INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING
WWW.IJRAME.COM
ISSN (ONLINE): 2321-3051

Vol.6 Issue.2, February 2018
Pg: -01-10

The Performance of Pre-Stress and Impact Damage Response of Concave and Convex Composite Laminates

BALAJI.H[1]

[1]Head of the Department,
Department of Aeronautical Engineering,
PMR Engineering college, Chennai-95, India.
[1]balaji.hk007@gmail.com;

***Abstract*— When laminated composite materials were widely used in the modern aircraft structures, which is subject to low velocity impact loads or energy. Therefore, in this present work the performance of a compressive and tensile preload on the low velocity impact behaviour of two different materials were investigated. Curved composite laminates are used in many applications, especially for aerodynamic shape in aerospace structures. Therefore in this present paper, the inspiration of the curvature type (convex or concave) and preloading on impact response of curved laminates are considered. For this aim, in previous researches were proving that the concave laminates is stiffer than the convex laminate. By changing material the performance of curvature type specimens are varying. It is applicable for some aerospace structure at impact conditions. For considering the damage mechanisms in different conditions some optical pictures are also presented.**

***Keywords*— Convex and concave laminates, Glass and Hybrid materials, Pre-stress, Impact loading.**

1. INTRODUCTION

Fiber-reinforced composite materials are known for their low weight and high specific strength mechanical properties and are therefore used in various lightweight engineering applications, as particular in aerospace structural application. However, constant concerns for such laminates are much more than for similar metallic structures, which are impact loads of foreign objects that can create internal material damage. A main weakness of laminated composites is subjected to low-velocity impacts, which is introduced accidentally during manufacture, operation or maintenance of the aerospace component, may result in delamination between the plies and matrix crack. Almost the available literatures are deals with impact on structures without any pre-stresses [1-2]. Typically, in analysis to impact loading, in composite structures the pre-stresses are produced either by service loads or by the manufacturing/assembly process.

The composite structure may be subject to compressive, tensile or shear loads in the operational environment or assembly process. Therefore, understanding of the effect of preloading on the impact behavior of composite laminates is of importance, since the damage development can be significantly different. Only very few studies in the literature cover this present project. The most of the studies concerning the effect of low velocity impact damage project literature are focused on thicker flat plates which are typically used for aircraft wing structures, but there are a few studies that address the low velocity impact response of thinner curved composite panels that

IJRAME

INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING
WWW.IJRAME.COM
ISSN (ONLINE): 2321-3051

Vol.6 Issue.2, February 2018 Pg: -01-10

are typical of fuselage skins and nosecone [3, 4]. While there is some information about these two topics in the literature individually and some papers [5, 6] consider tubes impacted under torsional preload, curvature and pre-stress effects during low-velocity impact loading [7]. As well as the GFRP laminates, most of the papers deal with experimental investigations of the influence of preloading on the low velocity impact behavior of carbon fiber-reinforced composites (CFRP). And in this research particular, uniaxial and biaxial tensile preloading is investigated, as by Butcher [8]. Mines et al. [9] and Whittingham et al[10] projects studies is the tensile preload affecting the failure behavior and failure modes, while subjected to impact loads. As per following of the last literature study, in this research the effect of preloading is measured for concave and convex laminates under low velocity impact loading and their results are compared for current project.

2. MATERIALS AND SPECIMEN MANUFACTURING:

In this study there are two types of fiber reinforcements are used that is glass fiber and carbon fiber. These fibers mechanical properties are shown in Table 1. Fig. 1 shows the configuration of all curved composite laminates. The stacking sequence of the curved laminates is $[0/90/0/90/0]_S$ (10 layers), and for Hybrid curved panel $[\text{Glass/carbon}]_5$, width and thickness of the panels are 100mm and 3.3± 0.1mm, respectively. Test specimens are manufactured by hand layup method by using wooden mould. This mould is prepared by CNC controller. A rotating saw was used to cut out the final test specimens with a size of 100 mm×168 mm. Each straight side of the specimen consists of end flange containing 3 holes with 25mm distance. These specimens designed considering the membrane effect during impact loading for concave and convex laminates. In convex panel, the specimen is under compression, while in concave sample, it is under tension.

