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Finite elements analysis of drop weight impact loading on GLARE-6A

Nabeel Mohsin *, Rafiullah Khan, Syed Athar Masood

Department of Mechanical Engineering, International Islamic University, Islamabad, Pakistan

* Corresponding Author: Nabeel Mohsin Email: nabeelmohsin786@gmail.com

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KEYWORDS

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ABSTRACT

Fibre Metal Laminate (FML) is a damage-tolerant material being opted in modern aerospace industries. FML impact absorbing properties were studied for determining FML response against impact loading. The author contributed by experimentation of drop weight impacts on FML GLARE 6A samples. In this paper, the author reproduced drop weight impact simulation using Finite Element Analysis (FEA). The author modeled GLARE FML, and a simulation of drop weight impact was performed using the explicit dynamics module of ANSYS. The drop weight impact method in Ansys was used to analyse the impact force effect on GLARE FML. Simulation results depicted drop weight impacts measured impact force, velocity, and energy vs time. Maximum deformation of plots was presented.

1. Introduction

GLARE (Glass Reinforced Aluminium Laminates) is a relatively new aerospace material with improvement in impact damage resistance [1]. These characteristics in the material could be achieved by the physical combining of composite and metal sheets. The combination of composite and metal material could adhere to impact fatigue crack growth and increased stiffness due to thin metal sheets. Glare materials constituents could provide lower density, high strength, lightweight, high bending stiffness, and good flexure and shear damage resistance.

GLARE is often used for airplane parts where impact-prone parts e.g. fuselage. Damage catering impacts by objects is an important design parameter for aerostructures. Impacts cause sudden fractures to a structure. The impact resistance of GLARE is higher due to the fiber bridging of the crack [2]. Fibers intact in the wake of crack provide additional load paths. This characteristic could enhance the damage resistance of FML [3]. In FML minimum metal and composite sheets combination could enable FML for use in different structures. An important parameter for fatigue damage-tolerant metal sheets is the rolling direction of Aluminium metal sheets [4, 5]. Debonding and delamination are important damage mechanisms commonly produced in the composite. NDT scan and RT could be used for structural health monitoring of GLARE. F. Taheri [6] investigated experimentally and numerically for determining the dynamic response of damage initiation in GLARE by using the Hashin damage criterion and VU material modeling in ABAQUS. He concluded that the formation process of GLARE and manufacturing produced defects could be vital parameters to enhance the damage resistance of GLARE. P. Jakubczak [7] proposed their own developed FEM failure criteria and cohesive zone for investigating parameters that influence the performance of CARALL FML and a comparison was done with GLARE FML results. Based on strain energy release rate Gc, elastic moduli, and traction stress cohesive zone length for simulating stable delamination in FML determined at six different energy levels. It was observed with the help of simulations that shear wave generated in lower metal and composite plates interface and this shear force caused delamination and debonding. The membrane effect caused the expansion of delamination in FML from the point of impact.

2. FEA Analysis

2.1 Geometry and Material of Model and Impactor

Fig. 1 shows the flow diagram of FEA Analysis of drop weight impact loading behaviour of GLARE.

In Fig. 2 and 3 geometry was made according ASTM standard D7136. It was 3 solid plate of size 150 mm x 100 mm and 3 sheets of Aluminium sheet had each thickness 0.5mm and intermediate layer of (GF/Epoxy) on each side of middle Aluminium sheet. Total thickness of laminate is 1.92mm. The layup scheme was shown in Table 1.

