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RESPONSE ANALYSIS OF LAMINATED COMPOSITES PRESSURE VESSEL SUBJECTED TO LOW VELOCITY IMPACT

Muayad M. Idan*, Nabil H. Hadi
* Ph.D. student, Mechanical Engineering Dept., Engineering College, Univ. of Baghdad, Iraq
Asst. Prof. Dr. Mechanical Engineering Dept., College of Engineering, Univ, of Baghdad, Iraq

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ABSTRACT
Composite materials most of the time used in the industry of marine and aerospace, the study care in understanding the response caused by the shock load in low velocity impact. The composite materials define as mixing two different materials to get good properties and light weight. The study involved impact load testing and a numerical analysis with Abaqus/Standard was used to compare with the experimental results, of many various variables of modeling, including(3)weight of impactor for open and closed end cylinders, three different thicknesses of layers of laminated composite cylinder. Various models are tested and results showed that the deflection and force with time are affected for these different models. Experimental and theoretical results showed good agreement for impact response magnitudes as well as contact forces with max. Percentage error of (7.5%).

INTRODUCTION
Composite materials are constructed by combining more of one material to improve the engineering properties better than the one material .such as strength, stiffness; fatigue life, wear resistance corrosion resistance and weight reduction are some of the properties may be improved in constructing composite materials. The vast of composite materials are created from two materials: the reinforcement material called fiber and the base material called matrix material. Long fibers are much stronger and stiffer than bulk form. The duty of matrix is supported the fiber and protect it. The matrix has lower strength, density, and stiffness than the fibers. The results are divided into two parts; the first part is the experimental results. This paper studied the response of laminated composite cylinder and other parameters. These modes obtained numerically by using ABAQUS finite element analyzer and compared with experimental results. The second parts are the low velocity impact test results including (displacement and contact force) for composite cylinder. The results of low velocity impact test obtained numerically by ABAQUS and compared with experimental results. Mark Kimber, Suresh V. 2009[1], discussed the vibration motion of curved shell and actuating it by some exciting source, type impact loading an example of this he use a thin elastic curved shell as attest specimens and vibrating it to get the motion to the curved shell that actuated, by one of the vibration types like a piezoelectric materials by bonding this to a shell. S.K Sahu M.K.Rath P.K Datta 2012[4], study the dynamic stability, analysis and the vibration in the present work there is a theoretical results A computer program in a MATLAB depend on the finite, element procedure by developing it to carry out all the necessary, computations deal with the laminated composite curved shell and the theory of shear deformation of the first order was used for the laminated composite shells subjected to impact dynamic loading using Bolotin's approach. Shaker Farid Sufian 2013[1], scout about the effect of each the side gaps and tip gaps in the laminates composite materials performance with the effect a fan of piezoelectric by a combination of numerical and experimental analyses.

PROBLEM DESCRIPTION
Impactor made of Teflon with diameter (21) mm weights (45) gm dropped on E-Glass/Polyester composite cylinder [4]. The dimensions of cylinder are (r=15, z=40, t=5) mm with stacking sequences [0/90o/0/90o]. The cylinder will be simulated with 3, 4, 6 Layers of woven fibers and with open and closed end cylinders. The impactor hit the cylinder at different points along lateral and longitudinal direction and velocity ranging from (1.5 –2) m/s [5]. The objective is to investigate the displacement, and contact force of the cylinder. All the steps of simulation will be explained.

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Experimental work

The aim of the experimental work is mainly to investigate the response of composite cylinder under test of low velocity impact test to examine the response performs of the parameters like displacement, and contact force. Also, to evaluate the mechanical properties used in experimental part of fabricated composite cylinder

Geometry of Models

In Table (1), (2) represents the range of the design parameters that have been studied for the models [6].

Table (1) dimensions and parameters of open ends composite cylinder

Specimen No.	No. of layers	Diameter (m)	Length (m)
1	3	0.30	0.45
2	4	0.30	0.45
3	6	0.30	0.45
4	8	0.30	0.45

Table (2) dimensions and parameters of closed ends composite cylinder.

Specimen No.	No. of layers	Diameter (m)	Length (m)
1	8	0.30	0.45

Verification Test

To validity the results of the present Experimental work, a comparison had been done with two types of tests impact load cell loading and hummer impacting, first comparison where explained in table (3) shows the deflection from impact loading from 5-cm height for the two types of tests to the cylinder for two types of layers of laminate composite cylinder, firstly cylinder with 3 layers and secondly cylinder with 4 layers. Second comparison where explained in table (4) shows the deflection from impact loading for two types of tests from 9-cm height to the cylinder and 3, 4-layers of laminate composite cylinder [7].