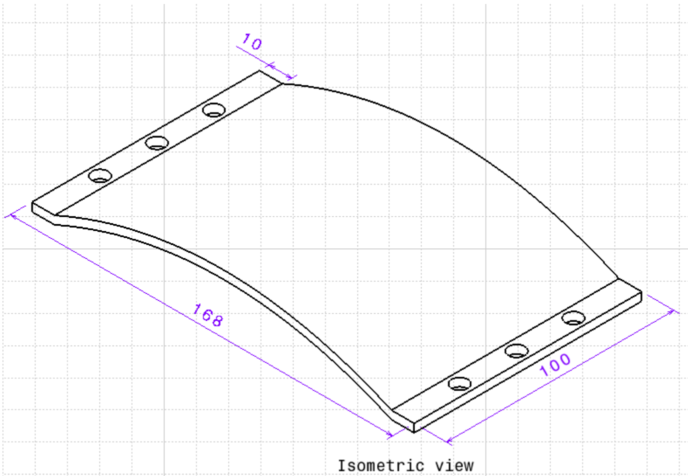


Fig.1-specimens configurations

IJRAME
INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING
WWW.IJRAME.COM
ISSN (ONLINE): 2321-3051
Vol.6 Issue.2, February 2018
Pg: -01-10

Fibre	Density (Lb/in^3)	Tensile Strength (ksi)	Elastic Modulus (msi)	Strain to Failure (%)	Diameter (mil)	Thermal Expansion Co-efficient (10^{-6}in/in/^{o}F)
E-Glasa	0.09	500	11.0	4.8	0.36	2.8
Carbon	0.065	530	33.0	1.5	0.32	-0.2

Table.1 Materials properties

3. PRE-STRESSING FRAME:

Pre-stressing frame is simple setup which is used to apply the pre-stress in the curved composite plate. From this setup can be apply pre-compression and pre-tension load. Due to change in bolt length, it undergoes deformation, which can be induces stress in a curved panel. The pre-stress was measured by dial indicator, which is placed in top of moving frame. For this present project 4500με pre-stress applied in curved panels.

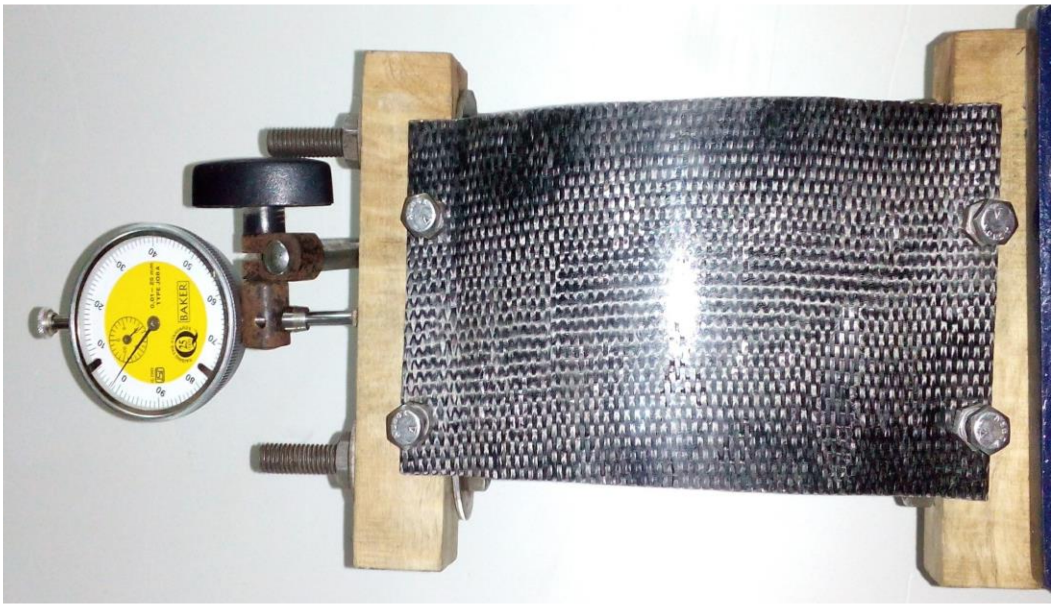


Fig.2-Pre-stressing frame

IJRAME

INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING
WWW.IJRAME.COM
ISSN (ONLINE): 2321-3051

