# Analytical Study for Impact Strength Evaluation of Composite Circular Plate as per ISO 6603-I

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**Abstract- In this paper, Analytical study for impact strength evaluation of composite circular plate. Circular plate having two different thickness 1mm and 3mm. Glass fiber reinforced polymer and Graphite fiber reinforced polymer circular plates are considered. To calculate the deformation, impact energy and impact force on the laminated composite plates. Various parametric study are performed includes thickness of laminates, lay-up sequence and material properties on the composite plate.**

**Keywords: FRP, ANSYS Explicit Dynamics, Laminate, Impactor, Lay-up sequence.**

## I. INTRODUCTION

Fiber reinforced composites have become increasingly important over the past few years and are now the first choice for fabricating structures where low weight in combination with high strength and stiffness are required. Fiber Reinforced Plastics (FRP) composites are in greatest commercial use. They have been extensively used in aerospace, automotive, marine and construction industries due to their inherent advantages over conventional metals. Fibers provides 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. Most common type of composite plates are used like lass fiber reinforced polymer and graphite fiber reinforced polymer circular plates because high specific strength and high impact strength.

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.As per, ISO 6603 part-1 Determination of puncture impact behavior of rigid plastics. Two type of specimens are considered circular plate and square plate. In this paper circular plate are considered. Specimens thickness between 1 mm and 4mm.Impactor velocity 4.4m/s.

## II.COMPOSITE LAMINATES

A Glass fiber reinforced polymer and Graphite fiber reinforced polymer with different stacking sequence [0/90/0/90]s and [45/-45/45/-45]s. In Glass fiber reinforced polymer and Graphite fiber reinforced polymer volume fraction 45% and 70% respectively. Two type of Composite circular plate dimensions considered. In both plated Diameter 140mm and thickness 1 mm and 3 mm. The ply thickness for 1mmand 3mm circular plates are 0.125mm and 0.375mm.The specimens were centrally loaded. The impactors dropped the plate at the center. All the side of laminated are Fixed. The material of the impactors is ordinary steel. An impactor of mass m and drop on the center of the laminated plate. Table 1 and Table 2 show the properties of lamina.

Table 1 Property of Glass/epoxy lamina

| | |
|---|---|
| Fiber volume fraction $V_f$ | 0.45 |
| Longitudinal elastic modulus $E_1$ | 38.6 GPa |
| Transverse elastic modulus $E_2$ | 8.27 GPa |
| Major poison's ratio $\nu_{12}$ | 0.26 |
| Shear modulus $G_{12}$ | 4.14 GPa |

Table 2 Properties of Graphite/epoxy lamina

| | |
|---|---|
| Fiber volume fraction $V_f$ | 0.7 |
| Longitudinal elastic modulus $E_1$ | 181 GPa |
| Transverse elastic modulus $E_2$ | 10.3 GPa |
| Major poison's ratio $\nu_{12}$ | 0.28 |

| | |
|---|---|
| Shear modulus $G_{12}$ | 7.17 GPa |

To evaluate the laminate properties from lamina use ANSYS ACP pre-post Software. ACP has a pre- and post-processing mode. In the pre-processing mode, all composite definitions can be created and are mapped to the geometry (FE mesh). These composite definitions are transferred to the FE model and the solver input file. In the post-processing mode, after a completed solution and the import of the result file(s), post-processing results (failure, safety, strains and stresses) can be evaluated and visualized. Composite materials are created by combining two or more layered materials, each with different properties.

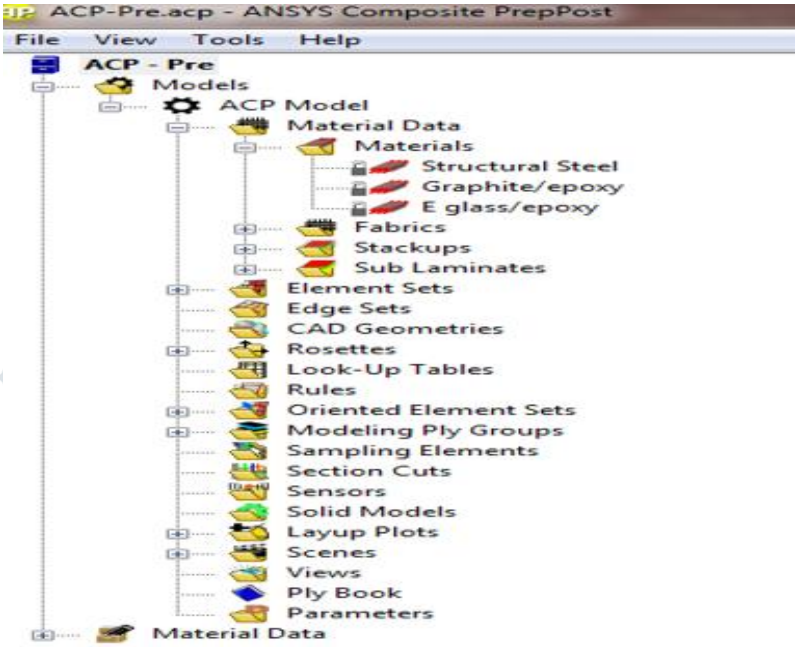



Fig. 1 ANSYS ACP Pre Tools

In ANSYS ACP pre different kind of tools Material data, Fabrics, Stickups, Element sets, Rosettes, oriented element sets, Modeling play groups, Sampling Elements Layup plots etc. Fabric should be defined in which laminate properties with their thicknesses are added. Then after stack up sequences are defined in which fibers orientation with global coordinate system are added.The definition of the Stack up can be given in both directions (Bottom-Up and Top-Down). In the Top Down sequence, Also, In this case to define different orientation angle like [0/90/0/90]s layup sequence is top-down.

