

# **Numerical Analysis of Low Velocity Impact on Woven Fabric Laminated Composite Plates**

Shravan B Kerur, Nagappa R Siddgonde, Ravikant B Mulage

Professor, Dept. of Mechanical Engineering, Basaveshwar Engineering College, Bagalkot, Karnataka, India

PG Student, M.Tech (Machine Design), Dept. of Mechanical Engineering, BEC, Bagalkot, Karnataka India

PG Student, M.Tech (Machine Design), Dept. of Mechanical Engineering, BEC, Bagalkot, Karnataka India

**ABSTRACT:** In this work, a numerical analysis is carried out to study the behaviour of a woven fabric composite plate under low velocity impact. The finite element simulation is carried out to investigate the stress distribution during the impact on woven fabric laminated composite plate. The usefulness of the developed numerical model is investigated by comparing the results in terms of the transverse stress, longitudinal stress, transverse deflection and impact force with those of available literature. Several parametric studies are carried out to the effect of boundary conditions, thickness of the laminates and lay-up sequence of the composite laminates. It is concluded that the stresses are distributed symmetrically along the top and bottom layers irrespective of the boundary conditions. Furthermore, it is shown yielding at the top layer is Maximum compressive stress, whereas yielding at the bottom layer of the composite plate is maximum tensile stress. It is also shown that the orientations and thickness of the composite plates plays an important role on the deflection of the plate

**KEYWORDS:** Low velocity impact, Woven Fabric Laminated Composite analysis, Explicit Dynamic Analysis, Ansys/Ls-Dyna, Contact Force.

## **I. INTRODUCTION**

The fiber reinforced composite laminates are widely used in many engineering fields, like aerospace, airostructure and industrial sector for owing to their high strength- to-weight and stiffness-to-weight ratios. These structures are fabricated in required direction with adopting a tailoring properties. They have been increasingly used in load-bearing structures such as aircraft and automobile industries. However, they are liable to damage due to low velocity impact loading during in service. This impact loading can cause extensive sub-surface damage that may not be visible on the surface but can lead to significant reduction in the strength of composite laminates. It can create internal defects in the form of delamination, matrix failure failure and fiber breakage which yields reduction in the residual strength and stiffness of the structure [1]

The resistance to impact depends on several factors of the laminate such as inter-laminar strengths, stacking sequence, impacting object size, velocity and mass of the composite laminates is very complex due to their many concurrent phenomena under impact load. Fiber breakage, delamination, matrix cracking and plastic deformations due to contact are few effects, which should be considered when a structure made from composite material is impacted by a foreign body [2]

Ashish and Naik [3] have presented an analytical model for the response of symmetric woven fabric and unidirectional composite laminates, simply supported on all four sides subjected to low-velocity impact at the midpoint of the plate. The plate is impacted by an impactor with a hemispherical tip. Contact forces at the impact point, lateral displacements and velocities of the plate and the impactor and the stress state within the plate have been determined using modal solution technique. Balasubramni.V, Rajendra Boopathy.S and Vasudevan. [4] have presented a numerical model for the response of symmetric woven fabric and unidirectional composite laminates, simply supported on all four sides subjected to low-velocity impact at the midpoint of the plate. The plate is impacted by an impactor with a hemispherical tip. The effectiveness of the developed numerical model is

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2015

investigated by comparing the results in terms of the transverse deflection and stress, longitudinal stress, shear stresses and impact duration with those of available and also he was done several parametric studies under low velocity Impact on woven fabric laminate composite plate with different orientations, thickness of plate, and several boundary conditions

Kranthi Kumar and Lakshmana Kishore [5] studied the damage generated on fiber-glass laminates subjected to low velocity but larger impactor mass. Finite element analysis was performed in terms of drop tower test using ANSYS/LS-DYNA. Furthermore, the analysis was extended to thick laminates and several parametric studies were performed in terms of several impact velocity and mass. Critical stress was also identified during the impact.

