



LOW VELOCITY IMPACT ANALYSIS OF COMPOSITE LAMINATES AND SHELL STRUCTURES BY FINITE ELEMENT METHOD

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Abstract:

In this work, numerical investigation is performed to study the behaviour of a composite laminates and shell structure under low velocity impact. Woven fabric composite shell having different radius of curvature is considered, the present paper discusses on the effect of the ratio of radius to arc length on the central deflection for plate and spherical shell. A Variety of examples are presented to study the impact responses. The parameters included in this study are curvature of the shell, boundary condition and impact velocity.using the commercial finite element analysis software ANSYS/ LS-DYNA. Finite element simulation is performed to investigate the stress distribution during the impact. Comparison of plate and spherical shell structure are considered in this paper Numerical analysis has been done by creating program in analysis software ANSYS and different results are obtained. The outcomes of results are compared with results available in the literature.

Key Words: Fibre-Reinforced Composites, Impact Behaviour, Finite-Element Analysis, Laminates & Failure Criterion

1. Introduction:

Laminated composite structures are very sensitive towards impact and resulting damage. So, impact loading in composite structures poses a problem of great concern. In aircraft structures, collisions with dropped tools, hail, debris thrown up from the runway, and with birds can be considered as impact. This impact loading can cause extensive sub-surface damage that may not be visible on the surface but can lead to a significant reduction in the strength of composite laminates. Curved shell can resist loading acting perpendicularly to the middle surface by the agency of membrane forces. In those cases where the membrane reactions can be resisted and the corresponding deformations of the shell can freely take place. Many approaches are used in the elasto plastic analysis of plates and shells. The finite element method has been successful in modelling the linear behaviour of shells and it is therefore natural to apply the same method to the non-linear analysis. Non-linear computations are based on incremental and/or iterative algorithms, which are computationally expensive. The efforts of many authors are not only directed to accuracy and wide applicability of their formulations, but also to computational efficiency. The objective of the present work is to develop a general procedure for the analysis of thick/thin plates and shells.

(Mishra 2010) have presented an analytical model for the damage initiation in laminated composite plates, simply supported on all four sides, subjected to low-velocity impact at the centre of the plate. Studies have been carried out on balanced, symmetric cross ply laminates made of UD layers and woven fabric composites. The influence of through-the-thickness normal stress on the magnitudes of in plane stresses is also considered using 3-D stress state. Contact force at the impact point, lateral displacements and velocities of the plate and the impact or and the stress state within the plate has been determined using modal solution technique. In-lane failure function and inter laminar failure function have also been determined using the quadratic failure criteria. Based on failure function, damage initiation in the form of matrix cracking as well as yarn/fibre breakage (Balasubramani 2013) studied the behaviour of composite plate under low velocity impact and investigated stress distribution during impact by comparing results in terms trans the transverse deflection and stress and longitudinal stress with literature. and performed various parametric studies such as effect of boundary conditions, thickness of laminates, impact or mass and velocity and composite lay-up sequence on stress variation of the composite laminates. (S. Channabasavaraju October - 2013) investigates the experimental study of low velocity impact properties of Kevlar fibre reinforced polymer matrix composite materials with respect to different thickness. The damage in the fibres was developed around the point of impact, which results in considerable strength loss. (Her 2004) Conducted low velocity impact analysis of composite laminated plate and shell structures using ANSYS/LS-DYNA finite element software and presented impact responses for the contact force and central deflection. It was concluded that the contact force is proportion to the impact or velocity. However, the contact period independent on the stiffness of the laminated structure such as the curvature and boundary condition. (Krishnamurthy 2001) successfully implemented the finite element code to model dynamic behaviour and subsequent damage of a composite shell subject to impact loading. The stiffness of the failed laminas is modified to account for their lack of contributions in appropriate directions in each time step during impact. It is shown that the degenerated shell element provides sufficient accuracy for use in impact-damage analysis. Various Parametric studies were performed involving the effect of mass, curvature, ply

orientations, etc. on the impact response. (Kumar 2012) studied the damage generated on fibre-glass laminates subjected to low velocity but larger impact mass. Using Ansys/Ls-Dyna drop tower test is performed by finite element analysis. Furthermore, the analysis was extended to thick laminates. During impact critical stress was calculated. Various parametric studies include impact mass and velocities. (Khalili 2011) provide a numerical treatment tool based on ABAQUS commercial finite element code for the reliable design of structures under transverse impact loadings. He gave a general solution for the modelling of dynamic and quasi-static simulation of impact on the composite plate and shell structures and cylindrical shells with various side-to-thickness ratios by ABAQUS. (Cho 1999) Analysed load distribution of laminated composite cylindrical shell subjected to transverse impact and deduced the following results,

- ✓ The response frequency, or impact duration, is independent of the impact velocity, and depends on the impact or mass, the material properties, and geometrical parameters of the shell.
- ✓ A large mass of impact or causes higher contact force and increases the contact time.
- ✓ Maximum contact force increases with the decrease of the radius of curvature.
- ✓ The position of the first failure is differently estimated between the infinite curvature laminate and finite curvature laminate. The first failure occurs at the bottom surface of the laminate plate and the opposite conclusion for the laminate shell.