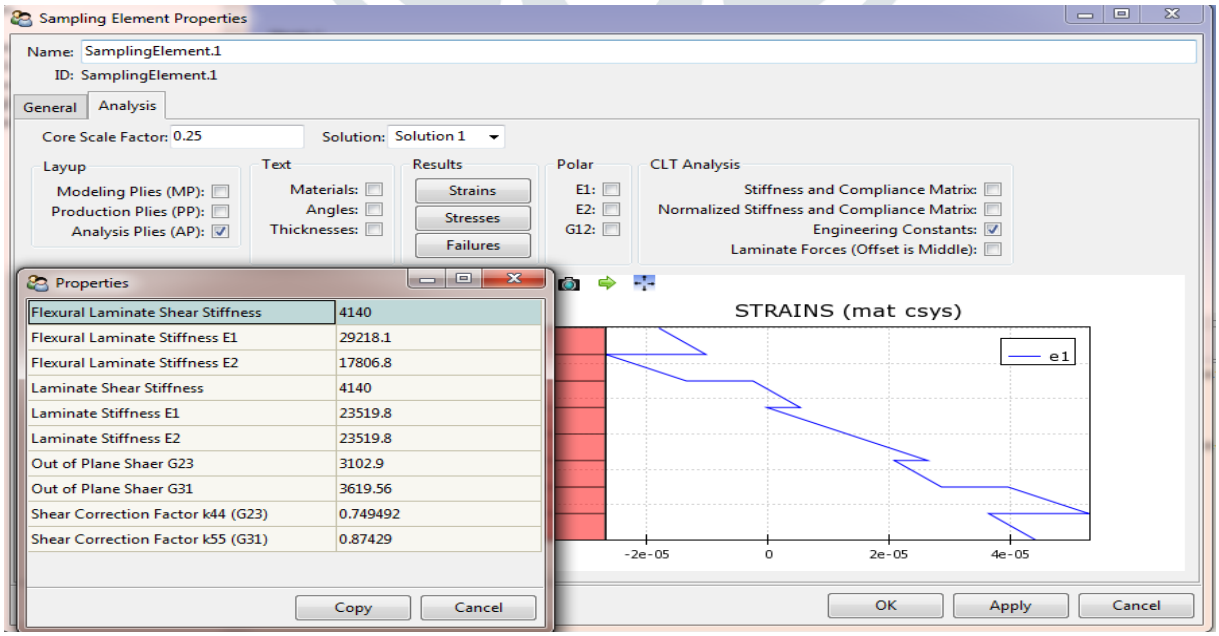



Figure 2 Element properties

As shown in Figure Element properties stiffness matrix and Engineering constant are get by ACP pre.

Stiffness Matrix:

| i | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| 0 | 70913 | 5004.9 | 6.8276e-13 | 0 | 0 | 0 | 0 | 0 |
| 1 | 5004.9 | 70913 | 1.2316e-11 | 0 | -9.0949e-13 | 0 | 0 | 0 |
| 2 | 6.8276e-13 | 1.2316e-11 | 12420 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 66091 | 3753.7 | 3.2004e-13 | 0 | 0 |
| 4 | 0 | -9.0949e-13 | 0 | 3753.7 | 40278 | 5.7733e-12 | 0 | 0 |
| 5 | 0 | 0 | 0 | 3.2004e-13 | 5.7733e-12 | 9315 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 12420 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12420 |

Figure 3 Stiffness matrix

$$A = \begin{bmatrix} 70913 & 5004.9 & 6.27e-13 \\ 5004.9 & 70913 & 1.2316e-11 \\ 6.827e-13 & 1.2316e-11 & 12420 \end{bmatrix}$$

$$A^{-1} = \begin{bmatrix} 1.43e-5 & -1e-6 & 2.15e-22 \\ -1e-6 & 1.42e-5 & 1.39e-20 \\ 2.11e-22 & -1.39e-20 & 8.05e-5 \end{bmatrix}$$

$$v_{12} = -\left(\frac{A^{12}}{A^{11}}\right)$$

$$v_{12} = -\left(\frac{-1e-6}{1.42e-5}\right)$$

$$v_{12} = 0.07$$

$$v_{21} = -\left(\frac{A^{12}}{A^{22}}\right)$$

$$v_{21} = -\left(\frac{-1e-6}{1.42e-5}\right)$$

$$v_{21} = 0.07$$

(1) Mechanical properties of Glass/Epoxy Composite (0/90/0/90)s :-

| | |
|---|---|
| Laminate stiffness $E_1$ | 23519.8Mpa |
| Laminate stiffness $E_2$ | 23519.8MPa |
| Laminate shear stiffness G12 | 4140 MPa |
| Out of plane shear G23 | 3120.9 MPa |
| Out of plane shear G31 | 3619.56Mpa |
| ν12 | 0.07 |
| ν21 | 0.07 |
| Density | 1800 kg/m$^3$ |

(2) Mechanical properties of graphite/Epoxy Composite (0/90/0/90)s :-

| | |
|---|---|
| Laminate stiffness $E_1$ | 95880 MPa |
| Laminate stiffness $E_2$ | 95880 MPa |
| Laminate shear stiffness G12 | 7170 MPa |
| Out of plane shear G23 | 4999.97MPa |
| Out of plane shear G31 | 6337.51MPa |
| ν12 | 0.025 |
| ν21 | 0.025 |
| Density | 1600 kg/m$^3$ |

(3) Mechanical properties of Glass/Epoxy Composite (45/-45/45/-45)s :-

| | |
|---|---|
| Laminate stiffness $E_1$ | 12477.4MPa |
| Laminate stiffness $E_2$ | 12477.4MPa |
| Laminate shear stiffness G12 | 10984.6MPa |
| Out of plane shear G23 | 3065.96MPa |

| | |
|---|---|
| Out of plane shear G31 | 3065.96MPa |
| ν12 | 0.51 |
| ν21 | 0.51 |
| Density | 1800 kg/m$^3$ |

