Dynamic Behaviour of CFRP Composite Panel for Various Impact Load Location

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Abstract

As these carbon-based composites with a high specific strength came into use, the most critical features were damage tolerance and damage resistance under impact loading. The impact location plays a notable role on the behaviour of carbon fibre-reinforced plastic (CFRP) hat-stiffened composite panel. The dynamic characteristics reveals the growth of delamination and its severity at two different locations. These locations are identified to exhibit the nature of failure and its associated effects. The changes in contact force, internal energy absorbed, resultant velocity, resultant acceleration and delamination length at top and bottom flanges of hat shaped stringer when the CFRP panel is hit by spherical impactor are compared using LS dyna software for the impact velocity of 150 m/s.

Keywords: Spherical Impactor, Hat Stringer, Composite Plate, Delamination, Impact Location.

DOI: 10.47750/pnr.2022.13.S03.118

INTRODUCTION

The stiffened panel increases bending strength to resist the buckling failure of plate [1]. There are many types of stiffeners used in aerospace industry. Among those, the hat shaped stringer has a unique characteristic because of its simple construction and high crippling strength. It is used on upper surfaces of aircraft wing, fuselage and other compression members.

The aircraft that can fly at velocity of 255 m/s was considered to understand the load characteristics of tapered wing. From the simulation results, the importance of stringer to stiffen the structure is understood. [3]. Hat shaped stringer is the famous design in recent days to avoid buckling failure [1]. The buckling behaviour in the presence and absence of test fixtures is investigated and optimal size is arrived using MATLAB tool [2].

The delamination process of the bullet-proof vests material made up of cross-ply unidirectional laminates is simulated using 7.62 X 39 mm rifle bullets penetrating laminates of different thicknesses [5]. The results revealed that an increased deflection and energy absorption for composite plates with a preload of 80% of the buckling load [7]. The influence of patch parameters on repair performance of the parent CFRP laminate plates has been understood by getting delamination surface area and absorbed energy of the repaired laminates [9]. The experimental findings derived from high velocity impact tests on woven-roving Glass Fibre-Reinforced Polymers (GFRP) Type E-800 g/m² and Type C-600 g/m² was presented to finalize the shape of the impactor, panel thickness and gas gun pressure [11].

MODELLING OF HAT STRINGER COMPOSITE PANEL

Because of the notable features, hat stringer specifications [12] are to be considered to reveal the delamination behaviour.

The fibre ply angle and thickness are highlighted in table below.

TABLE 1 CONFIGURATION OF HAT STRINGER COMPOSITE PANEL

S. No	Parameters	Orientation/ Values
1.	Skin layup configuration (15 layers)	+45/-45/90/0/+60/-60/-15/-90/+15/-60/+60/0/90/-45/+45
2.	Stringer layup configuration (16 layers)	+45/-45/0/0/90/0/0/-15/+15/0/0/90/0/0/-45/+45
3.	Total thickness of skin	2.82 mm
4.	Total thickness of stringer	3.01 mm

For the study, the hat stringer composite panel is made up of

carbon fibre 270 GSM and epoxy resin GY257 in vacuum bag laminating method.

LS DYNA Modelling of CFRP Composite Skin

The values of 1 and 0 indicate elastic and failed conditions in LS dyna modelling. Based on the literatures, the history variables 1,2,3,4 and 5 are set to represent tensile fibre mode ef (i), compressive fibre mode [ec (i)], tensile matrix mode [em (i)], compressive matrix mode [ed (i)] and max[ef(ip)] [efail] respectively.

In this paper, the spherical impactor is considered to understand the features of delamination failure in two parts such as composite skin and composite skin with stringer individually. This numerical investigation uses spherical impactor of diameter 11.1 mm and mass 11.1 g.

The top surface of plate is hit by hemispherical impactor at 150 m/s, the indentation in zone of delamination and the distribution of x-stress, y stress, z stress and its variation are shown in figure below. The delamination length is also measured. Then, the top surface of hat shaped stringer under impact load at velocity of150 m/s is studied and the variations of performance of the above said parts are clearly addressed here.

