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A NUMERICAL STUDY ON IMPROVING THE IMPACT RESISTANCE OF CFRP LAMINATES USING METAL CONSTITUENTS

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ABSTRACT

This paper deals with embedding metal layers(Aluminum) in the composite material, Carbon fiber reinforced polymer(CFRP) to form a new type of material called Carbon reinforced aluminum laminate(CARALL) which is basically a fiber metal laminate(FML), in order to improve the impact resistance of the CFRP laminates.
In this paper, impact resistance of CARALL laminates with 5/12(Al/0°/60°/-60°/Al/-60°/60°/0°/Al/0°/-60°/60°/Al/60°/-60°/0°/Al) configuration with thickness of aluminum and CFRP as 0.18mm and 0.15mm are studied and compared with that of CFRP laminates of thickness 3mm.
Numerical analysis has been performed on ANSYS LS-DYNA explicit to simulate the impact performance of CARALL. Low velocity impact has been carried out by impacting a mass of 25g at an impact velocity of 10m/s onto a 50x50 mm CARALL specimen. The deflection-time plot, velocity-time plot of above mentioned layup has been obtained and compared.
By studying the results, it is shown that CARALL exhibits superior impact resistance than CFRP, which implies that impact resistance of CFRP layer is improved by embedding metal layers in between them.

KEYWORDS: Fiber metal laminates; Carbon reinforced aluminum laminate; Carbon fiber reinforced polymer; Impact resistance.

1. INTRODUCTION

Composite materials have become a trend in most of the industries like aerospace, automobile and aviation, due to its superior properties like high strength to weight ratio, higher fatigue resistance, higher fracture toughness and improved corrosion resistance, but these materials exhibit poor performance under impact loading. The poor impact resistance and residual strength after impact are the major drawback of composite structures.to overcome these limitations, a combination of metal alloys and composites has been developed which is termed as Fiber-metal laminates (FML) [1]. FMLs are of different types namely Aramid reinforced fiber aluminum laminate (ARALL), Glass fiber reinforced aluminum laminate (GLARE) and Carbon Fiber reinforced aluminum laminate (CARALL).

Research studies show that FMLs have excellent impact resistance of metals and other superior properties of fiber reinforced composites [2, 3]. Low velocity and high velocity impact responses are also studied on GLARE and ARALL [4, 5]. [6] Investigated the impact behavior of a polypropylene based glass fiber reinforced fiber metal laminates from which it is concluded that energy is absorbed by FMLs through plastic deformation in aluminum and micro cracking in composites. Carbon fibers, as compared to aramid and glass fibers offers more crack bridging to aluminum layers due to higher stiffness of carbon fibers. Bieniaset al. [7] studied the low velocity impact resistance of aluminum alloys and a carbon/epoxy composite laminates. They concluded that the ply orientation in unidirectional carbon/ epoxy and aluminum laminates has major influence on the impact resistance. [8] Showed that, on improving the properties of aluminum alloy, impact resistance of CARALL increases. Only few researchers have simulated finite element analysis of CARALL in the past few years, therefore this paper focuses on developing a 3dimensional model of CARALL with different stacking sequence

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and performing low velocity impact. Carbon fiber reinforced polymer is also analyzed and the improvement in the impact resistance for that of CARALL is studied.

2. MATERIALS AND METHODS

Finite Element Analysis of CARALL

General model properties
ANSYS LS-DYNA explicit is used to simulate the model. The general model consists of Spherical ball, which represents the projectile, and a specimen. The spherical ball is modeled as a rigid body with a mass of 25g and 5 mm radius, whereas the CARALL specimen is modeled using element type Solid 164 with dimension 50x50 mm. the specimen consists of aluminum (Al 5052) and CFRP with varying thickness and stacking sequence.

Table 1. Configuration Of CARALL

Nomenclature	Stacking sequence	Thickness of Aluminum	Thickness of CFRP
CARALL, 5/12	Al/0°/60°/-60°/Al/-60°/60°/0°/Al/0°/-60°/60°/Al/60°/-60°/0°/Al	0.18 mm	0.15 mm

Both Aluminum and CFRP laminates are created using Solid 164 element type. Solid 164 is used for 3-D modeling of solid structures and is defined by 8 nodes having the following degrees of freedom at each node: translations, velocities and accelerations in the nodal x, y and z directions.

The spherical ball is constrained in all direction except translation along Z-direction which is the out of plane direction of specimen. The ball is given an initial velocity of 10 m/s in Z-direction to impact the specimen. Fully clamped boundary conditionalong the edges of the specimen constrains all the degrees of freedom.