(4) Mechanical properties of Graphite/Epoxy Composite (45/-45/45/-45)s :-

| | |
|---|---|
| Laminate stiffness $E_1$ | 25029.3MPa |
| Laminate stiffness $E_2$ | 25029.3MPa |
| Laminate shear stiffness G12 | 46781.3MPa |
| Out of plane shear G23 | 4521 MPa |
| Out of plane shear G31 | 4521 Mpa |
| ν12 | 0.6 |
| ν21 | 0.6 |
| Density | 1600 kg/m$^3$ |

(5) Mechanical properties of Steel Impactor : -

| Impactor Properties | |
|---|---|
| Density | Kg/m$^3$ |
| Young's modulus | 210 Gpa |
| Poisson's ratio | 0.3 |

**III.ANSYS MODELING:-**

A basic model data of impact analysis as shown in figure 4 and 5.

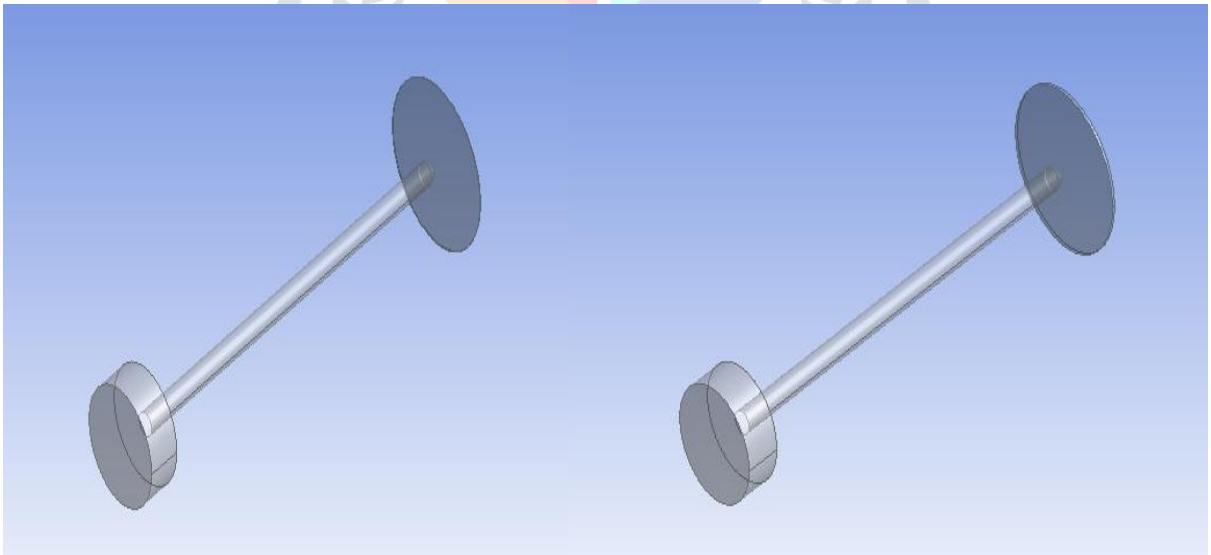


Figure 4 mm Circular plate

Impactor height = 496.66 mm
Circular plate Diameter 140 mm
and thickness 1 mm
Distance between impactor and plate 7.5 mm

Figure 5 mm Circular plate

Impactor height = 496.66 mm
Circular plate Diameter 140 mm
and thickness 3 mm
Distance between impactor and plate 7.5 mm

In this paper 8 models are study (table 3 ) for the To Evaluate the deformation, impact energy and impact force on the laminated composite plates. Various parametric study are performed includes thickness of laminates, lay-up sequence and material properties on the composite plate.

Table 3 Model Data

| | MODEL NAME |
|---|---|
| MODEL1 | 3 mm circular glass epoxy [0/90/0/90]s |
| MODEL2 | 3 mm circular glass epoxy [45/-45/45/-45]s |
| MODEL3 | 3 mm circular graphite epoxy [0/90/0/90]s |
| MODEL4 | 3 mm circular graphite [45/-45/45/-45]s |
| MODEL5 | 1 mm circular glass epoxy [0/90/0/90]s |
| MODEL6 | 1 mm circular glass epoxy [45/-45/45/-45]s |
| MODEL7 | 1 mm circular graphite epoxy [0/90/0/90]s |
| MODEL8 | 1 mm circular graphite epoxy [45/-45/45/-45]s |