In this work presents, a finite element analysis is carried out to study the behavior of a woven fabric composite plate under low velocity impact. A composite plate with an isotropic impactor is modeled by using the commercial finite element analysis software ANSYS®14.5 and the impactor is considered to be rigid & comes in contact with the composite plate under low velocity impact, The finite element simulation is performed to investigate the stress distribution during the impact. The effectiveness of the developed numerical model is investigated by comparing the results in terms the transverse-deflection and stress and longitudinal stress with those of available literature. Furthermore the impact force is calculated analytically with the help of impact duration time using the current finite element analysis is also compared with those available in literature. Effect of boundary conditions, thickness of the laminate, impactor mass and velocity and composite layup sequence on stress variation of the composite laminate are studied.

## II. NUMERICAL MODELING IN ANSYS

A composite plate having stacking sequence of  $[0_12]_s$  with 0.25 mm ply thickness and dimensions of the plate 150 mm x 150 mm x 6 mm is considered for the impact analysis using commercial available software ANSYS14.5. The various material properties of the composite plate assumed for the analysis are presented in Table 1 [3]. The spherical impactor with radius of 6.5 mm is considered to be made up of steel with a mass of 4.7 kg. The various material properties of the impactor are: Young's modulus,  $E = 210$  GPa, Poisson ratio,  $\nu = 0.3$ , density,  $\rho = 7800$  kg/m<sup>3</sup>

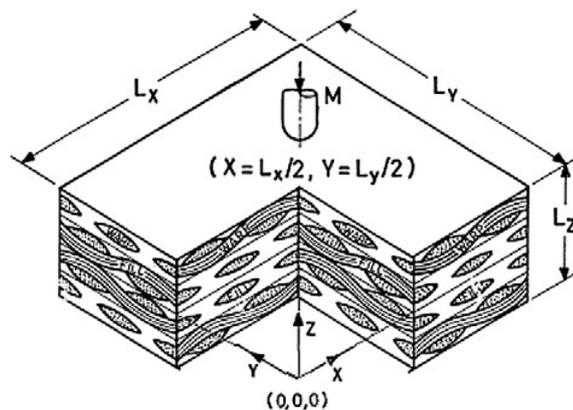


Fig .1 Schematic diagram of impact on a composite plates

The composite plate is meshed using SHELL 163 having 4 nodes and 12 degrees of freedom at each node the degrees of freedom are translation, accelerations and velocities at each node in three perpendicular axes and rotational degrees of freedom about those axes. Furthermore, the impactor is meshed using SOLID 164 element having eight nodes and 9 degrees of freedom

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2015

are translation accelerations and velocities at each node in three perpendicular axes at each node [3]

Table. I Materials properties and ultimate strength, along three perpendicular directions, X, Y and Z of E-glass epoxy woven fabric composite lamina Ref [3]

Young`s Modulus in GPa		Shear Modulus in GPa		Poisson`s ratio	
E <sub>11</sub>	36.3	G <sub>12</sub>	4.47	ν <sub>12</sub>	0.173
E <sub>22</sub>	36.3	G <sub>13</sub>	4.68	ν <sub>13</sub>	0.279
E <sub>33</sub>	31.1	G <sub>23</sub>	4.68	ν <sub>23</sub>	0.279
Tensile strength (MPa)		Shear strength (MPa)		Compressive strength (MPa)	
X <sub>T</sub>	330	S <sub>12</sub>	35	X <sub>T</sub>	320
Y <sub>T</sub>	330	S <sub>13</sub>	35	Y <sub>T</sub>	320
Z <sub>T</sub>	35	S <sub>23</sub>	35	Z <sub>T</sub>	500

Method of analysis	Longitudinal stress (Mpa)	Transverse stress (Mpa)	Maximum Deflection in (mm)	Impact Force N
Analytical Ref.[3]	300	306	2.6	5652
Numerical Balasubramni.V	304	305	2.608	-
Present (FEA)	307	306	2.808	5737
% Deviation	-1.02	0	-7.4	-1.48