Vol.6 Issue.2, February 2018 Pg: -01-10

4. DROP-WEIGHT MACHINE:

The tests were conducted in a custom built drop-weight machine in impact testing laboratory at IIT-Madras. In that equipment with a piezoelectric load cell attached to the impactor. A piezoelectric load transducer is attached to measure the force–time history. In the drop-weight impact machine, the hemispherical head of the load cell had a diameter of 12.7 mm and the total mass of the impactor was 6.89 kg, which can be raised to a maximum of 5 m. the curved specimen fixed at pre-stress frame, this fixture is developed for this current project. The fixture was positioned under this drop tower, and it is fixed by using C-clamp. The impact tests were conducted under 36J and two different preloading: 0 and 4500με.

It should be mentioned that the specimen is only fixed in the straight side ends and the curved ones are completely free at pre-stressing fixture.

5. RESULTS AND DISCUSSION

5.1 Impact Parameters:

The Force-Time and Force-Displacement curves obtained from impact tests are shown in Fig 3 and Fig 4. Each condition has a specific code in this figure which is defined as follows: The type of curvature (Convex and Concave) – The amount of preloading (0 or 4500με) – Impact energy 36J. As per graph in maximum impact energies, the maximum force and maximum displacement in concave laminates are higher and lower, respectively, in comparison with convex curved laminates. This phenomenon shows that generally Concave laminates is stiffer than convex laminates. It is suitable for both materials (Glass and Hybrid). Because of the membrane stress induced on curved composite laminates during impact: At free end fixing the in-plane boundary condition amplifies the compressive membrane stresses developed in the initial loading of the convex composite shells, but it is totally opposite regarding concave laminates in which boundary conditions cause tensile stress.

It is also shown that the preloading at 4500με- could increase the maximum impact force and decrease maximum displacement, in Glass fiber laminate as well as hybrid laminates. An interesting phenomenon which can be seen in the graph is that maximum force of the non-preloaded concave laminates is lower than preloaded convex ones in glass fiber laminate, but in hybrid composite panel that is maximum forces only at pre-loaded concave and pre-loaded convex specimens. And the behavior of force-displacement curve, the maximum deformation of convex panel higher than concave panel. But in hybrid panel the maximum displacement of pre-loaded convex is less, compare with non-pre-loaded concave hybrid composite laminates. Which means their response is completely inverse in comparison the pre-loaded convex is stiffer than non-pre-loaded concave laminates.

Impact parameters, such as maximum force, maximum displacement, time-duration of impact, and damaged area, are shown in Fig. 6. The effect of curved type composite panel and preloading on maximum force and maximum displacement were considered in the last passage. by applying preload on concave and convex laminates were conducting tests under 36J, maximum force increased 11.03% and 18.35% for glass laminates, for hybrid laminates 24.04% and 22.6% of force increased by applying pre-load on concave and convex, that is almost nearby similar in hybrid panels. This fact is not suitable for all impact parameters. Then it is also proved that changing the curvature type from convex to concave panel and applying preload lead to decrease the time duration of impact.

IJRAME

INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING
WWW.IJRAME.COM
ISSN (ONLINE): 2321-3051