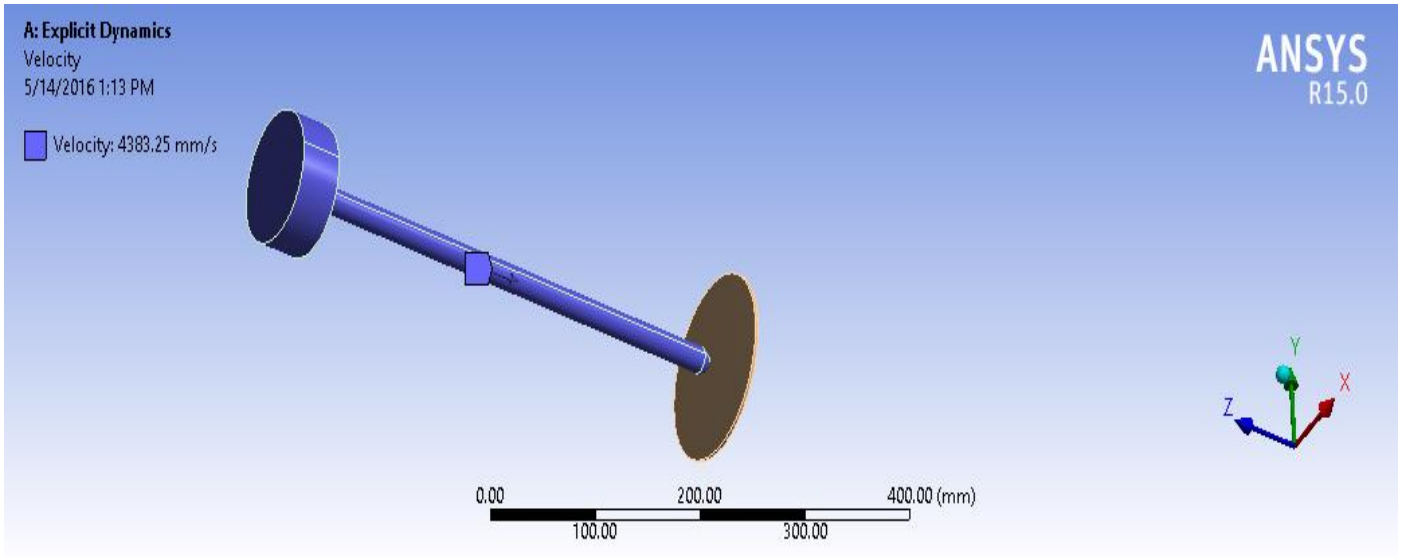



Figure 6 Velocity direction along the impactor

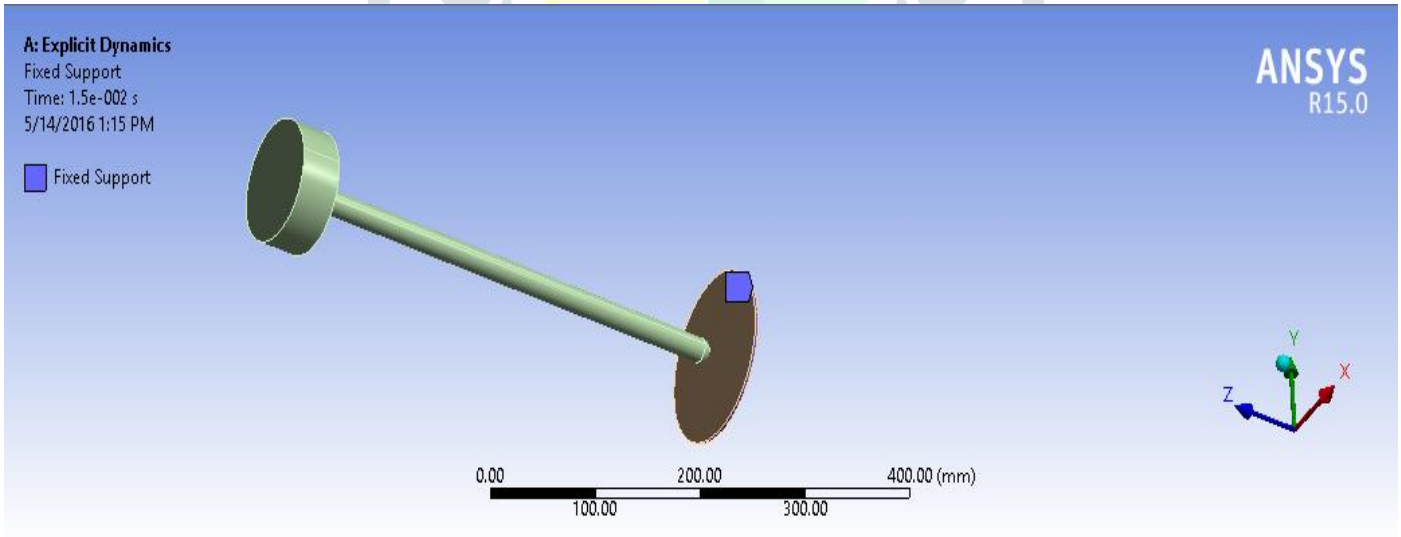
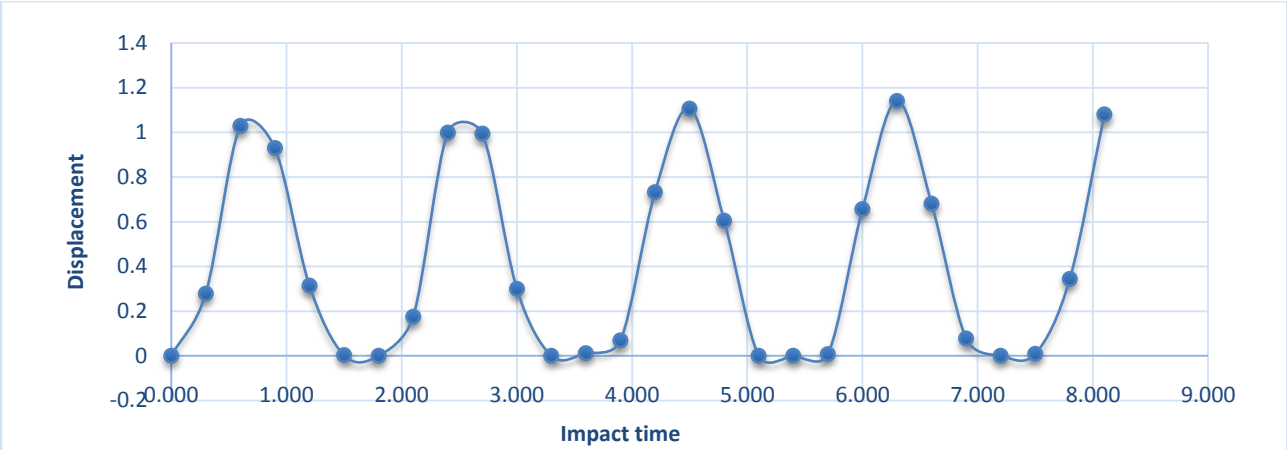



Figure 7 Fixed at circular plate edge

In Initial conditions to define Low velocity 4383.25mm/s in impactor directions shown in figure. In analysis setting to define the boundary conditions shown in figure, Circular plate edge defined the Fixed. In ANSYS Explicit Dynamics, analysis setting end time 0.015s.