Volume fraction Vf (%) = 0.4

Density of the woven fabric composite ρ = 1750 kg/m<sup>3</sup>

### III. VALIDATION

The developed numerical modeling and analysis is demonstrated by comparing the results in terms of deflection, longitudinal (σ<sub>x</sub>) and transverse (σ<sub>y</sub>) stresses at the center of the bottom and top layer where X=75 along Ly of the composite plate and impact force is calculated theoretically based on impact duration time obtained by using the current finite element formulation with analytical and numerical results available in literature [3] and [4] respectively. The simulation is performed by considering the impactor mass of 4.7 kg with a velocity of 1.68 m/s impact on a composite plate. The plate having identical dimensions as mentioned in section 2 are considered to be simply supported at four edges (S-S-S-S). The impact energy yielded on the plate is 6.63 J. The results are presented in a very good agreement was observed between the results obtained using the current finite analysis and the analytical and numerical solution available in table II.

It can be seen that the maximum longitudinal and transverse stresses occur at the center of the laminate. This can be attributed to the fact that the impact load is applied at the center of the plate, the maximum stress is developed at the same location. Here the impact force is calculated theoretically with the help impact duration obtained directly by a finite element analysis Impact force

$$F_{max} = \frac{2mv}{t}$$

F<sub>max</sub> = Maximum impact force in N

m = Mass of the impactor in kg,

v = Velocity of the impactor m/sec,

t = impact duration time in second

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2015

Table. II Comparison of longitudinal and transverse stresses, transverse deflection at bottom layer of the plate and impact force evaluated using current FE formulation Ref. [3] & [4]

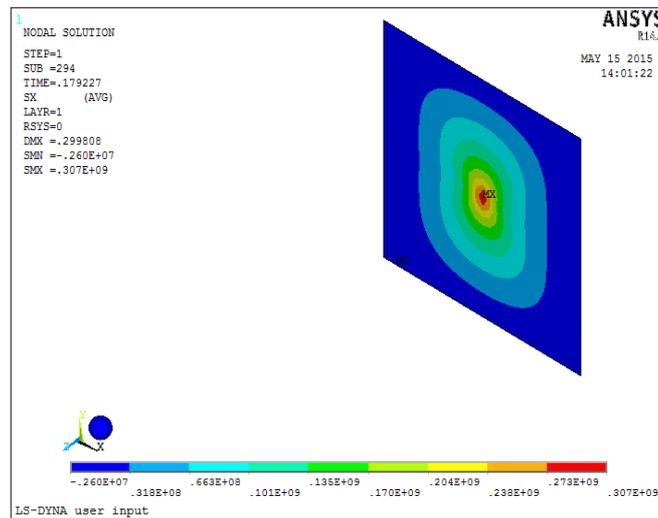


Fig.2. Longitudinal ( $\sigma_x$ ) stress distribution of  $[0_{12}]_s$  plates at the center of the bottom layer under (S-S-S-S)

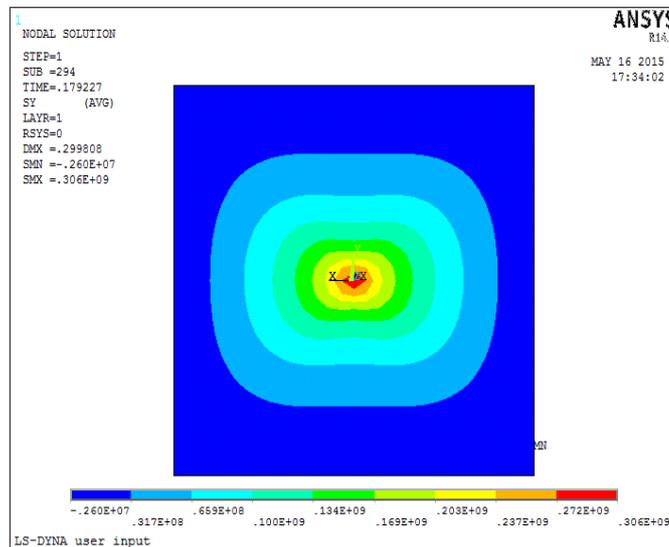


Fig.3. Transverse ( $\sigma_y$ ) stress distribution of  $[0_{12}]_s$  plates at the center of the bottom layer under (S-S-S-S)