2. Numerical Modeling in Ansys:

A woven fabric composite plate of dimension 150mm×150mm×1.5mm is considered for the impact analysis using commercial available software ANSYS .The material properties for composite shell assumed for the analysis are presented in Table 1 (Mishra 2010). The spherical impactor with radius of 6.5mm is considered to be made of steel with a mass of 4.7 kg. The composite shell is meshed using SHELL 163 having 4 nodes 12 degree of freedom at each node .The degree of freedom are translations, accelerations, and velocities in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. Furthermore, the impactor is meshed using SOLID 164 element having 8 nodes and 9 degrees of freedom at each nodes. The ANSYS LS-DYNA/Explicit dynamic analysis is selected to perform the low-velocity impact test on laminated composite shell.

Table 1: The material properties for E-glass/epoxy woven fabric composite plate/shell and steel impactor (Mishra 2010)

Young's modulus (Gpa)			Shear modulus (Gpa)			Poisson's ratios			Density (kg/m3)
E11	E22	E33	G12	G23	G13	v12	v13	v23	ρ
31.1	36.6	36.6	4.68	4.68	4.47	0.279	0.279	0.173	1750

Material properties for Sphere

Young's modulus (Gpa)	Poisson's ratios	Radius (mm)	Velocity (m/s)	Density (kg/m ³)
210	0.3	6.5	1.68	4085.725×10^3

3. Validation:

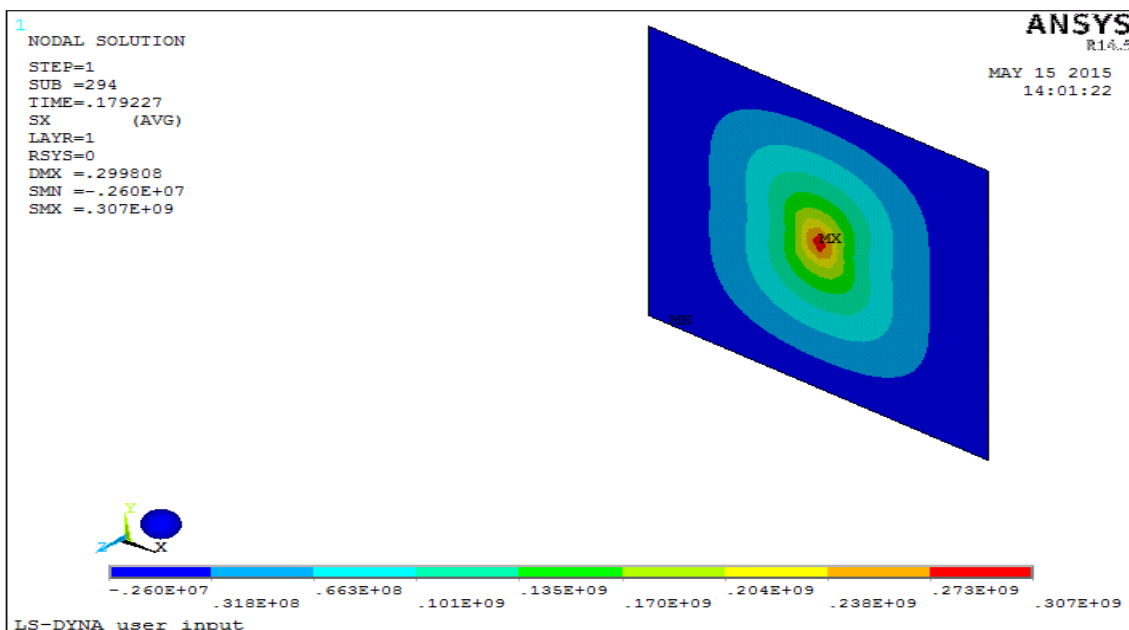


Figure 1: Longitudinal Stress Distribution of [0₁₂]S Laminated Plate at The Center of The Bottom Layer under Simply Supported All Sides

The validation is done by comparing the results in terms of deflection, longitudinal stresses at the centre of the bottom layer of the composite plate and impact duration obtained using the plate of dimension 150mm×150mm×6mm with $[0_{12}]_s$ with analytical results available in literature (Mishra 2010). A very good agreement was observed between the results obtained using the plate and the analytical solution available in Ref (Mishra 2010).