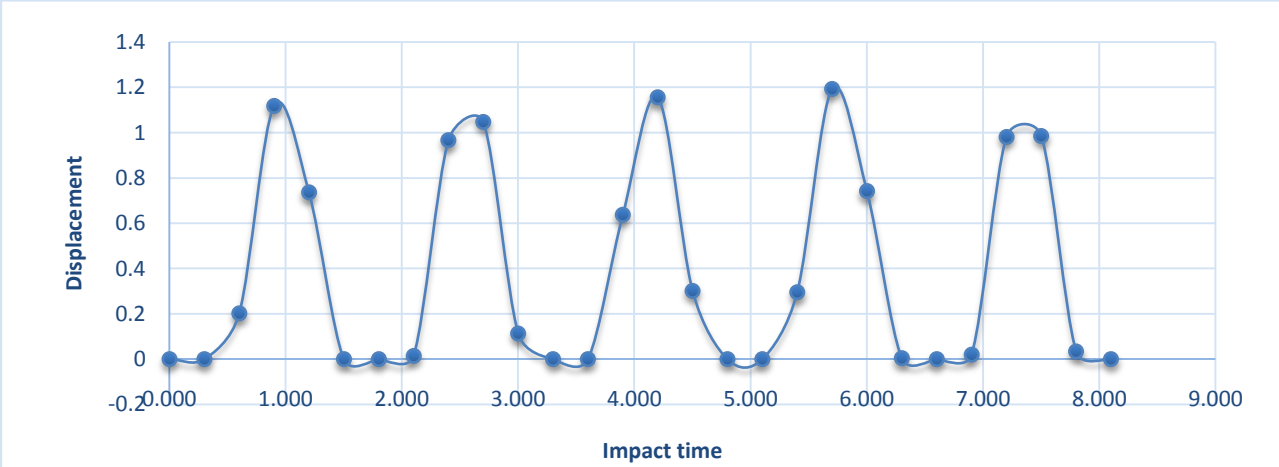
**IV.ANALYSIS AND RESULTS**:-

Analytical study has been done to circular plate having to different thickness of 1mm and 3mm were subjected to low velocity impacts for different lay-up sequence as shown in table. To get out charts of Maximum deformation vs impact time, Impact energy vs impact time and Maximum force.



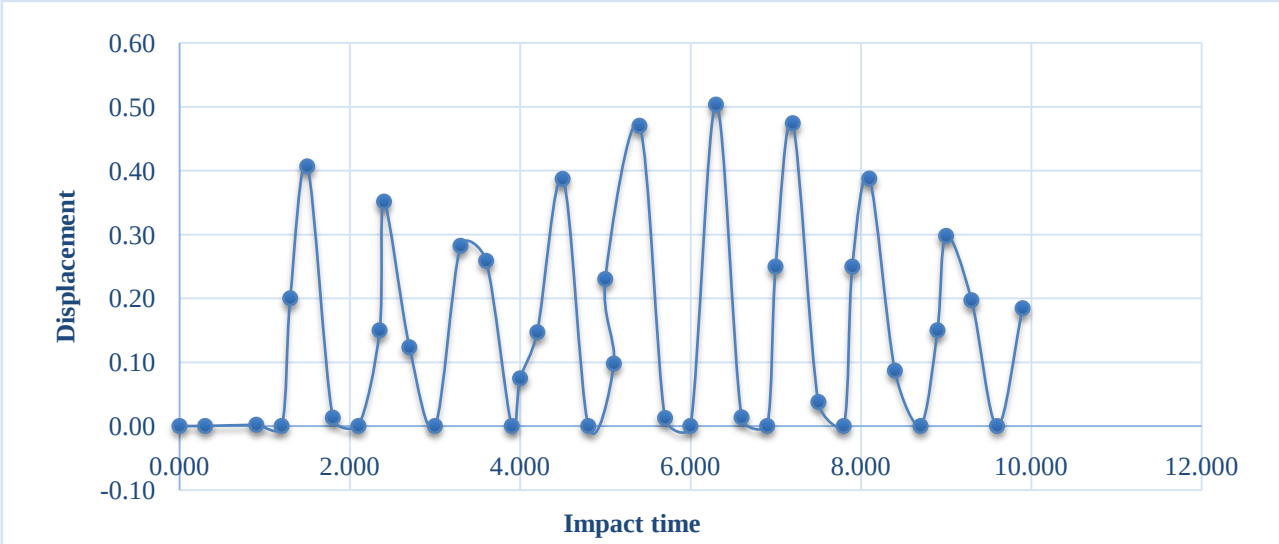

Displacement(mm) vs Impact time(ms)