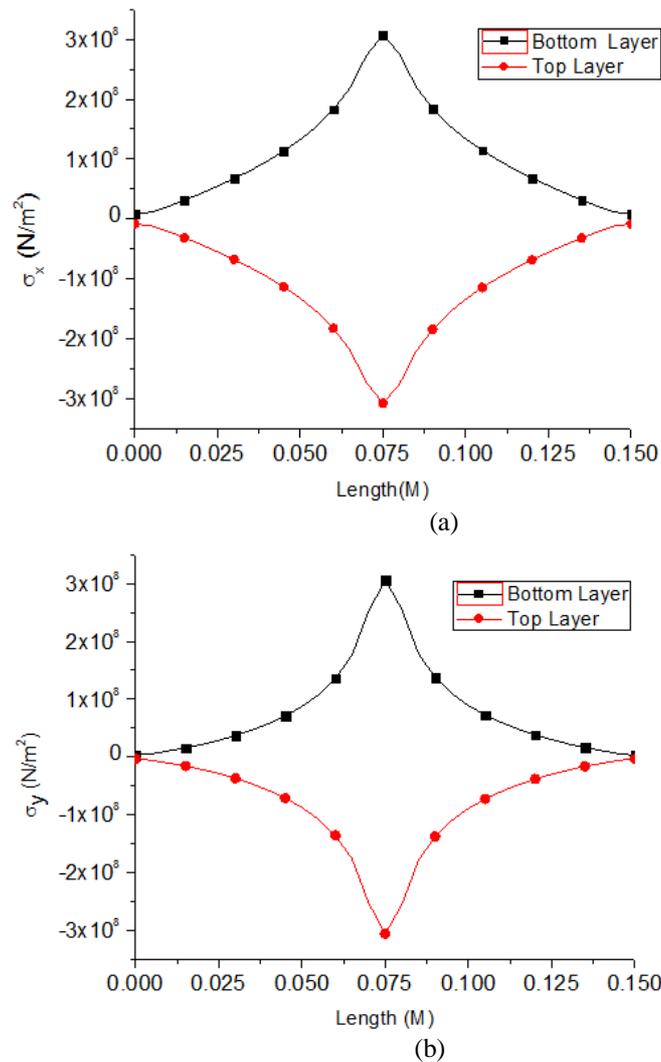


Fig.4. Variation of a)longitudinal ( $\sigma_x$ ) and b) transverse ( $\sigma_y$ ) stresses distribution at  $X=75\text{mm}$  along  $L_y$  in top and bottom layers of the composite laminate under simply supported end condition at all the four edge

#### IV. PARAMETRIC STUDY

The damage mechanism of the composite laminates under low velocity impact depends on several factors of the laminate, such as strengths, stacking sequence, velocity and mass of the impactor, boundary conditions and the thickness of the laminates.

The proposed FEM model is used to perform the various parametric studies to investigate the effect of those parameters on the variation of longitudinal, transverse and in-plane shear stresses along the laminate.[3]

##### 4.1 Effect of boundary conditions on the stress distribution

The effect of boundary conditions on the variation of stress distribution along the laminate is studied by performing the low velocity impact simulation under various boundary conditions. A woven fabric composite plate having different angle of orientation of the laminate and the impact energy is assumed to be  $[0]_1, [15]_1, [30]_1, [45]_1$ , and 6.63J, each sequence having single layer with 6 mm ply thickness and dimensions of the plate 150 mm x 150 mm x 6 mm is considered for the impact analysis using commercial available software

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2015

ANSYS14.5. The table III shown the results of parametric study under impact load on various boundary conditions are i) Simply supported at four edges (S-S-S-S) (ii) Clamped at four edges (C-C-C-C); iii) Clamped-Free-Clamped-Free (C-F-C-F); iv) Clamped-Simply supported-Clamped-Simply supported (C-S-C-S).

