FEA OF LOW VELOCITY IMPACT ON WOVEN TYPE GFRP COMPOSITE LAMINATES WITH AND WITHOUT DEFECTS

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Abstract— Numerical investigation was performed to study the behaviour of a composite plate of both undelaminated and delaminated composite plate having voids under low velocity impact. Finite element simulation has been done to calculate impact energy on the laminated composite plates. Various parametric studies performed includes boundary conditions, thickness of the laminate, lay-up sequence, mass and velocity of the impactor on the composite laminates. Woven type Glass Fibre Reinforced Polymer [GFRP] composite plates having two different thicknesses of 2 mm and 4 mm has been considered and the specimens were subjected to low-velocity impact at different velocities and the impact simulation has been performed on composite plate using explicit finite element analysis software LS-DYNA.

Index Terms— Boundary conditions, Laminate, Mass, Velocity, Impactor, lay-up sequence, LS-DYNA and Impact energy.

I. INTRODUCTION

A composite material is a macroscopic combination of two or more distinct materials, having a recognizable interface between them. Composite laminate is a combination of fiber and resin mixed in proper form. One of the unique properties of composite laminate is that, it has high specific strength. Composites are being utilized instead of metallic materials in structures where weight is a major consideration, example aerospace structures, high speed boats and trains [1]. The use of composites has evolved commonly to 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 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.

Impact is defined as “the striking of one component against another with force instantly”; it involves the collision of two bodies:

the impactor and the target. During collision, an impactor indents the target and makes indentation on the plate. The knowledge of dynamic response of structure and its damage resistance is much needed to optimize the structure requiring high safety like aircraft structural applications. The majority of impact test has been carried out on a flat plate with either simply supported or clamped boundaries. The inability to visualize the internal damage of composites makes the research community to focus on the low-velocity impact phenomena stringently. Impact phenomenon is a very complicated process in which the performance depends on many parameters like duration of the impact, kinetic energy, velocity of the impactor, properties of target and the impactor materials [2].

Defects in composite materials are produced during the manufacturing process. In that most common defects which are voids and delamination, voids can be caused by incorrect curing. Delaminations are a planar defect usually at ply boundaries and are fairly rare during the manufacture of the basic material but may be produced by contamination during lay-up or by machining. These defects will effects on mechanical performances, in general such defects cause a decrease in the static and fatigue strength of the laminate and a greater susceptibility to water penetration and environmental conditions[12].

The experimental analysis is often used to study loading, deformation, and damage of composite plates. However, this method is expensive, time consuming and requires multiple standardized test prototypes, equipment and strongly regulated test settings [3]. A significant advantage of finite element analysis is that an advanced preliminary study can be carried out by using a virtual prototype in a virtual environment which can substantially cut costs, reduce the development time and substantially optimize the overall development process. The main objective of this paper is to investigate the impact behaviour of the composite plate under three different velocities by using finite element analysis software LS-DYNA.

II. NUMERICAL PROCEDURE

A woven fabric composite plate having stacking sequence of 0/90/0/90/0/90/0/90/0/90 with bi-directional configuration, having a ply thickness of 0.2mm is considered for impact analysis using explicit finite element analysis software LS-DYNA [5]. In Figure 1, Let x be the variable that describes the position of the projectile. The impact energy was calculated by using the formula.

$$E = 1/2 m_i v_i^2$$

Where m_i is mass of the impactor, thickness of the composite plate is taken as h and v_i is the impact velocity measured before impact event.

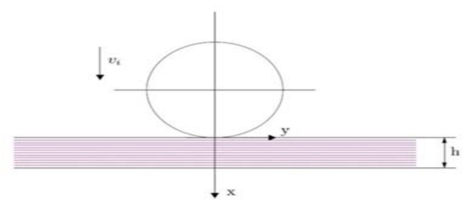

Fig.1:Impactor and target configuration setup

The number of layers on both 2 mm and 4 mm thickness composite plate is shown in table 1. The values were adopted from experimental data as per the work presented in reference [1]. The failure mechanism of the GFRP composite laminates under low velocity impact depends on several factors such as strength of the composite plate, velocity and mass of the impactor, boundary conditions which are applied to the model.

TABLE 1: DIMENSIONS AND NUMBER OF LAYERS

Material	Dimension of the component in mm	No. of Laminates	
		2mm thickness	4mm thickness
GFRP	150×50	10	20

III.FINITE ELEMENT SIMULATION

Finite element simulation was done to analyse the impact energy dissipated on both undelaminated and delaminated composite plates.