Table (3) Verification and Comparison between maximum central theoretical & experimental deflection for 5cm height of impact loading.

Specimen type	Num.Results from ABAQUSE(m)	Experimental Deflection(m) Hummer	Experimental Deflection(m) Load cell	Error % Hummer	Error % Load cell
3-layers	0.00025	0.00026	0.000234	6.4	9.23
4-layers	0.000215	0.00022	0.000201	6.5	8.6

Table (4) Verification and Comparison between maximum central theoretical & experimental deflection for 9cm height of impact loading.

Specimen type	Num.Results from ABAQUSE(m)	Experimental Deflection(m) Hummer	Experimental Deflection(m) Load cell	Error % Hummer	Error % Load cell
3-Layers	0.00037	0.00034	0.00033	12.12	3.01
4-Layers	0.00032	0.00029	0.00026	11.53	23.04

RESULTS AND DISCUSSION

The results of both the part of experimental results and the part obtained numerically by using ABAQUS finite element analyzer are explained in this paper with the comparing of each other of the results. The low velocity impact test results including (displacement, contact force) for composite cylinder for different position on longitudinal and lateral or circumferential direction of the impactor and laminated composite cylinder and different position of accelerometer. In the experimental work this is done by applying impact load on laminate composite cylinder and the obtained results are compared with those obtained numerically by ABAQUS for the same condition.

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Results of displacement.

a- the maximum displacement was in the composite cylinder which was numerically (1.32) mm and that of experimentally (1.27) with error percentage (2.3%). the maximum displacement occurred in the time equal to 0.0015sec [8].

b-the maximum displacement which was occurred in the composite cylinder which was numerically and experimentally are almost equals with error percentage (0.108%) at the point near the point of maximum displacement at time equal to (0.0018)sec.

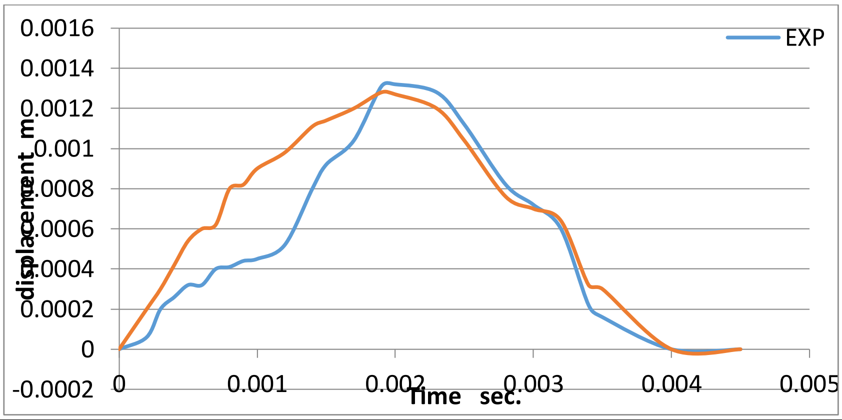

Figure (1) displacement for composite cylinder.

Table (5) Comparison between theoretical & experimental deflection.

Time (Sec)	weight(kg)		
	Displacement (m) Abaquse	Displacement (m) Experimental	**Discrepancy percent%**
0.0002	0.00006	0.0002	70
0.0003	0.0002	0.0003	33.3
0.0004	0.00026	0.00042	38.0
0.0005	0.00032	0.00054	40.7
0.0006	0.00032	0.0006	46.6
0.0007	0.0004	0.00062	35.4
0.0008	0.00041	0.0008	48.7
0.0009	0.00044	0.00082	46.3
0.001	0.00045	0.0009	50
0.0012	0.00052	0.00098	46.9
0.0014	0.0008	0.00111	27.9
0.0015	0.00092	0.00114	19.2
0.0017	0.00104	0.0012	13.3
0.0019	0.00131	0.00128	2.3
0.002	0.00132	0.00127	3.9
0.0023	0.00128	0.0012	6.6
0.0025	0.00112	0.00104	7.6
0.0028	0.00082	0.00076	7.8
0.003	0.00072	0.0007	2.8
0.00f32	0.0006	0.00064	6.2
0.0034	0.00022	0.00032	31.2
0.0035	0.00016	0.0003	46.6