Vol.6 Issue.2,
February 2018
Pg: -01-10

Glass specimens **Hybrid specimens**

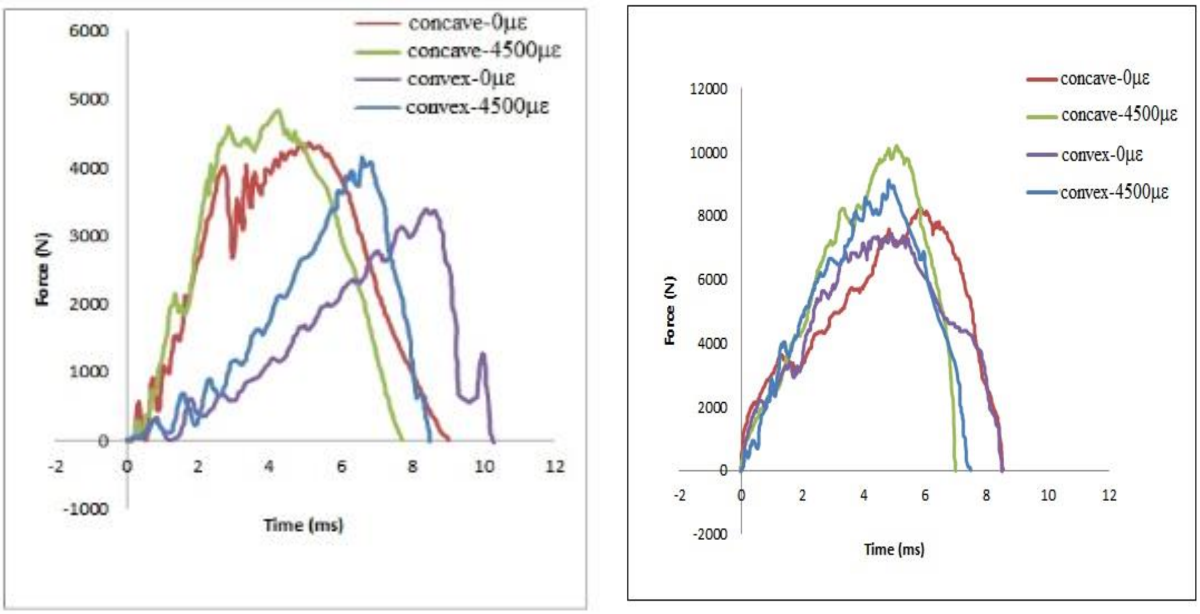


Fig.3- Force Vs Time History

Glass specimens **Hybrid specimens**

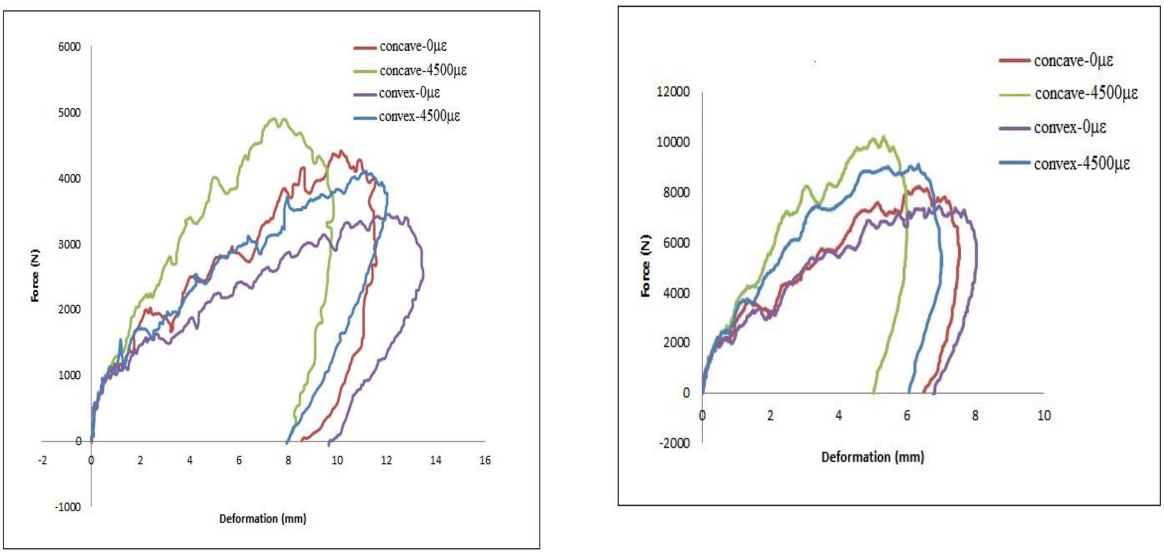


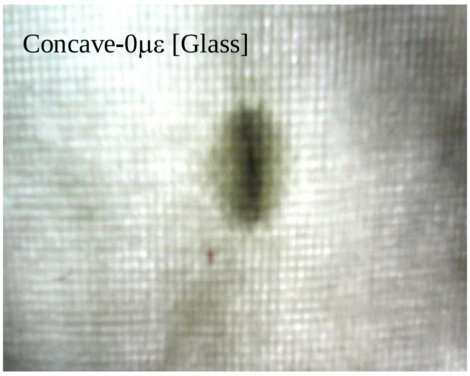
Fig.4- Force Vs Impactor displacement

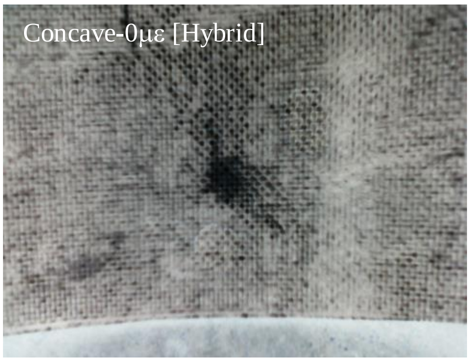
INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING
WWW.IJRAME.COM
ISSN (ONLINE): 2321-3051

Vol.6 Issue.2,
February 2018
Pg: -01-10

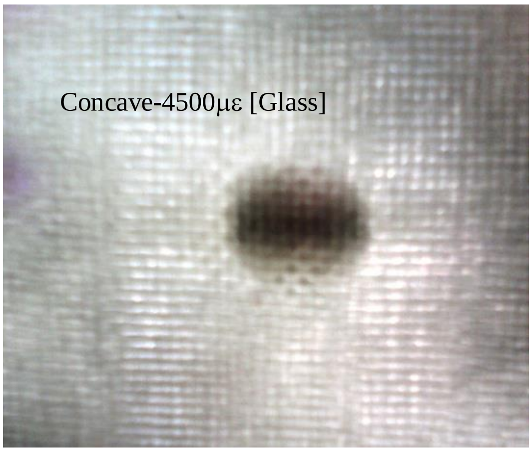
5.2 Damage mechanism:

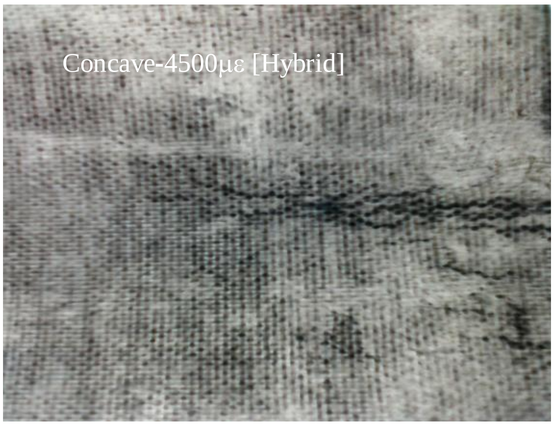
The damaged area in the lowermost surface of the convex and concave curved laminates is shown in Fig. 6. An interesting phenomenon which can be seen in this sector is regarding the difference between the damaged area of concave and convex laminates. While the maximum force is lesser in convex laminates at maximum impact energies, its damaged area is greater in comparison with concave specimens, it suitable for all types of materials. This is related to compression pre-stress acting in panel, during impact loading of convex laminates. So this stress causes laminate buckling is promotes delamination growth. Here seen delamination, matrix crack and reinforcement failure is dominant in this test. To analysis Difference between the failures of convex and concave laminates: in glass convex specimens, when preloading was applied on that specimen the matrix cracks are lower than in without preloading specimens. Due to the compression stress applied by preloading in system. However in hybrid specimen the response of impact is completely inverse, that is the failure of non-preloaded specimen compare with preloaded panel is less in impact. In concave laminates the density of cracks is almost nearby similar for preloaded and non-preloaded laminates as shown in Fig. For hybrid specimen the failure is deferent.