The interaction between the spherical ball and the specimen is defined by automatic surface to surface contact. The nodes in contact with aluminum and CFRP are merged

Material model of Aluminum and CFRP
Bilinear kinematic hardening property is applied to aluminum 5052 which takes into account the material non-linearity.

Table 2.Material properties of Al 5025

Material	Density	Young's modulus	Poisons ratio	Yield stress	Tangent modulus
Al 5025	2700 kg/m^3	70 GPa	0.3	300 Mpa	140 MPa

Linear orthotropic property is applied to Carbon fiber reinforced polymer

Table 3. Material properties of CFRP

Material	E1	E2	E3	G1	G2	G3	μ_{12}	μ_{23}	μ_{13}
CFRP	125 GPa	6 GPa	6 GPa	4 GPa	4 GPa	4 GPa	0.32	0.3	0.32

Finite Element Analysis of CFRP
The general model consists of Spherical ball, which represents the projectile, and a specimen. The spherical ball is modeled as a rigid body with a mass of 25g and 5 mm radius, and the CFRP specimen is modeled by as a 50x50 mm square plate with thickness of 0.3 mm. Properties of CFRP are taken as mentioned in the previous problem.

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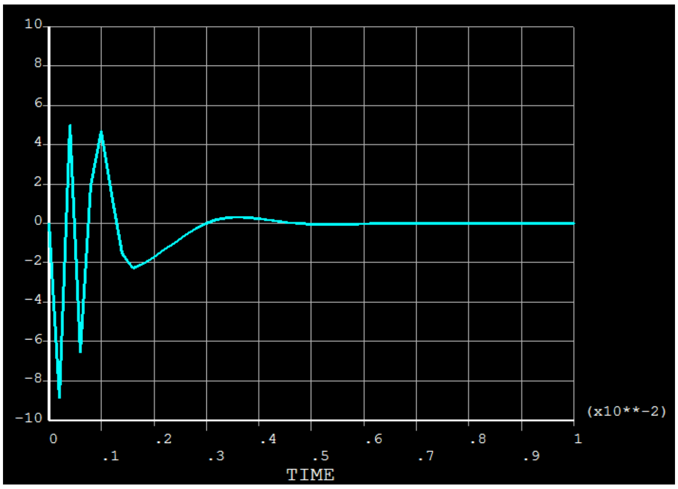
Finite Element Analysis of Aluminum specimen for validation

The general model consists of a cube, which represents the projectile, and a specimen. The cube is modeled as a rigid body with side 10 mm, and the Aluminum specimen is modeled by as a 100x100 mm square plate with thickness of 0.5 mm. Properties of Aluminum are same as that of previous problem.

3. RESULTS AND DISCUSSION

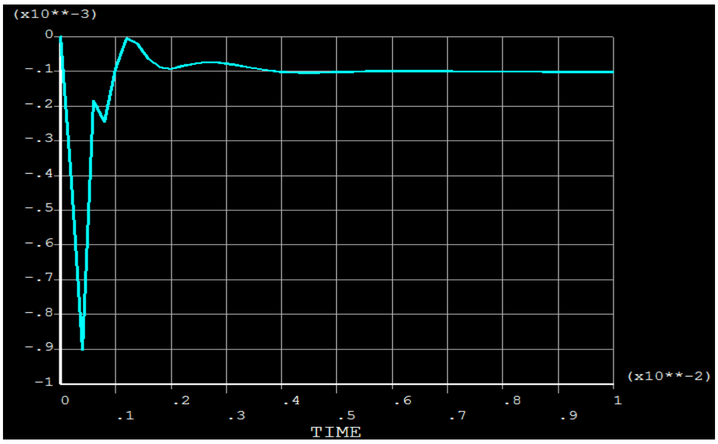
The velocity-time plot at the impact zone of specimen CARALL shows that the plate vibrates till 0.004 seconds and later it comes to rest. The maximum velocity attained by the plate is at 0.0004 seconds which is 9 m/s and this will be the time at which maximum deflection occurs.



Velocity- time plot at the impact zone of the specimen CARALL

Now we can take the stress contour plot, strain contour plot at the time at which deflection will be maximum, that is at 0.0004 seconds and the stress and strain at this time will be the maximum.

From the deflection-time plot, the maximum deflection was about 0.9 mm which reduces as time passes and finally permanent deformation occurs at 0.004 seconds and is about 0.1 mm.
Therefore it shows that the specimen deforms plastically about 0.1 mm.



Deflection-time plot at the impact zone for the specimen CARALL

The velocity-time plot at the impact zone of specimen CFRP shows that the plate vibrates periodically at 0.0025 seconds and amplitude of velocity as 8 m/s. The maximum velocity attained by the plate is at 0.0004 seconds which is 9.86 m/s and this will be the time at which maximum deflection occurs.