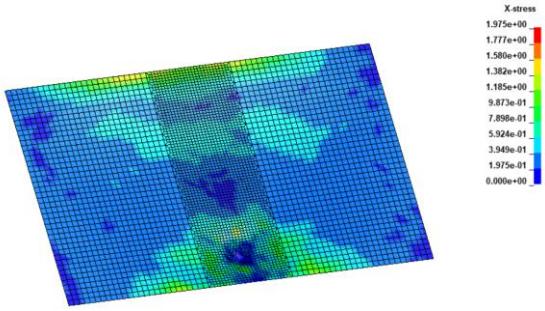


Fig 1. The distribution of x stress

The x stress value is maximum along x-direction and it is seen close to edges. The x-stress keeps on decreasing from the edges to the centre of the plate. The maximum x-stress value is 1975 MPa from this simulation. The x and y distance of delamination is 21mm and 24 mm.

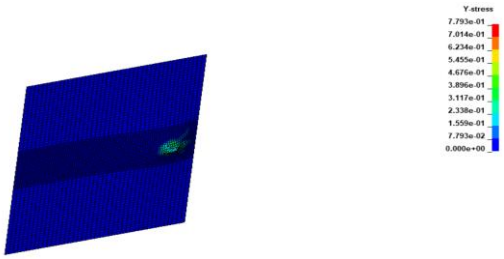


Fig 2. The distribution of y stress

The maximum y-stress value is 779.3 MPa and it is found at the delamination area. In the remaining area, zero stress is noted.

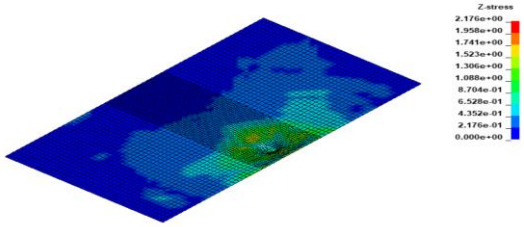


Fig 3. The distribution of z stress

At the top surface of plate, the observed maximum z-stress value is 2176 MPa and its value decreases from impact location to the opposite edge. In comparison with x stress and y stress, z stress is the largest value.

LS DYNA Modelling of CFRP Skin with HAT Shaped Stringer for Impact Velocity of 150 m/s

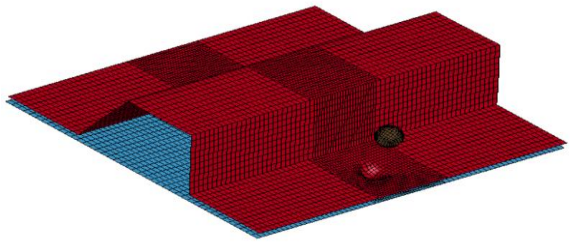


Fig 4. CFRP skin with hat shaped stringer

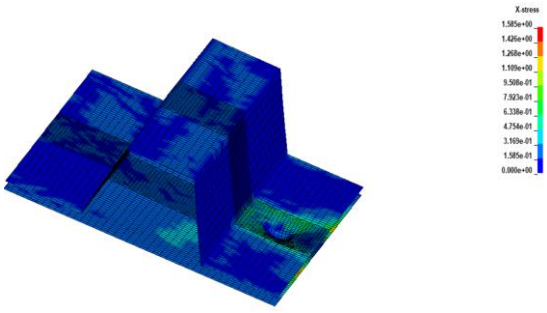


Fig 5. The distribution of x stress

The maximum x stress value is 1585 MPa. Based on rule of thumb, the length of delamination (x, y) is (27,30) mm.

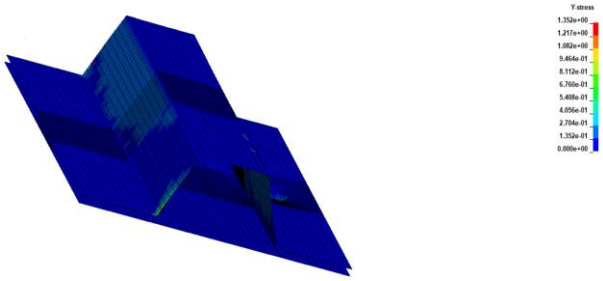


Fig 6. The distribution of y stress

The maximum y stress value is 1352 MPa and it is noted near the edge of web on the opposite side of impact.