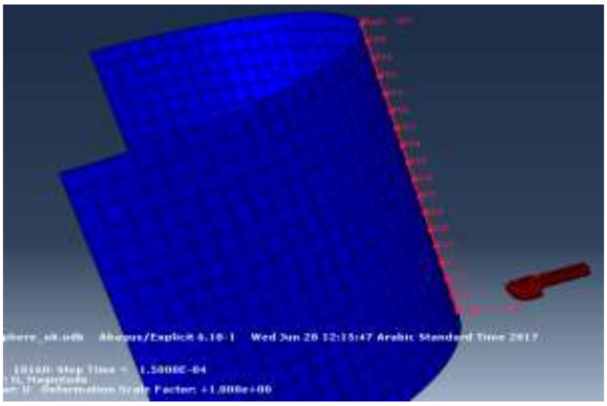

Figure (2) longitudinal path for composite cylinder.

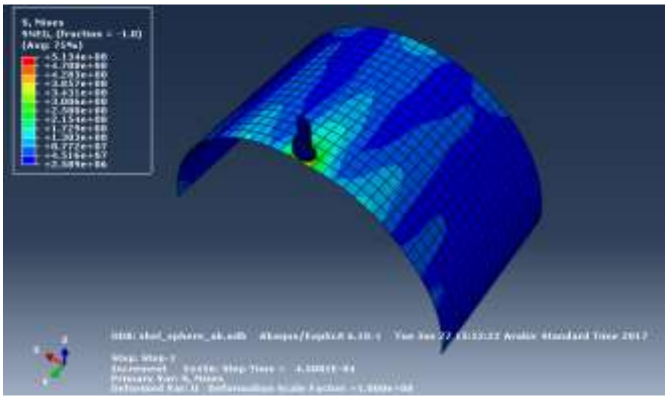

Figure (3) circumferential path for composite cylinder.

Results of stresses in the normalize longitudinal distance.

The maximum stresses in composite cylinder which was numerically (9.2 E+3) in the normalized circumferential direction equal to (x/pi.R =0.22) figure (4), the decreasing percentage in the stresses was (43.47%) with the stresses in the normalized circumferential direction equal to (x/pi.R =0.24) this stresses occurred at the time equal to0.00015sec [9]. and the stresses numerical results was less than maximum stresses result at this point figure (4). maximum stresses result at this point figure (5).

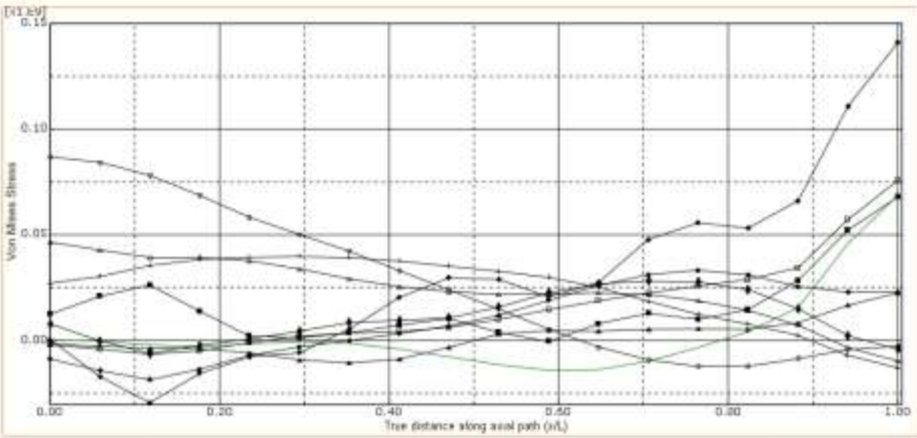

Figure (4) The stresses with normalize longitudinal distance for time from (0 to 1.5 E-3) sec.