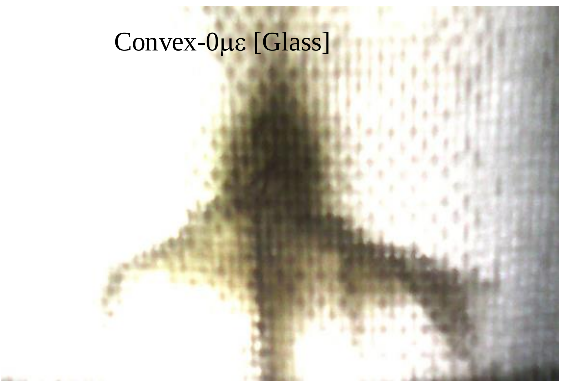


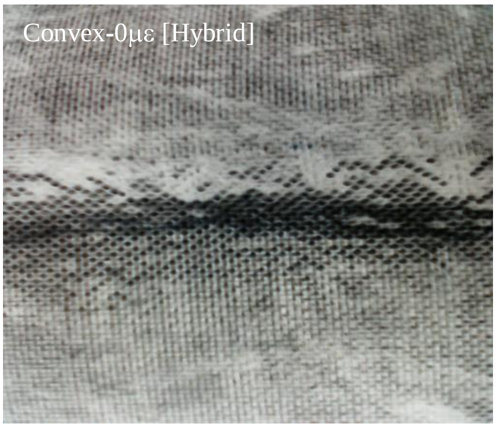


IJRAME
INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING
WWW.IJRAME.COM
ISSN (ONLINE): 2321-3051
Vol.6 Issue.2, February 2018
Pg: -01-10





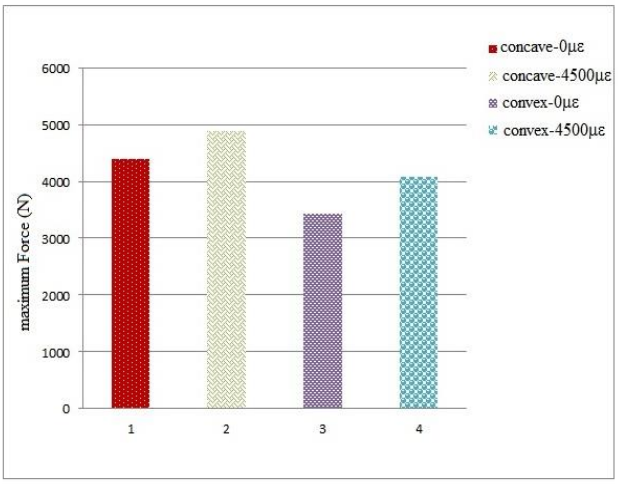


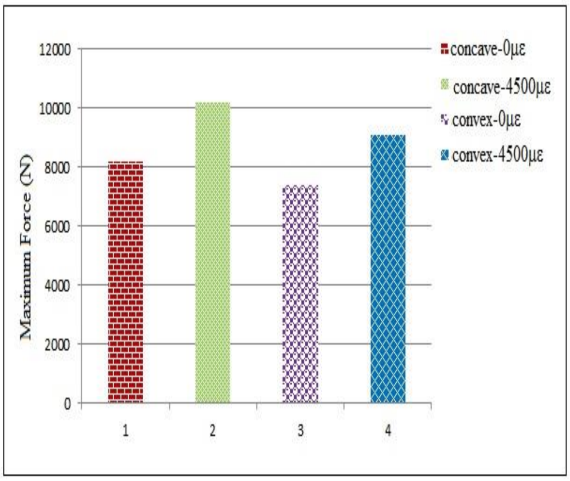


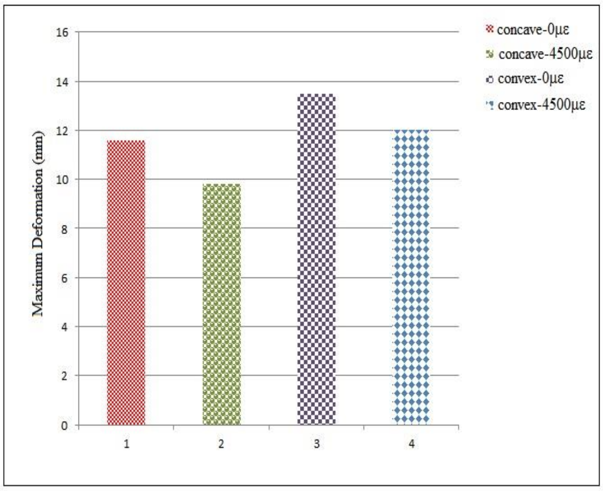
IJRAME

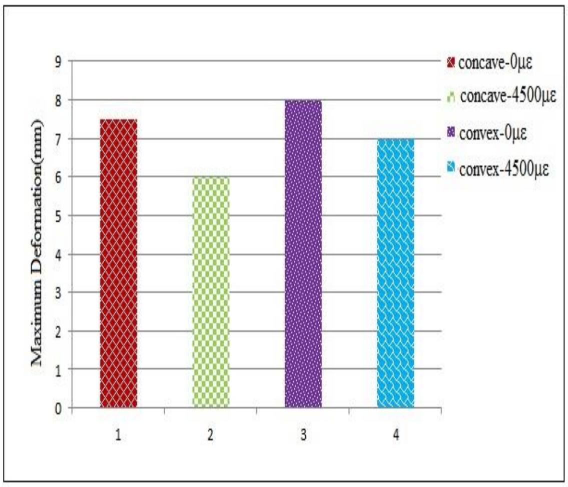
INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING
WWW.IJRAME.COM
ISSN (ONLINE): 2321-3051

