicit Dynamics workbench. The indenter is considered as a rigid body and no deformation is taken into account, and flexible body consideration is used for the test laminate. To save computational time the distance between the indenter and the laminate is reduced in the modeling. The specimen is meshed with minimum edge length of 0.65mm shown in figure 4 and quad element is chosen for the specimen since it is a flat laminate.

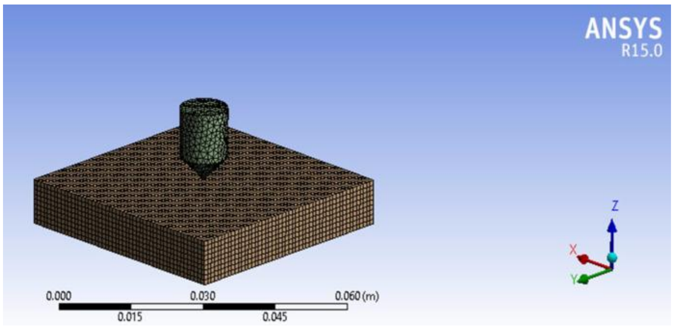

Fig -9: FE Model of the laminate and indenter after mesh

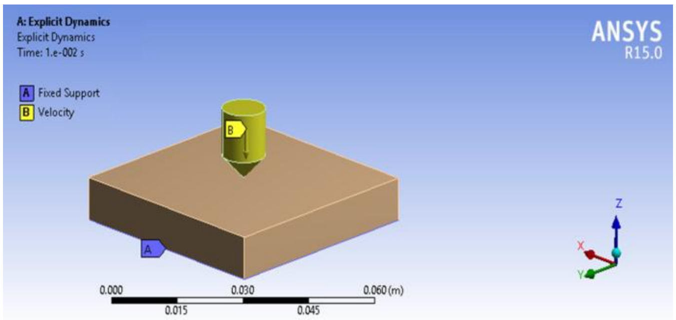

Fig -10: Boundary Condition applied to FE Model

4.1 FEM Results

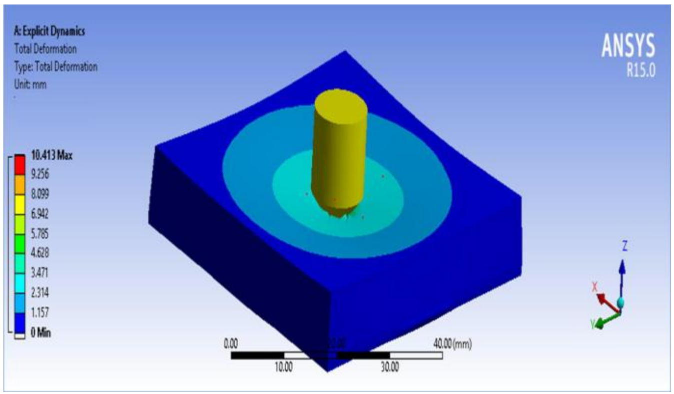

Fig -11: Deformation of Specimen 1

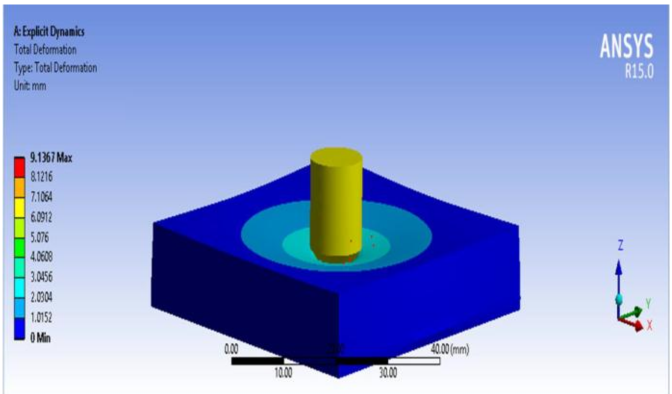

Fig -12: Deformation of Specimen 2

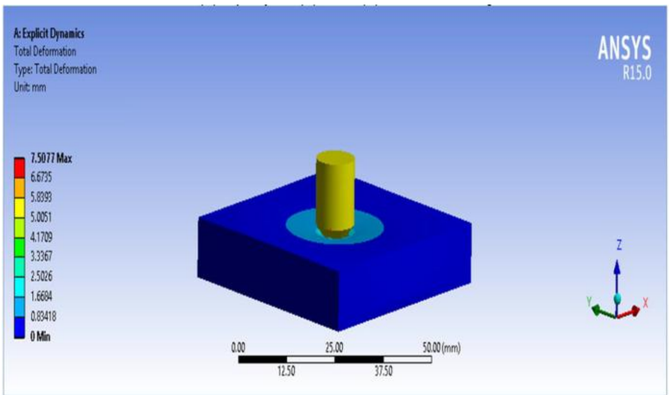

Fig -13: Deformation of Specimen 3

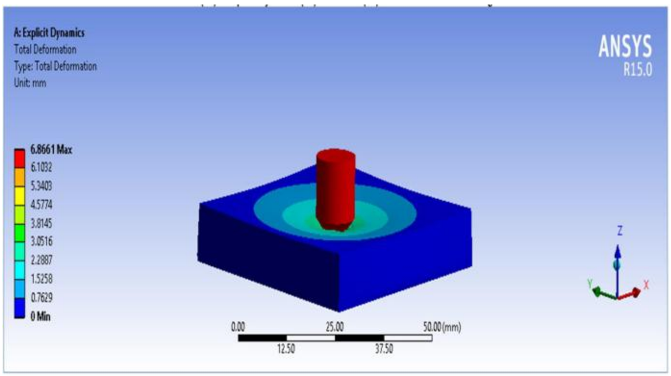

Fig -14: Deformation of Specimen 4

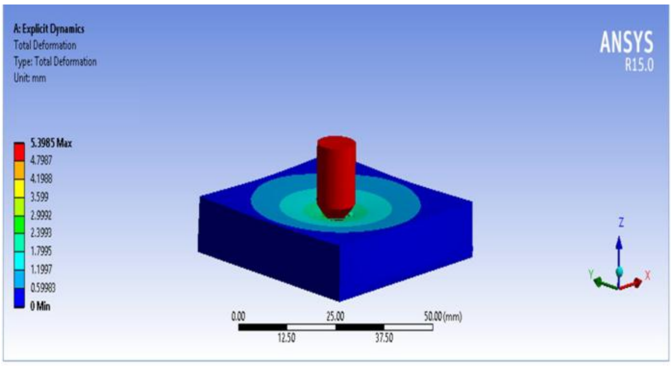

Fig -15: Deformation of Specimen 5

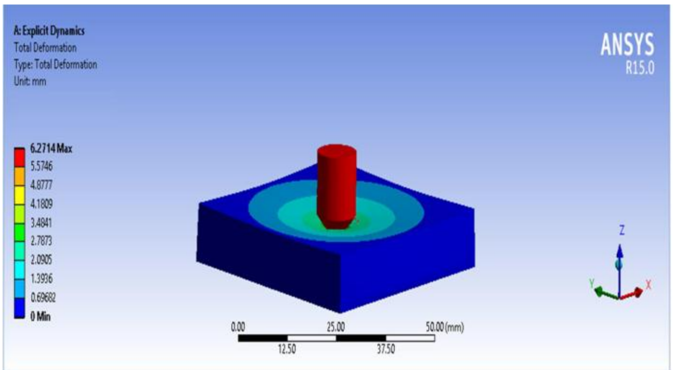

Fig -16: Deformation of Specimen 6

4.2 Comparison of Experimental and FEA Results