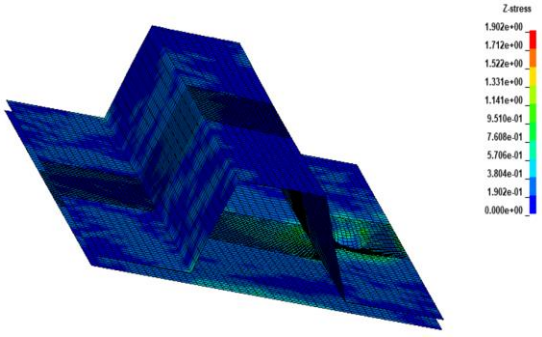


Fig 7. The distribution of z stress

The maximum z stress value is 1902 MPa and it is located near the impact. Its magnitude is higher at the bottom flange of hat stringer than the top flange.

The ten nodes are picked randomly and the resultant velocity plot at these nodes is shown in fig below.

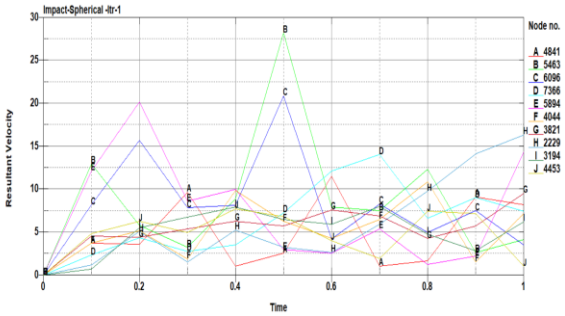


Fig 8. The resultant velocity

The resultant acceleration with time for the same ten nodes chosen above is shown in fig below.

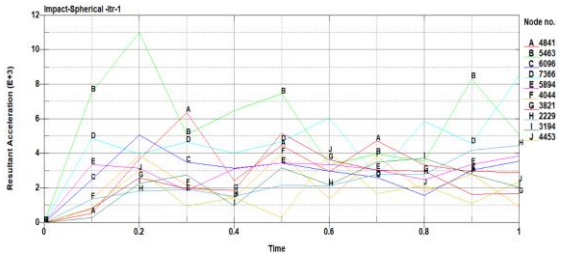


Fig 9. The resultant acceleration

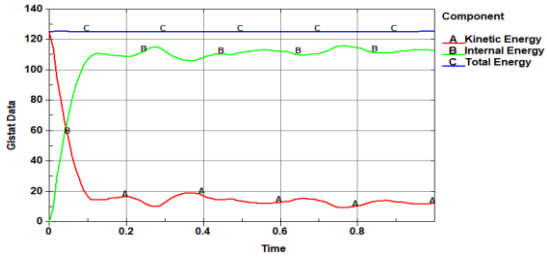


Fig 10. Energy plot for impact velocity of 150 m/s

The internal energy absorbed reaches the value of 116 kJ. The kinetic energy falls to 18.95 kJ from 125.26 kJ. Since the impactor comes back to the plate, the kinetic energy is a non-zero value.