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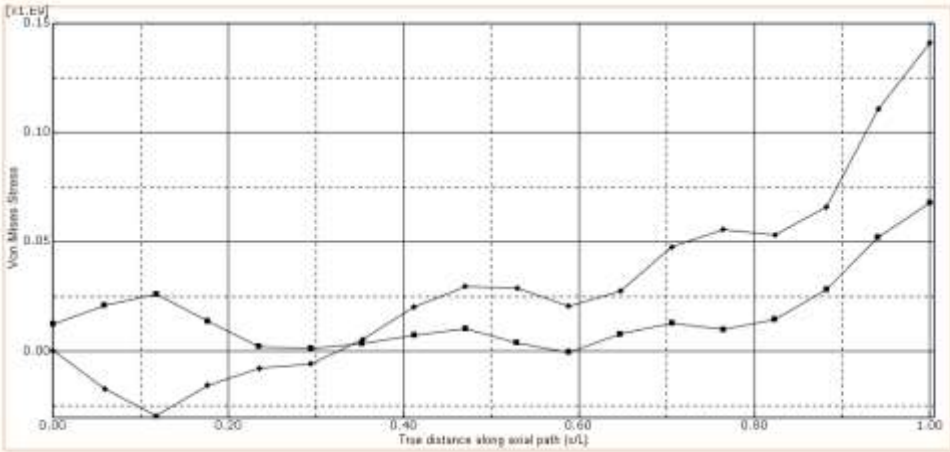

Figure (5) The stresses with normalize longitudinal distance for time (0.0006 and 0.00105) sec.

Results of the stresses with normalize circumferential.

The maximum stresses in composite cylinder which was numerically (0.35 E+9) at x/pi.R=0.5 in the normalized circumferential direction see figure (6) at time equal to 0.0015 this time is the last interval of time (∇T=0.0015sec.), the decreasing percentage in the stresses was (97.14%) with the stresses (0.01 E+9) in the same normalized distance in circumferential direction equal to (x/pi.R =0.5) and at the first interval of time this stresses occurred at the time equal to0.00015sec.and this numerical results was less than the last result at this point see figure (7) .

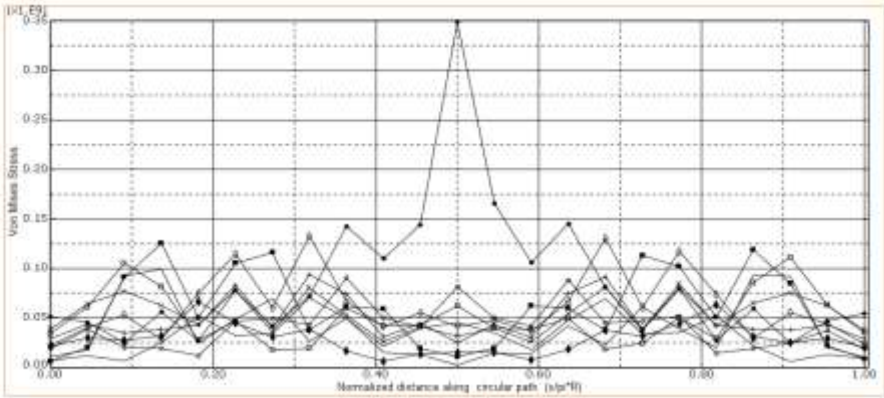

Figure (6) The stresses with normalize circumferential distance for time from (0 to 1.5 E-3) sec.

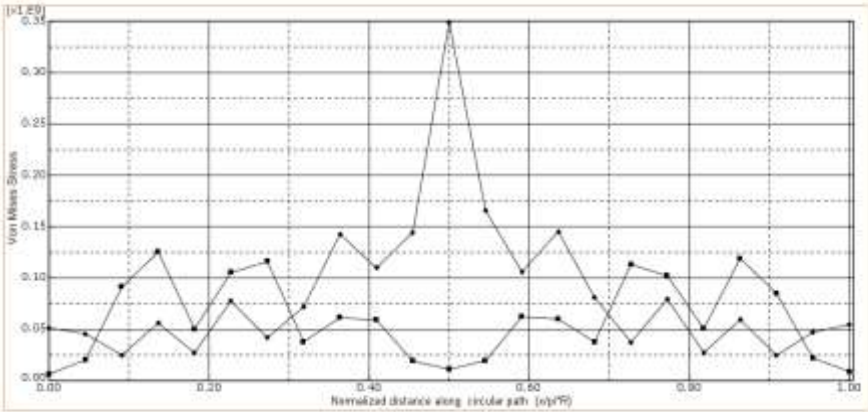

Figure (7) the stresses with normalize circumferential distance for time (0.00015 to 0.0015) sec.