**MODEL 1**



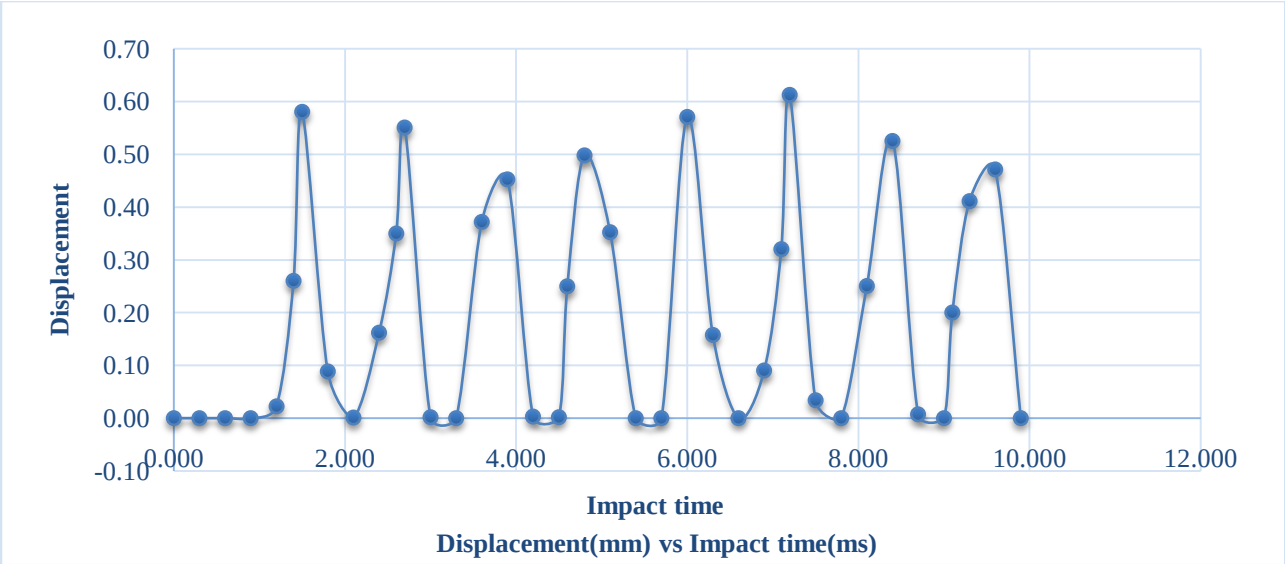

Displacement(mm) vs Impact time(ms)

**MODEL 2**

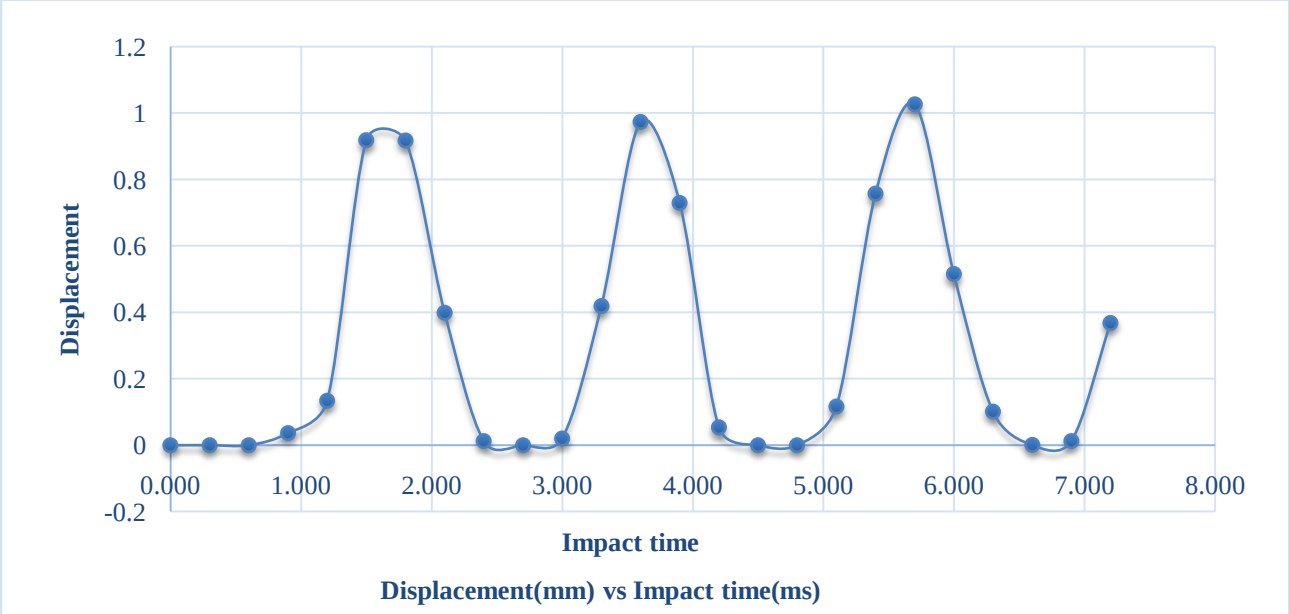



Displacement(mm) vs Impact time(ms)