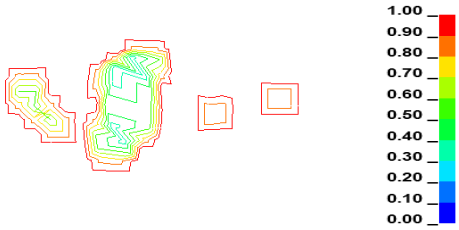


Fig 11. Contour of history variable 1

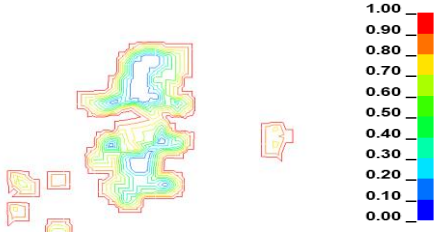


Fig 12. Contour of history variable 2

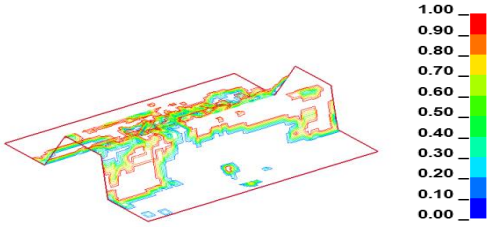


Fig 13. Contour of history variable 3

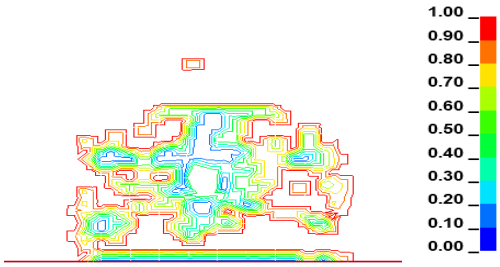


Fig 14. Contour of history variable 4

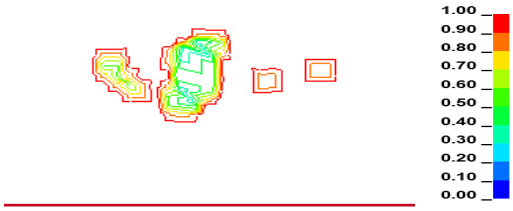


Fig 15. Contours of history variable 5

All fringes are taken at impact location. Zero indicates failure and 1 indicates elastic fringe.

LS DYNA Modelling for Impact Loadind at top of Stringer

The effect of applying impact load at top of the hat shaped stringer is discussed here. The same velocity is used here.

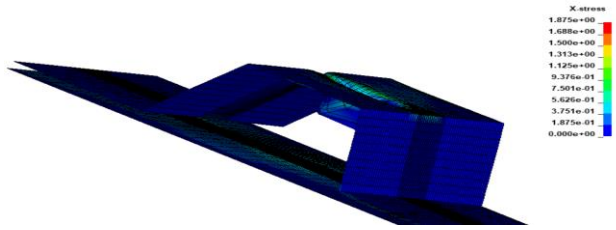


Fig 16. The distribution of x stress

The maximum x stress value is 1875 MPa. Delamination length (x, y) is (30, 42) mm and the penetration is not reached the composite plate.

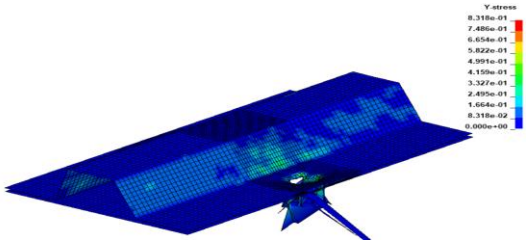


Fig 17. The distribution of y stress

The maximum Y-stress value is 0.8209 MPa and it is noted near the location where the impactor hits.

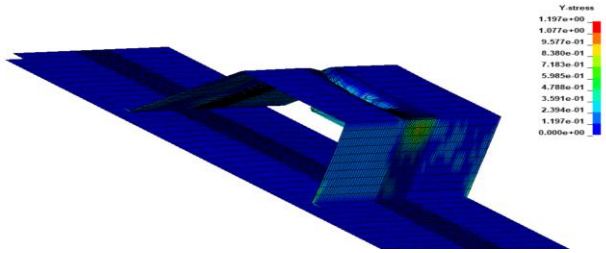
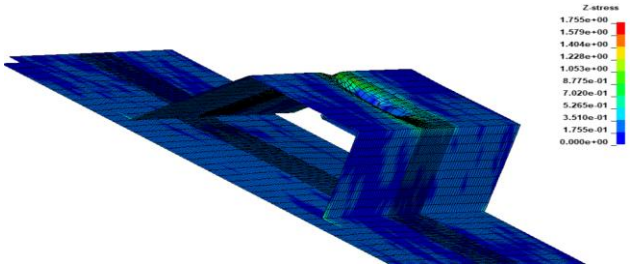


Fig 18. The distribution of y stress



The maximum z stress value is 1755 MPa.

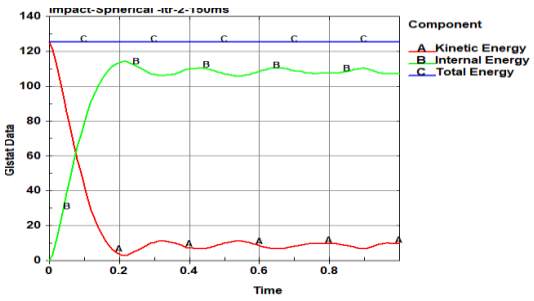


Fig 19. Energy plot

The internal energy absorbed is 107 kJ.