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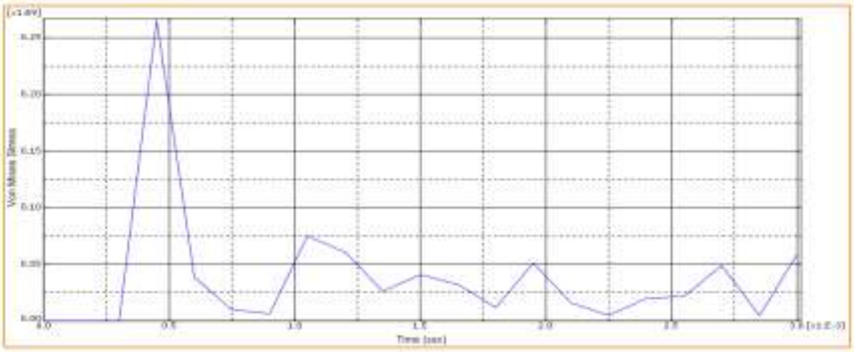
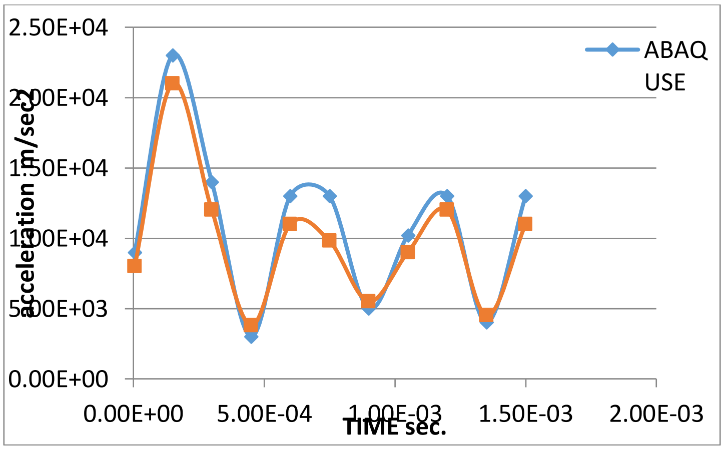


Figure (8) stresses-Time History under the impactor.

The numerical and experimental results of acceleration with time for normalize longitudinal distance.
a-the maximum acceleration in composite cylinder which was numerically (23 E+6 m/sec2) and that that experimentally (21 E+6 m/sec2) by error percentage (8.7%) this case at mid distance in the axial direction see table (6). Decreasing percentage in the acceleration was (30.43%) was happened in this case with the acceleration in the distance equal to the axial length of the cylinder (x/L=1) and the numerical results was greater than experimental result at this point [10] see figure (9).

Table (6) numerical and experimental results of acceleration for normalized longitudinal direction at x/L = 0.08 or x=L/2.

Time sec.	ABAQUSE(m/s^2)	Experimental(m/s^2)	Discrepancy percent%
5.00E-06	9.00E+03	8.00E+03	11.1
1.50E-04	2.30E+04	2.10E+04	8.70
3.00E-04	1.40E+04	1.20E+07	14.3
4.50E-04	3.00E+03	3.80E+03	26.7
6.00E-04	1.30E+04	1.10E+04	15.4
7.50E-04	1.30E+04	9.80E+03	24.6
9.00E-04	5.00E+03	5.50E+03	10.0
1.05E-03	1.02E+04	9.00E+03	11.8
1.20E-03	1.30E+04	1.20E+04	7.69
1.35E-03	4.00E+03	4.50E+03	12.5
1.50E-03	1.30E+04	1.10E+04	15.4



Figures (9) numerical and experimental results of acceleration for normalized longitudinal direction at x/L = 0.08 or x=L/2.