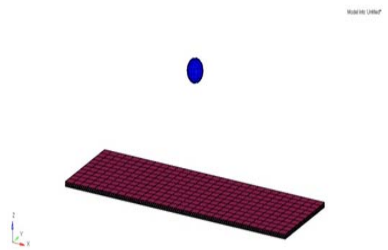

Fig.2: HYPERMESH Model

Glass fiber reinforced polymer composite laminates were modelled using software known as HYPERMESH. All the four sides of the specimen were fixed in x, y and z directions and orthotropic material was selected for modelling the material, the laminates were impacted at the centre of the composite plate by a steel impactor having a spherical tip of 10 mm in diameter and a weight of 15.69 N has been used. The material properties of the impactor and composite plate are as shown in table 2 and 3 respectively.

Table 2: Impactor properties

Young's modulus	Poisson's ratio	Density
210 GPa	0.3	7800 Kg/mm^3

The impactor is allowed to move only in z direction and treated as a rigid body. An automatic surface to surface contact condition is assigned between the composite plate and impactor to accommodate impact initiation and progress. Time step is one of the most important parameter, which normally causes divergence in non-linear finite element analysis. By choosing an adequate time step value simulation has been done [7]. The finite element model of the impactor and composite laminates are shown in Figure 2 and was prepared by using pre-processing finite element analysis software known as HYPERMESH. Here LS-DYNA program manager was used as a processor to solve the problem and LS-PrePost was used as post processing software, where we can see the displacements, stress results and deflection animations [8].

Table 3: Composite plate properties

Young's Modulus in GPA	E_{11}	20.8
	E_{22}	20.8
	E_{33}	8.7
Shear Modulus in GPa	G_{12}	3.92
	G_{23}	4.2
	G_{31}	4.2
Poisson's Ratio	γ_{12}	0.173
	γ_{23}	0.28
	γ_{13}	0.28
Density in Kg/m^3	ρ	1750

Delamination and voids have been created on both 2 mm and 4 mm thickness composite plate having same geometry as that of undelaminated composite plate and impact analysis has been conducted.

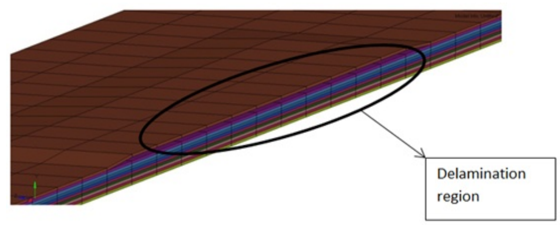

Fig.3: Half sectional view of delaminated composite plate

Delamination of 0.2 mm gap between the top layer and its next layer of the composite plate has been created at the center to an area of 50 mm × 20 mm. Figure 3 shows half sectional view of delaminated composite plate and it has been created using HYPERMESH software.

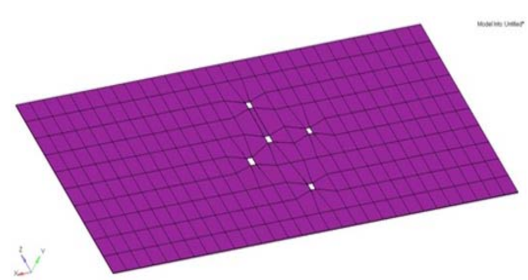

Fig.4: Voids on the composite layer

Figure 4 shows the voids on the composite plate and it has been created at the center of the composite plate on the second layer from the top, where the impactor is going to impact. It was created by using HYPERMESH software, by removing the elements on the composite plate.

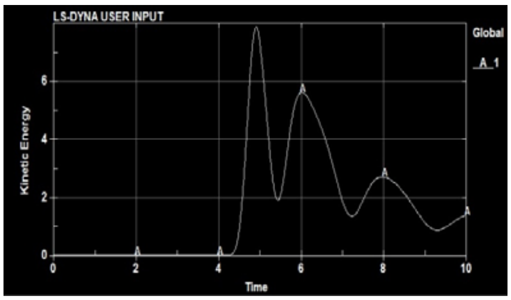

Fig.5: Impact energy result for undelaminated composite plate

Finite element simulation was done by using explicit finite element analysis software LS-DYNA, impact energy results in case of undelaminated composite plate is shown in figure 5. In that graph the point where maximum deviation occurs, that value has been taken as impact energy.