Table 1: Longitudinal stresses and deflection at bottom layer of the plate and impact duration evaluated using current FEA formulation and Ref. (Mishra 2010).

Comparison	Longitudinal stress (Mpa)	Maximum Deflection (mm)	Impact Duration (μ sec)
Ref. (Mishra 2010)	300	2.6	5652
Plate(a/h=25)	307	2.8	5737
%Deviation	0.32	7.14	1.48

4. Result and Discussion:

The finite element model of the E-glass/epoxy woven fabric composite plate/shell and steel impactor developed in ANSYS/LS-DYNA. Initially a composite plate of dimension 150mm×150mm×1.5mm is considered for impact analysis and then the plate is compared with spherical shell by varying radius of curvature of spherical shell keeping all material properties, geometrical dimension and impactor velocities are constant. The material properties of the steel impactor and E-glass/epoxy woven fabric composite plate/shell were taken from the work of AshishandNaik (Mishra 2010)the material model selected for the steel impactor was considered to be a rigid body. The material model selected for the composite plate/shell, which represents an orthotropic material. For the simulation Gauss quadrature rule was defined and one integration point was assigned for each layer. Thus there were 1 integration points, single layer and 0^0 orientations are considered for the E-glass/epoxy woven fabric composite plate/shell. The figure 2 shows the geometrical representation of steel impactor spherical shell target.

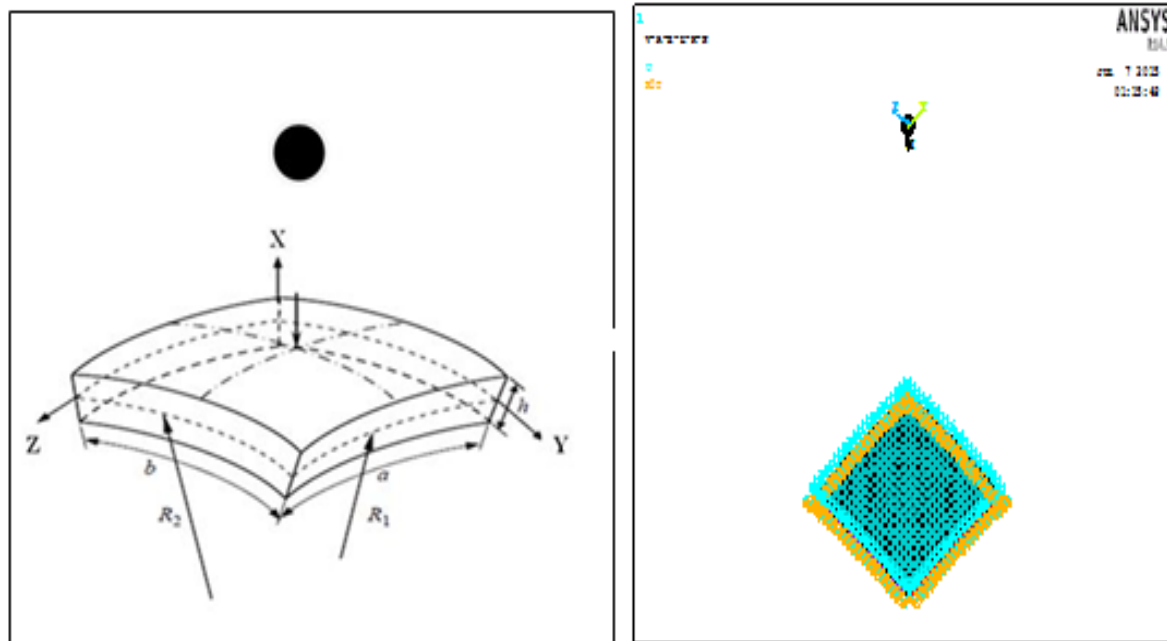
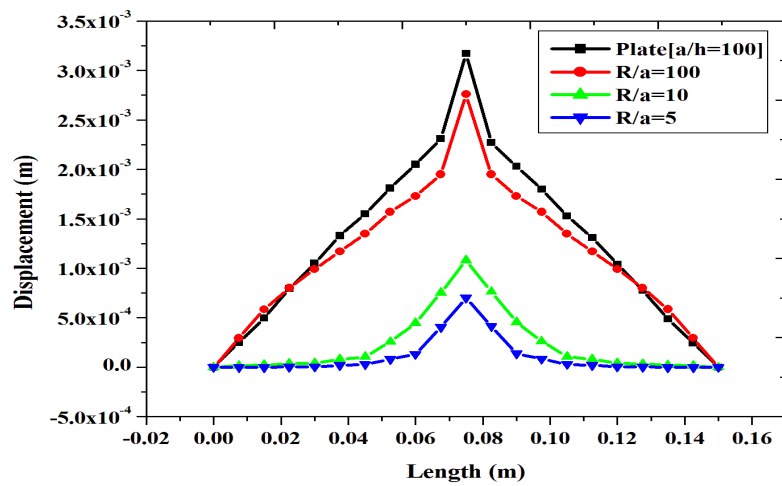