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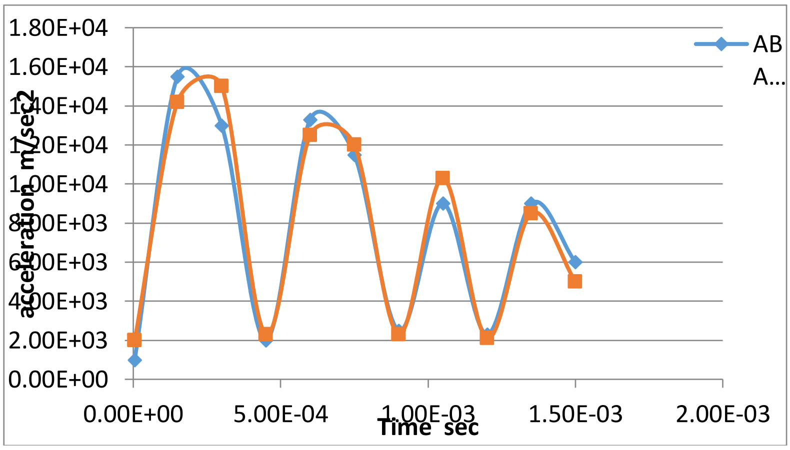
b- The maximum acceleration in composite cylinder which was numerically (15.5 E+6 m/sec2) and that that experimentally (14.2 E+6 m/sec2) by error percentage (8.39%) this case at end distance in the axial direction see table (9-b). the numerical results was greater than experimental result at this point see figure (10).

Table (7) numerical and experimental results of acceleration for normalized longitudinal direction at x/L = 0.164 or x=L.

Time sec.	ABAQUSE(m/s^2)	Experimental(m/s^2)	Discrepancy percent%
5.00E-06	1.00E+03	2.00E+03	1
1.50E-04	1.55E+04	1.42E+04	8.39
3.00E-04	1.30E+04	1.50E+04	15.4
4.50E-04	2.00E+03	2.30E+06	15.0
6.00E-04	1.33E+04	1.25E+04	6.02
7.50E-04	1.15E+04	1.20E+04	4.35
9.00E-04	2.50E+03	2.30E+03	8
1.05E-03	9.00E+03	1.03E+04	14.4
1.20E-03	2.30E+03	2.10E+03	8.70
1.35E-03	9.00E+03	8.50E+03	5.56
1.50E-03	6.00E+03	5.00E+03	16.7



Figures (10) numerical and experimental results of acceleration for normalized longitudinal direction at x/L = 0.164 or x=L.

The numerical and experimental results of acceleration with time for normalize circumferential distance.

a-the maximum acceleration in composite cylinder which was numerically (30 E+6 m/sec2) and that that experimentally (25 E+6 m/sec2) by error percentage (16.6%) this case at mid distance in the circumferential direction see table (8). Decreasing percentage in the acceleration was (10%) was happened in this case with the acceleration in the distance equal to the circumferential length of the cylinder (x/pi.R=1) and the numerical results was greater than experimental result at this point see figure (11).

Table (8) numerical and experimental results of acceleration for normalized circumferential direction at x/pi.R = 0.08 or x=pi.R/2.

Time sec.	ABAQUSE(m/s^2)	Experimental(m/s^2)	Discrepancy percent%
1.50E-04	8.30E+03	9.00E+03	1.50E-04
3.00E-04	2.15E+04	1.50E+04	3.00E-04
4.50E-04	3.00E+04	2.50E+04	4.50E-04
6.00E-04	2.30E+04	1.10E+04	6.00E-04

7.50E-04	2.00E+03	3.00E+03	7.50E-04
9.00E-04	4.00E+03	6.00E+03	9.00E-04
1.05E-03	1.60E+03	1.00E+03	1.05E-03
1.20E-03	1.50E+03	2.00E+03	1.20E-03
1.35E-03	3.70E+03	3.00E+03	1.35E-03
1.50E-03	7.00E+03	5.80E+03	1.50E-03
1.50E-04	8.30E+03	9.00E+03	1.50E-04

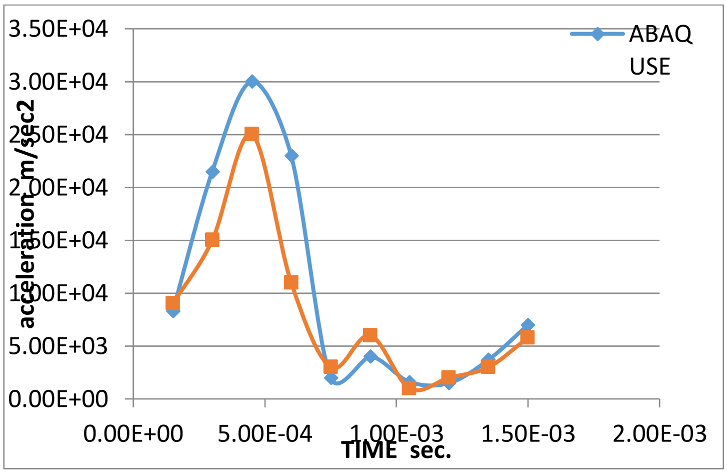


Figure (11) numerical and experimental results of acceleration for normalized circumferential direction at x/pi.R = 0.08 or x=pi.R/2.

b- The maximum acceleration in composite cylinder which was numerically (27 E+6 m/sec2) and that that experimentally (25 E+6 m/sec2) by error percentage (7.4%) this case at end distance in the circumferential direction see table (9). the numerical results was greater than experimental result at this point see figure (12).