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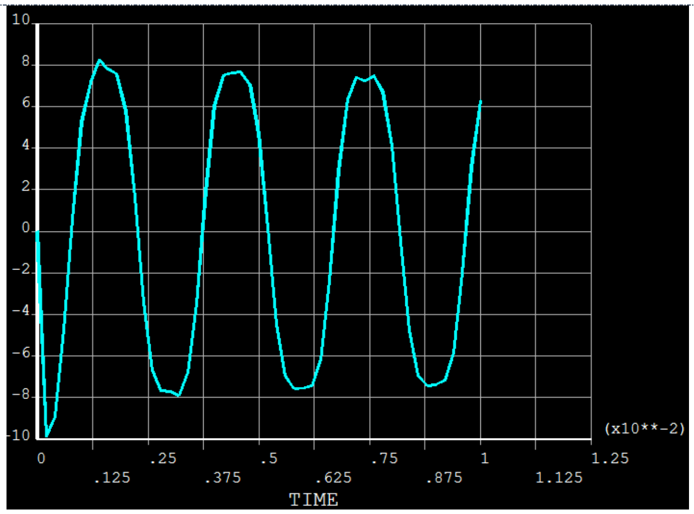
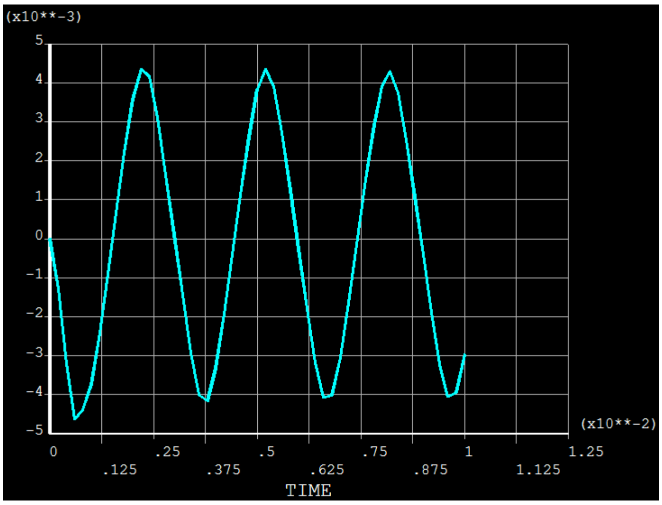


Velocity-time plot at the impact zone for the specimen CFRP

From the deflection-time plot of CFRP, it is seen that there is an elastic deflection with magnitude 4.5 mm and it repeats for every 0.0025 seconds and finally permanent deformation occurs at 0.01 seconds and is about 3 mm. Therefore it shows that the specimen deforms permanently at about 3 mm.



Deflection-time plot at the impact zone for the specimen CFRP

Table 4. Comparison of deflections for CARALL and CFRP

	CARALL	CFRP
Permanent Deflection (mm)	0.1	3
Maximum deflection (mm)	0.9	4.5

4. CONCLUSION

The impact behavior of CFRP and CARALL were investigated by numerical studies.it is seen that, the permanent deflection in CARALL is much lesser than in CFRP. With the addition of metal layers, the metals absorb part of the impact by yielding, whereas in CFRP, it shows elastic behavior and then shows a much larger deformation than CARALL. Energy absorbing capability is improved by embedding metal layers, thus the CARALL exhibits superior impact resistance than CFRP.

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REFERENCES

[1] T. Sinmazçelik, E. Avcu, M. Ö. Bora, and O. Çoban, "A review: Fibre metal laminates, background, bonding types and applied test methods," Materials & Design, vol. 32, no. 7, pp. 3671–3685, 2011.
[2] Cantwell W (2000) The mechanical properties of ?bre-metal laminates based on glass ?bre reinforced polypropylene. Compos SciTechnol 60(7):1085–1094
[3] Vogelesang LB, Vlot A (2000) Development of ?bre metal laminates for advanced aerospace structures. J Mater Process Technol 103(1):1–5. doi:10.1016/S0924-0136(00)00411-8
[4] Abdullah MR, Cantwell WJ (2006) The impact resistance of polypropylene-based ?bre–metal laminates. Compos SciTechnol 66(11–12):1682–1693. doi:10.1016/j.compscitech.2005.11.008
[5] Caprino G, Spataro G, Del Luongo S (2004) Low-velocity impact behavior of ?breglass–aluminium laminates. Compos AApplSciManuf 35(5):605–616. doi:10.1016/j.compositesa.2003.11. 003
[6] Bienias ´ J, Jakubczak P (2012) Low velocity impact resistance of aluminium/carbon-epoxy ?ber metal laminates. Compos Theory Pract 12(3):193–197.