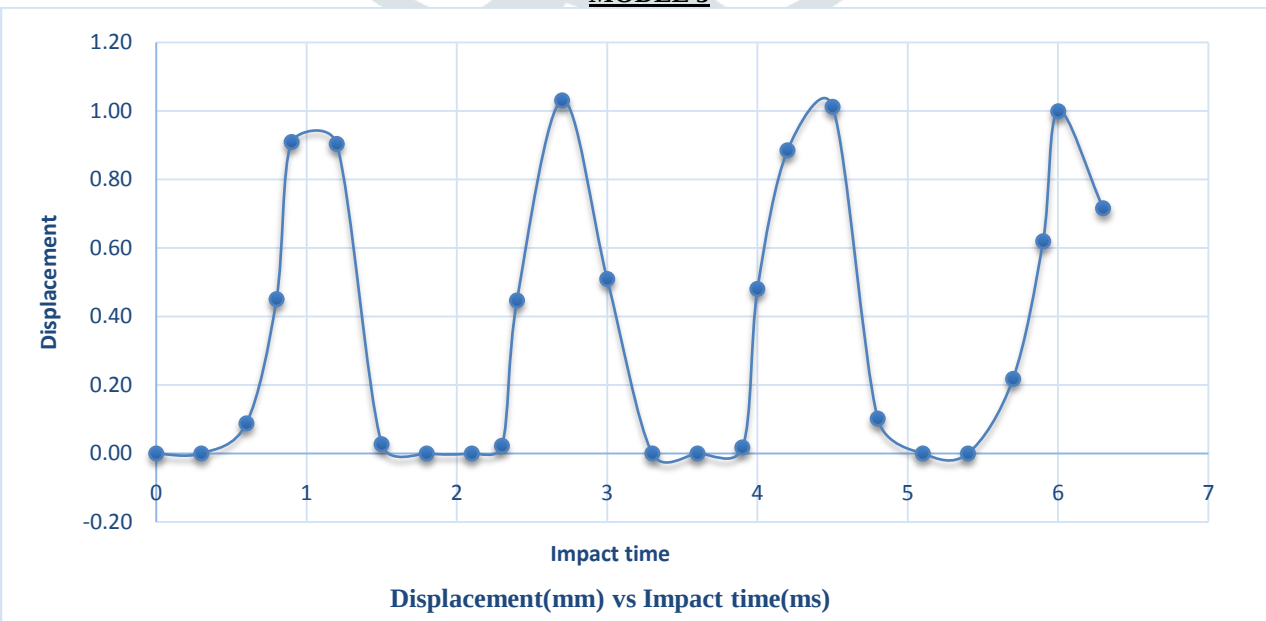
**MODEL 3**



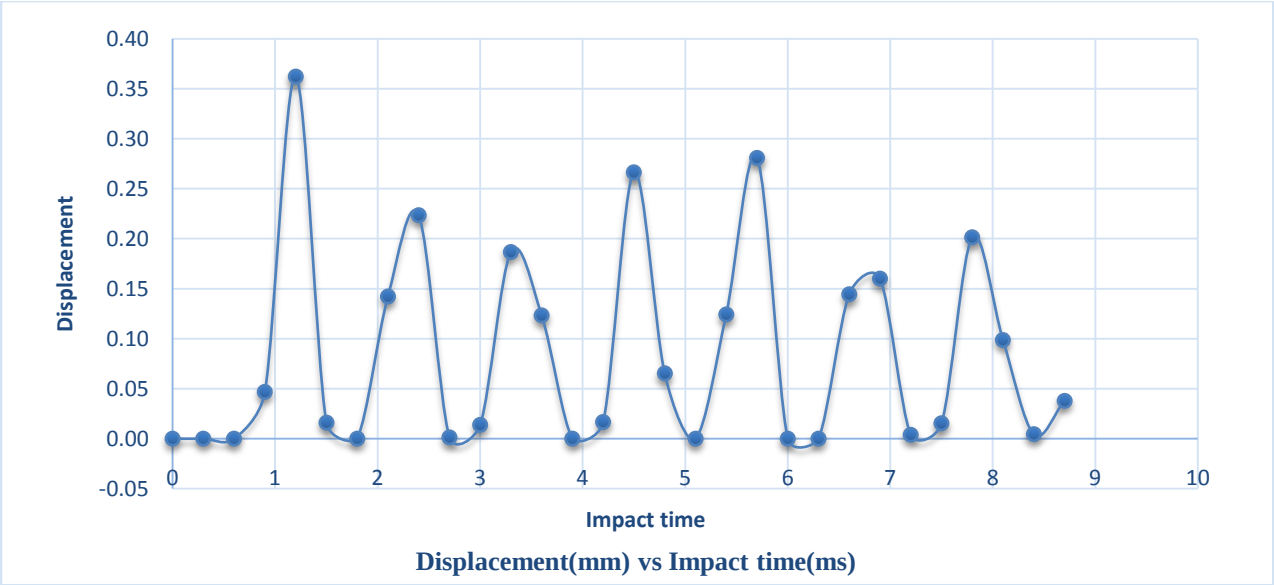

**MODEL 4**



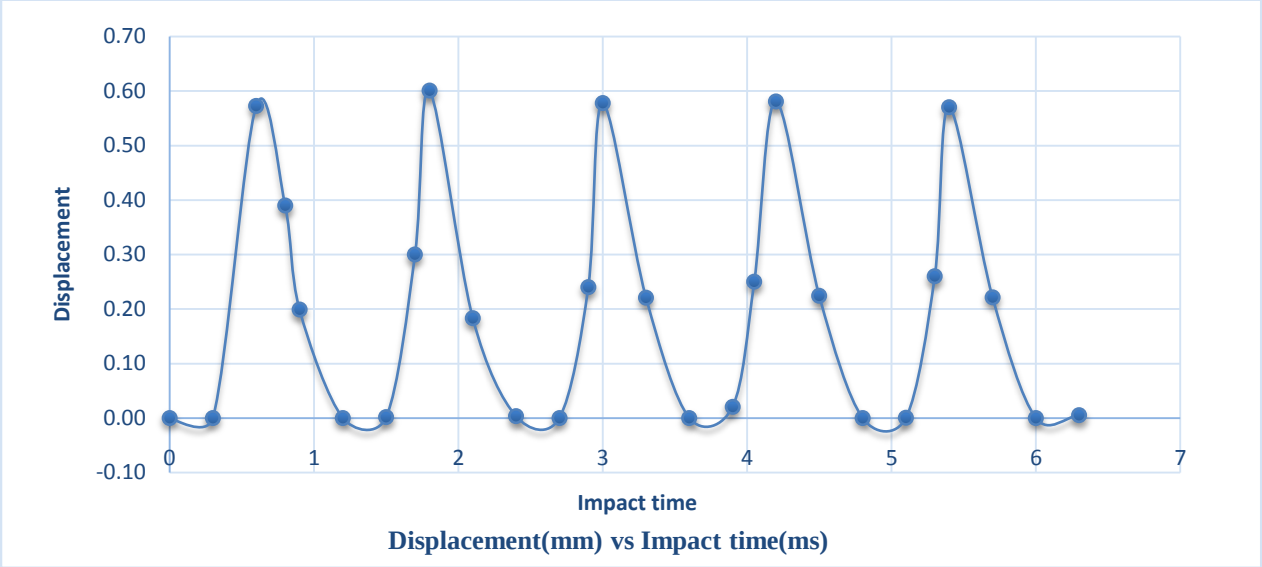

**MODEL 5**




**MODEL 6**

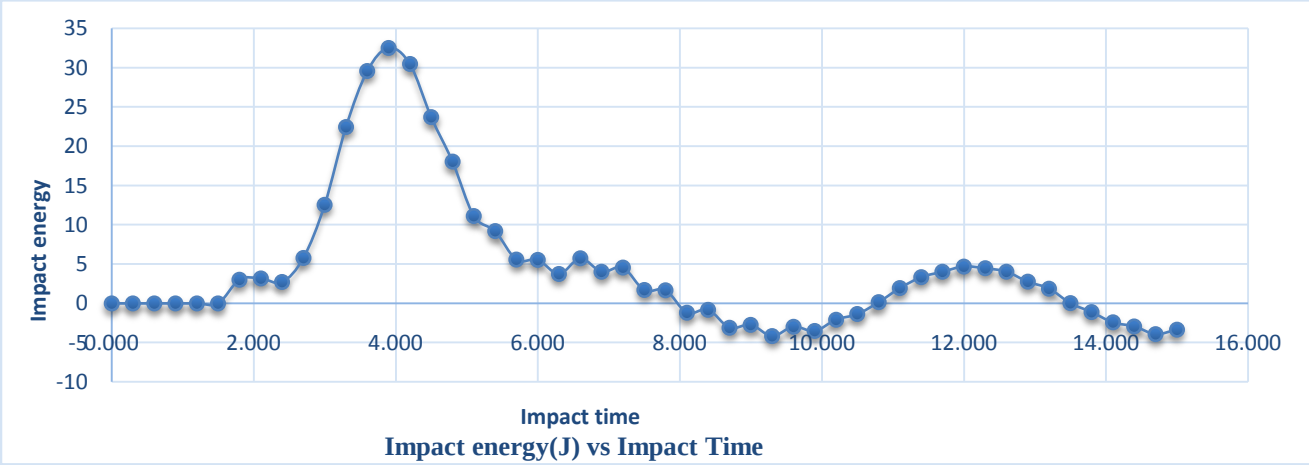



**MODEL 7**




**MODEL 8**

As per above results, Maximum central displacement obtained by 1.14 mm for impact time about 6.3ms in model 1. Maximum central displacement obtained by 1.19 mm for impact time about 5.7ms in model 2. Maximum central displacement obtained by 0.50mm for impact time about 6.3ms in model 3. Maximum central displacement obtained by 0.61 mm for impact time about 7.2ms in model 4. So, 3 mm circular plate Graphite fiber reinforced polymer are stiffer than glass reinforced polymer. Similarly, 1 mm circular plate Graphite fiber reinforced polymer are stiffer than glass reinforced polymer.




**MODEL 4**

Impact energy range 30 to 32.52 J for all models are almost same. but,Graphite fiber reinforced circular plate is more impact energy as compared to Glass fiber reinforced circular plate. Maximum Impact energy value about 32.52 J for impact time 3.9ms obtained in Model 4 - 3 mm circular graphite epoxy [45/-45/45/-45]s.

Table 4 Maximum Force for different Models

| MODEL | | MAXIMUN FORCE(KN) |
|---|---|---|
| | | |
| MODEL1 | 3 mm circular glass epoxy [0/90/0/90]s | 0.71 |
| MODEL2 | 3 mm circular glass epoxy [45/-45/45/-45]s | 0.39 |
| MODEL3 | 3 mm circular graphite epoxy [0/90/0/90]s | 0.69 |
| MODEL4 | 3 mm circular graphite [45/-45/45/-45]s | 0.16 |
| MODEL5 | 1 mm circular glass epoxy [0/90/0/90]s | 0.47 |
| MODEL6 | 1 mm circular glass epoxy [45/-45/45/-45]s | 0.15 |
| MODEL7 | 1 mm circular graphite epoxy [0/90/0/90]s | 0.18 |
| MODEL8 | 1 mm circular graphite epoxy [45/-45/45/-45]s | 0.02 |