Table (9) numerical and experimental results of acceleration for normalized circumferential direction at x/pi.R = 0.44 or x/pi.R=L

Time sec.	ABAQUSE(m/s^2)	Experimental(m/s^2)	Discrepancy percent%
1.50E-04	7.00E+03	7.50E+03	-7.14E-02
3.00E-04	1.90E+04	1.70E+04	1.05E-01
4.50E-04	2.70E+04	2.50E+04	7.41E-02
6.00E-04	2.10E+04	1.70E+04	1.90E-01
7.50E-04	1.75E+04	1.49E+04	1.49E-01
9.00E-04	3.50E+06	5.60E+06	-6.00E-01
1.05E-03	1.40E+03	9.00E+05	3.57E-01
1.20E-03	1.30E+03	1.60E+03	-2.31E-01
1.35E-03	3.20E+03	2.80E+03	1.25E-01
1.50E-03	6.20E+03	5.10E+03	1.77E-01

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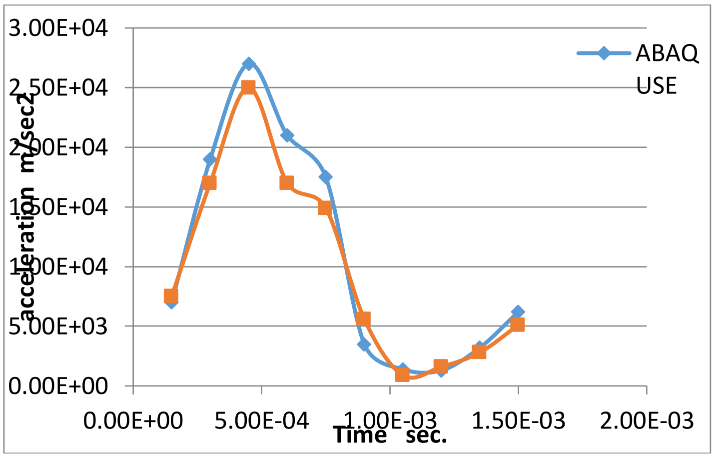

Figure (12) numerical and experimental results of acceleration for normalized circumferential direction at x/pi.R = 0.44 or x=pi.R/2.

CONCLUTION

The composite cylinder with open ends of 3 layers, 4 layers, 6 layers and 8 layers also 8 layers with closed ends of laminated composite cylinder, it clear that the effect of increasing the layers on the mechanical properties useful for composite cylinder. It can be seen that the response frequency, or impact duration, is independent of the impact velocity, and depend on the mass ratio and the material and geometrical parameters of the cylinder. Can also be seen that the impact velocity contributes only to the amplitude of the response and it is a linear contribution. For a smaller impactor mass, higher response frequencies start to become important with dynamic effects becoming more evident. However, the impact response of the shell dose not only depends on the mass ratio but also depends on the shell geometry and material properties. For the displacement on the longitudinal direction of the composite cylinder, the maximum displacement occurred in point under the impactor and the minimum displacement occurred in point on the end of length of longitudinal direction far away from the impactor. It was cleared that the displacement increased by decreasing the distance on the path of the longitudinal direction on the line of the impactor. The displacement also increased by decreasing the no. of layers of laminated composite cylinder. For the displacement on the circumferential direction of the composite cylinder, the maximum displacement occurred in point under the impactor and the minimum displacement occurred in point on the end of path of circumferential direction far away from the impactor. It was cleared that the displacement increased by decreasing the distance on the path of the circumferential direction on the path of the impactor. The displacement also increased by decreasing the no. of layers of laminated composite cylinder. For the stresses, it decreased if the distance in the path of longitudinal direction decreased, also with decreasing the time of impact. The composite cylinder with open ends of 3-layers laminated composite cylinder need time less than the composite cylinder (4and6)-layers laminated composite cylinder to reach the maximum displacement.

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