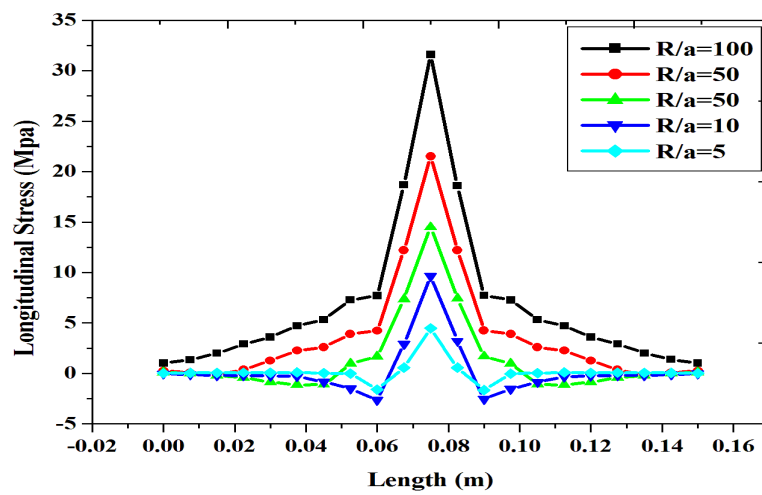
Figure 2: Schematic representation of impactor and spherical shell

5. Impact Analysis of Spherical Shells:

A doubly curved laminated shell structure subjected to an impact by a steel ball is shown Fig. 2. The numerical examples are considered to demonstrate the capability of ANSYS/LS-DYNA on the impact analysis of a spherical shell structures for study the impact responses. The analysis is carried out by varying curvature of the spherical shell. The lay up for the laminated shell is a single layer cross ply of $[0]$ orientation and thickness 1.5 mm. The impactor is a steel ball of radius 6.5 mm and density is $4085.725 \times 10^3 \text{ kg/m}^3$. The geometric properties used are $a=b=150\text{mm}$, $R_1=R_2=R$ for a Spherical shell and plate.

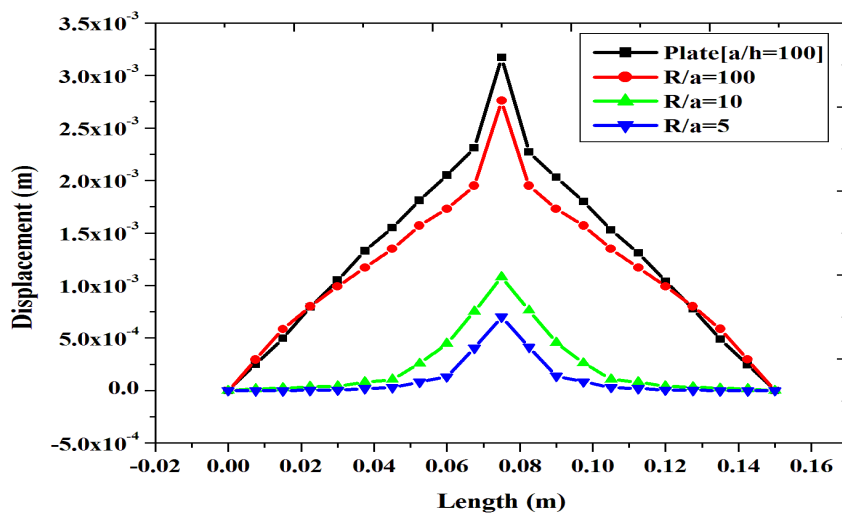


(a)