Maximum impact force obtained about 0.71KN for 3 mm circular glass epoxy[0/90/0/90]s and 0.39KN for 3 mm circular glass epoxy[45/-45/45/-45]s. As per above table Maximum impact force Glass epoxy[0/90/0/90]s stacking sequence is more than Glass epoxy [45/-45/45/-45]s. Similarliy,Maximum impact force Graphite epoxy[0/90/0/90]s stacking sequence is more than Graphite epoxy [45/-45/45/-45]s. Maximum impact force depend upon lau-up sequence. Also thickness of circular plate as per above results.

**V.CONCLUSION:-**

Analytical Study for performed impact strength evaluation of composite circular plate under ANSYS Explicit Dynamics. Graphite reinforced polymer circular plate has more impact strength than Glass reinforced polymer circular plate. Composite lay-up sequence [0/90/0/90] has more impact force than [45/-45/45/-45] lay-up sequence. Maximum impact energy obtained by 32.52 J in Graphite reinforced polymer circular plate. Also, the thickness of plate plays a major role in impact resistance. Minimum deformation is also observed in case of graphite-epoxy laminate with lamina sequence of $[0/90/0/90]_S$. Hence it can be concluded that graphite-epoxy laminate with lamina sequence of $[0/90/0/90]_S$ has superior impact resistance over the others.



**REFERENCES**

[1] Determination of puncture impact behaviour of rigid plastics part 1 : Non-instrumented impact test (ISO 6603-1 : 2000)
[2] Chitrcor Mihael, Dumitrache Ramona and Dumitrache Cosmin Laurentiu “The Impact Behaviour of composite Materials” International Conference on Maritime and Navl Science and Engineering
[3] Martin Hildebrand “A Comparison of FRP-sandwich penetrating impact test methods” VTT Manufacturing Technology.
[4] ANSYS® workbench manual 2015
[5] ANSYS® ACP PrepPost manual 2015

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