Vol.6 Issue.2,
February 2018
Pg: -01-10









6. CONCLUSIONS

From this current project, low velocity impact tests were conducted on non-preloaded/preloaded concave and convex laminates to consider the effect of specimen shape (curvature type) and pre-stress on impact parameters. The following data results can be concluded as:

- From this experiment project could be justified the concave laminates are stiffer than convex laminates, due to membranes effect in curved specimens. Thus the maximum load is higher, and then the maximum displacement and time duration of impact are lower in concave laminates.
- In other hand Hybrid panel preloaded convex panel is stiffer than non-preloaded concave panel.
- The effect of preloading of curvature specimen on damaged area of concave laminates is much lower than on the convex specimen. It is suitable to both materials.
- In concave specimens the amount of matrix cracks in preloaded and non-preloaded laminates is almost the same in glass fiber, but in hybrid little bit varying.
- Compare between glass convex panel and hybrid convex panel, more stiffness and less damage area in hybrid ones.
- Hybrid pre-loaded convex specimens is stiff than non-preloaded concave specimen.

REFERENCES

[1] R. Karakuzu, E. Erbil, M. Aktas. Impact characterization of glass/epoxy composite plates: an experimental and numerical study. *Composites Part B,* 41(5):388-395, 2010.
[2] N.K. Naik and S. Meduri. Polymer–matrix composites subjected to low velocity impact: effect of laminate configuration. *Composite Science and Technology,* 61(10):1429-1436, 2001.
[3] L.S. Kistler and A.M. Waas. Experiment and analysis on the response of curved laminated composite panels subjected to low velocity impact. *International Journal of Impact Engineering,* 21(9):711-736, 1998.
[4] Z. Leylek, M.L. Scott, S. Georgiadis, R.S. Thomson. Computer modelling of impact on curved fibre composite panels. *Composite*
Structures, 47(1-4):789-796, 1999.
[5] G. Minak, S. Abrate S, D. Ghelli ,R. Panciroli,A. Zucchelli Low-velocity impact oncarbon/epoxy tubes subjected to torque – Experimental results, analytical models and FEM analysis. *Compos Composite Structures,* 92(3):623–32, 2010.
[6] G. Minak, S. Abrate S, D. Ghelli ,R. Panciroli,A. Zucchelli A. Residual torsional strength after impact of CFRP tubes. *Composites Part B*
41(8):637–45, 2010.
[7] H. Saghafi, G. Minak, A. Zucchelli. Effect of preload on the impact response of curved composite panels.
Composites: Part B, 60:74–81, 2014.
[8] Butcher BR. The impact resistance of unidirectional CFRP under tensile stress.
Fibre Sci Technol 1979;12:295–326.
[9] Mines RAW, Li QM, Birch RS. Static behaviour of transversely loaded CFRP laminate panels subject to in-plane tension. Strain 2000;36(2):71–80.
[10] Whittingham B, Marshall IH, Mitrevski T, Jones R. The response of composite structures with pre-stress subject to low velocity impact damage. Compos Struct 2004;66(1–4):685–98.
[11] Chiu ST, Liou YY, Chang YC, Ong CI. Low velocity impact behavior of prestressed composite laminates. *Mater Chem Phys* 1997;47(2–3):268–72.

[12] Zhang Z, Davies GAO, Hitchings D.
Impact damage with compressive preload and post-impact compression of carbon composite plates. *Int J Impact Eng* 1999;22(5):485–509.
[13] Herszberg I, Weller T. The impact damage resistance of stitched and unstitched postbuckled carbon/epoxy laminates. In: *Proc. 5th Japan International SAMPE Symposium 1997*, Japan. p. 703–8.