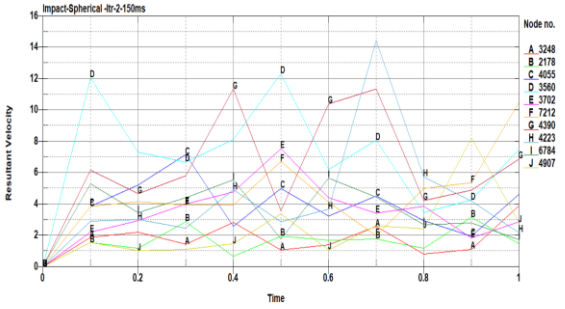


Fig 20. The resultant velocity plot

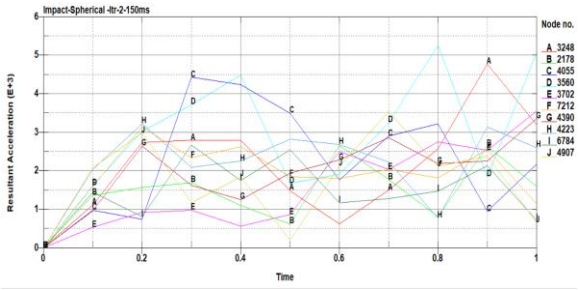


Fig 21. The resultant acceleration plot

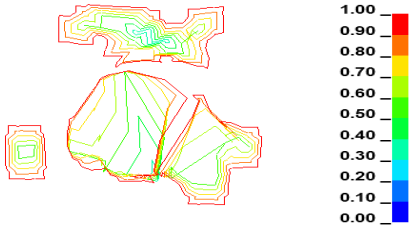


Fig 22. Contours of history variable 1

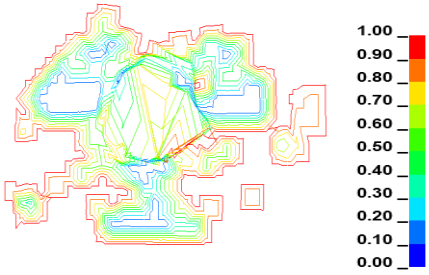


Fig 23. Contours of history variable 2

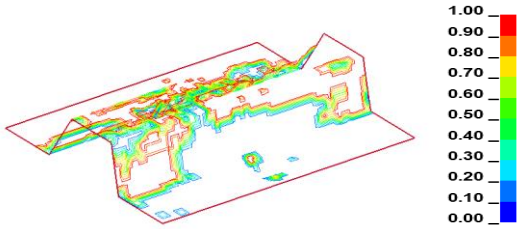


Fig 24. Contours of history variable 3

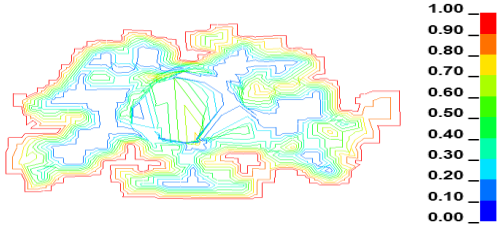


Fig 25. Contours of history variable 4

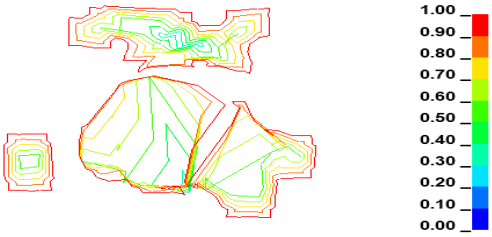


Fig 26. Contours of history variable 5

All fringes are taken at impact location to display failure and elastic conditions.

Conclusion

It is concluded that stiffeners increase the bending strength. As more internal energy is absorbed, the induced damage at top flange of stringer is more. The resultant velocity and acceleration plots help to understand the structure and it clearly tells values are not same at all nodal points. The history plots display the fringe patterns when the component is hit by high velocity impact load.

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