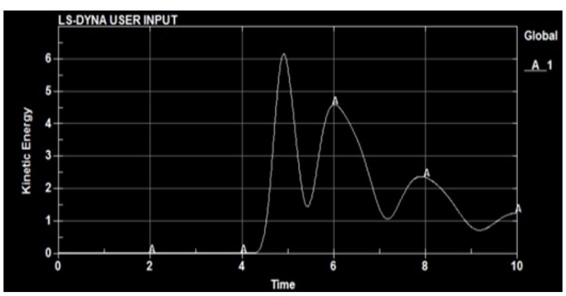

Fig.6: Impact energy result for delaminated composite plate

Figure 6 shows impact energy results for delaminated composite plate. Here impact energy results have been varied because of defects like delamination and voids which is introduced on that plate. These defects will reduce the strength of the composite plate so impact energy results were reduced.

IV. RESULTS AND DISCUSSION

Numerical analysis has been done for both undelaminated and delaminated composite plate having two different thickness of 2 mm and 4 mm were subjected to low velocity impacts at three different velocities (3.132, 4.429 and 5.425 m/s).

Table 4: Impact energy results for undelaminated composite plate

Mass of the impactor in N	Velocity in m/s	Impact Energy in Joules	
		2 mm	4 mm
15.69	3.132	7.9	8.9
15.69	4.429	14.01	16.13
15.69	5.425	21.07	24.94

Impact energy results for undelaminated composite plate are shown in Table 4. For both 2 mm and 4 mm thickness composite plate, impact energy results were increased with increasing the velocity of the impactor [13].

Table 5: Impact energy results for delaminated composite plate with voids

Mass of the impactor in N	Velocity in m/s	Impact Energy in Joules	
		2 mm	4 mm
15.69	3.132	6.23	7.01
15.69	4.429	12.9	14.1
15.69	5.425	20.05	20.90

Impact energy results for delaminated composite plate with voids have been recorded in table 5. Impact analysis has been conducted for the same velocity as that of undelaminated composite plate but here impact energy results are reduced. Reduction of impact energy results due to defects which are introduced on the composite plate.

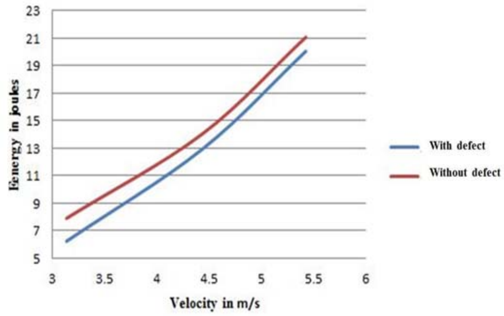

Fig.7: Results comparison for 2mm thickness plate

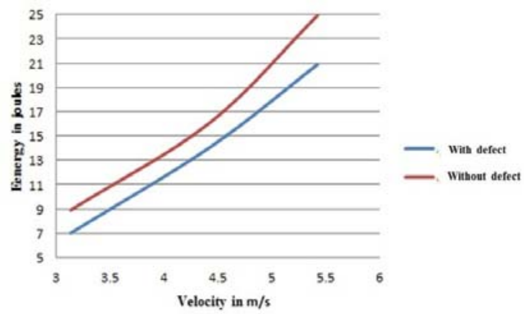

Fig.8: Results comparison for 4mm thickness plate

Comparison of 2mm and 4mm thickness undelaminated composite plate with delaminated composite plate is shown in figure 7 and 8 respectively. In that blue line indicates composite plate with defects and red indicates without defect. Here we can see the variation of the results on defected and un-defected composite plates.

V. CONCLUSION

NUMERICAL ANALYSIS WAS PERFORMED TO STUDY THE BEHAVIOUR OF GLASS FIBRE REINFORCED POLYMER COMPOSITE PLATE UNDER LOW VELOCITY IMPACT USING EXPLICIT FINITE ELEMENT ANALYSIS SOFTWARE LS-DYNA. UNDELAMINATED COMPOSITE PLATE OF BOTH 2 MM AND 4 MM THICKNESS PLATE WAS COMPARED AGAINST DELAMINATED COMPOSITE PLATE WITH VOIDS. IN THAT IMPACT ENERGY RESULTS WERE VARIED BECAUSE OF DEFECTS LIKE DELAMINATION AND VOIDS WHICH ARE INTRODUCED IN COMPOSITE PLATE. THESE DEFECTS WILL REDUCE THE STRENGTH OF THE COMPOSITE PLATE SO IMPACT ENERGY RESULTS WERE REDUCED. IT IS ALSO CONCLUDED THAT IMPACT ENERGY RESULTS ARE MAINLY DEPENDS ON SOME OF THE PARAMETERS LIKE, BOUNDARY CONDITIONS, VELOCITY OF THE IMPACTOR AND PROPERTIES OF TARGET AND THE IMPACTOR MATERIALS.

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