Symmetric distribution of stresses is observed along the bottom and under simply supported at all edges conditions. This can be attributed to the symmetric boundary conditions of the laminate. Furthermore, it has been observed that the maximum stress and deflection yield at the center of the laminate which is due to the consequence of the application of the impact load at the center of the laminate and the below fig 5-8 shown the variation of longitudinal and transverse stresses distribution with at  $X=75\text{mm}$  along  $L_y$  in bottom layer of the composite laminates plates under different boundary conditions

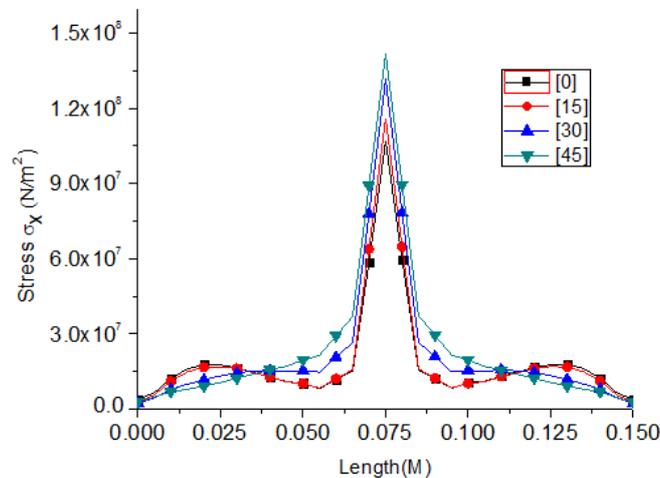


Fig.5. Variation of longitudinal ( $\sigma_x$ ) stresses distribution under simply supported all edge condition (S-S-S)

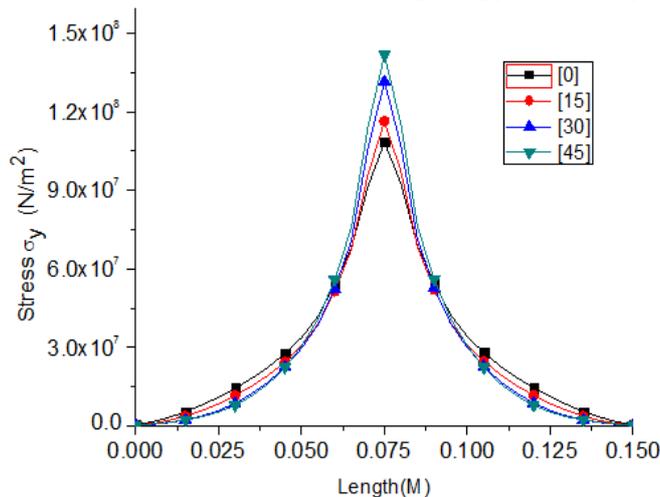


Fig.6. Variation of transverse ( $\sigma_y$ ) stresses distribution under simply supported all edge condition (S-S-S-S)

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2015

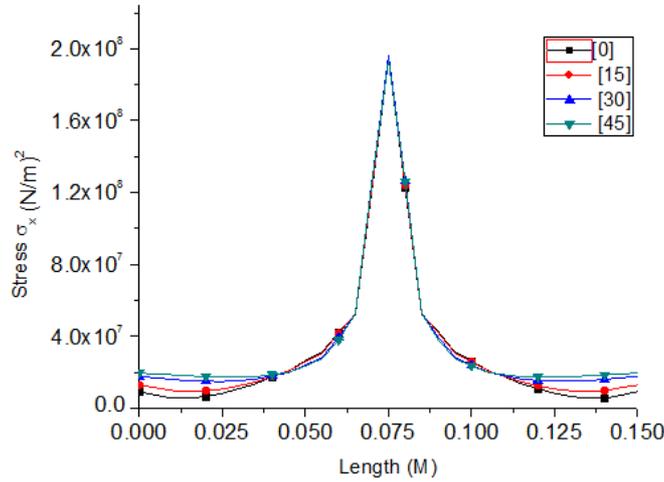


Fig.7. Variation of longitudinal ( $\sigma_x$ ) stresses distribution under clamped all edge condition (C-C-C-C)