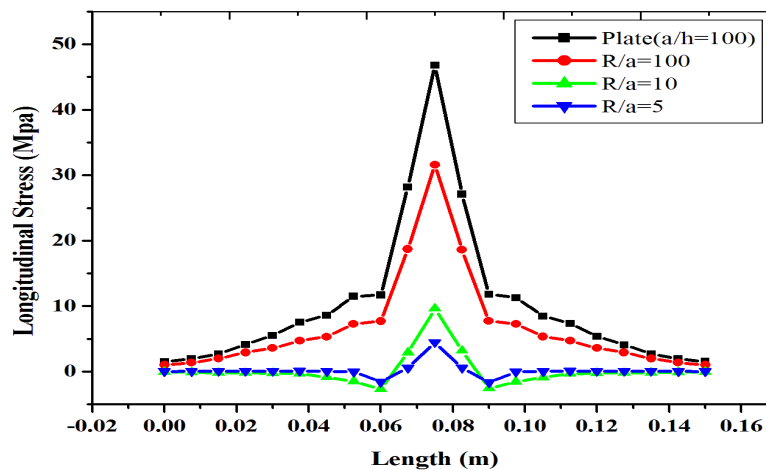


(b)

Figure 3: (a) Displacement for different radius of spherical shell. (b) Longitudinal stress for different radius of spherical shell.



(a)



(b)

Figure 4: (a) Variation of Displacement with L_Y at $X = L_X/2$ for PLATE and L_Y at $Z = L_Z/2$ for SPHERICAL SHELL E-glass/epoxy laminates, simply supported. (b) Variation of stress with L_Y at $X = L_X/2$ for PLATE and L_Y at $Z = L_Z/2$ for SPHERICAL SHELL E-glass/epoxy laminates, simply supported.

Figure 3: (a) and (b) shows the effect of the ratio of the radius to arc length R/a on the central displacement and longitudinal stresses for a spherical shell. The impactor velocity is 1.68 m/s and the shell is simply supported for all the five ratios R/a . The graphical results show that for shell having larger radius is deflect more with maximum stresses compared shell having minimum radius. This may be due to the stiffening effect on the spherical shell.

A comparison between plate and spherical shell under simply supported boundary shown in Figs. 4. (a) and (b), respectively. The deflection and stresses for the plate is maximum compared to shell

Table 2: Central deflection and stresses for spherical shell panel and plate

Spherical shell	a/h	Orientation	R/a					Plate
			5	10	25	50	100	
Max Displacement (mm)	100	[0] Single Layer	0.0007	0.00108	0.00164	0.00239	0.00276	0.00317
Max Longitudinal Stress (Mpa)			9.63×10^6	3.16×10^7	1.45×10^7	2.15×10^7	4.48×10^6	4.68×10^7

6. Conclusions:

The composite laminated plate and shell structures subjected to low velocity impact have been analyzed using ANSYS/LS-DYNA finite element software. The impact responses are presented for the stresses and central deflection. The numerical results show curved shell has stiffer than plate surface.

7. References:

- Balasubramani, V and Boopathy, S Rajendra and Vasudevan, R. "Numerical Analysis of Low Velocity Impact on Laminated Composite Plates." Procedia Engineering. Elsevier, 2013. 1089--1098.
- Cho, Chongdu and Zhao, Guiping. "Dynamic response and damage of composite shell under impact." KSME International Journal. Springer, 1999. 596--608.
- Her, Shih-Chuan and Liang, Yu-Cheng. "The finite element analysis of composite laminates and shell structures subjected to low velocity impact." Composite Structures. Elsevier, 2004. 277--285.
- Khalili, SMR and Soroush, M and Davar, A and Rahmani, O. "Finite element modeling of low-velocity impact on laminated composite plates and cylindrical shells." Composite Structures. Elsevier, 2011. 1363--1375.
- Krishnamurthy, KS and Mahajan, P and Mittal, RK. "A parametric study of the impact response and damage of laminated cylindrical composite shells." Composites Science and Technology. Elsevier, 2001. 1655--1669.
- Kumar, B Kranthi and Kishore, Lakshmana T. "Low Velocity Impact Analysis of Laminated FRP Composites." International Journal of Engineering Science and Technology. Engg Journals Publications, 2012.
- Mishra, Ashish and Naik, NK. "Failure initiation in composite structures under low-velocity impact: Analytical studies." Composite Structures. Elsevier, 2010. 436--444.

8. Razali, N and Sultan, MTH and Mustapha, F and Yidris, N and Ishak, MR. "Impact Damage on Composite Structures--A Review." International Journal of Engineering and Science. Engg Journals Publications, 20 July 2014. 08-20.
9. S. Channabasavaraju, Dr. H. K. Shivanand, Santhosh Kumar. S. "Investigation of Low velocity Impact Properties of Kevlar Fiber Reinforced." International Journal of Engineering Research & Technology. Engg Journals Publications, October - 2013.
10. ANSYS 14.5 User's Manual