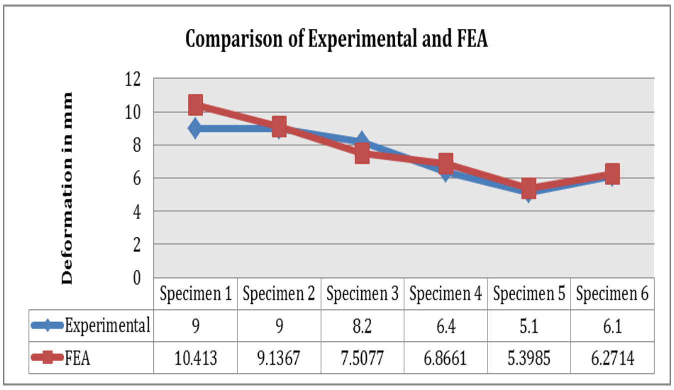

Chart -1: Comparison of Experimental and FEA Deformation

5. CONCLUSIONS

The present study focused on determining the low velocity impact strength of density graded E-glass fiber reinforced composite laminates. To find out the optimum density grading for impact resistance composite laminates of 9mm thickness were prepared by hand layup process. The specimens are then subjected to drop weight impact test at low velocity of 4m/s to 5m/s. It is found that optimal density grading is found for 90^0 symmetrically graded laminate which had the least deformation for the maximum load. The same results are validated through FEM software Ansys in explicit dynamics work bench. The factors that influence the impact performance include material property of the yarn, indenter geometry, impact velocity and boundary conditions. The individual effects cannot lead to a conclusive result. A combination of computational modeling and simulation is required to understand the deformation and low velocity failure mechanism.

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