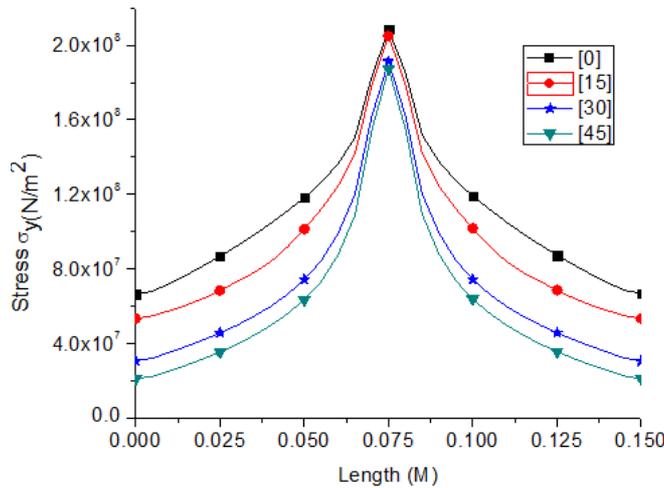


Fig.8. Variation of transverse ( $\sigma_y$ ) stresses distribution under clamped all edge condition (C-C-C-C)

Table.III Shown the results of variation of longitudinal  $\sigma_x$  and transverse ( $\sigma_y$ ) stresses (MPa) distribution at X= 75mm along Ly in bottom layer of the composite laminates under different boundary conditions with different angle of orientation

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2015

Orientation	Stresses in S-S-S-S Condition (MPa)		Stresses in C-C-C-C Condition (MPa)		Stresses in C-S-C-S Condition (MPa)		Stresses in C-F-C-F Condition (MPa)	
	$\sigma_x$	$\sigma_y$	$\sigma_x$	$\sigma_y$	$\sigma_x$	$\sigma_y$	$\sigma_x$	$\sigma_y$
[0]	107	108	194	195	134	208	131	210
[15]	116	116	195	195	143	205	140	207
[30]	132	131	196	196	147	191	145	190
[45]	142	142	194	194	152	187	148	197

## V. CONCLUSIONS

In this study, the validation study is carried out and validation results are in a very good agreement between the results obtained using the current finite analysis and both analytical and numerical solution with available literature in a table (II).

It is shown that S-S-S-S and C-C-C-C conditions yields the highest and lowest deflection, respectively under identical impact energy and the numerical results are compared in terms of transverse-deflection, transverse stress, longitudinal stress and impact force. It is concluded that the symmetrically distribution of the stresses increases as the number of layer of the composite plates increases, whereas stresses decreases as the number of the layer of composite plate decreases and also the distribution of stress depends on thickness of the laminates, stacking sequence and boundary conditions. It also concluded that the maximum compressive stress yielded at the top layer, while the maximum tensile stress yielded at bottom layer of the plate.

## REFERENCES

- [1] Cantwell, W.J., Morton, J., "The impact resistance of the composite materials", are view, Composites22, p.347,1991
- [2] Richardson, M.o.W., Wisheart, M.J., Review of low velocity impact properties of composite materials, Composite –Part A27,p.1996
- [3] Ashish Mishra, Naik, N.K., "Failure initiation in composite structures under low velocity impact Analytical studies", Composite Structures, Vol,92, pp,436,2010
- [4] Balasubramni.V., Rajendra Boopathy.S., and Vasudevan. R., "Numerical analysis of low velocity impact on laminated composite plates", IConDM. Vol. 64, pp, 1089-1098, 2013
- [5] KranthiKumar.B., Lakshamanakishore.T. "Low velocity impact analysis of laminated FRP composites", International Journal Of Engineering Science and Technology, vol,4,pp,115-125, 2012
- [6] ANSYS 14.5 user`s manual
- [7] S.Thimoshenko, Theory of plates and shell, Rectangular plates with various edge conditions chapter10,pp, 180-185
- [8] Serge Abrate., "Impact engineering of composite structure", CISM Courses and Lectures Vol. 526,2011