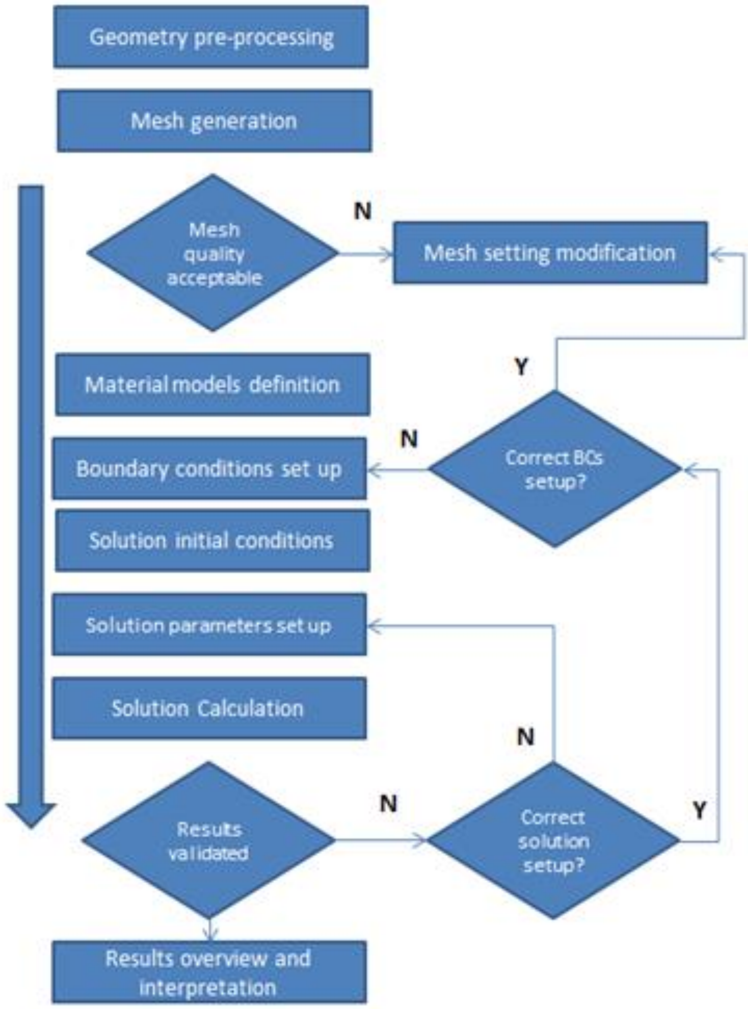


Fig. 1. Flow diagram for FEA Simulation of Impact

Table 1

Layup scheme of GLARE 6A in FEA model

Name of specimen	Lay up	Total thickness (mm)
Single impact(SP1) Single impact(SP2) Single impact(SP3)	AL(0.5)/[0/90]TWG/0.5AL/[0/90]TWG/0.5AL	1.92

A FEA model was developed in ANSYS v19.0 Design modeller. A hybrid model for performing Explicit Dynamics were produced by combining metal in mechanical module and composite part in ACP Pre. Solid model of composite were modelled in ACP Pre. FEA model of FML were meshed Ansys mechanical meshing. Composite ply for simulation in GLARE 6A was had layup [Al/0/90/Al/0/90/Al]. Impactor modelled in Ansys was dropped from height of 1 m to achieve impact velocity 4.4287 m/sec. Impactor diameter and mass were 16mm. Impactor mass was adjusted to vary potential energy of dropping impactor from height. The height and velocity was kept constant for simulation. Specimen was modelled using design modeller and ACP modules of ANSYS. Taking advantage of symmetry 1/4th model was used.

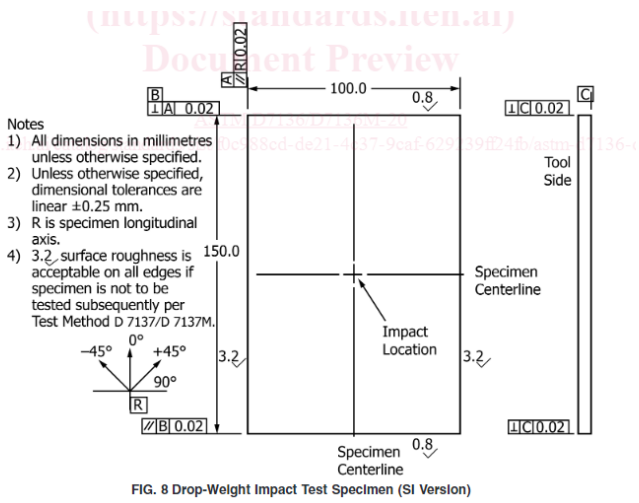


Fig. 2. Specimen Description for Impact Simulation

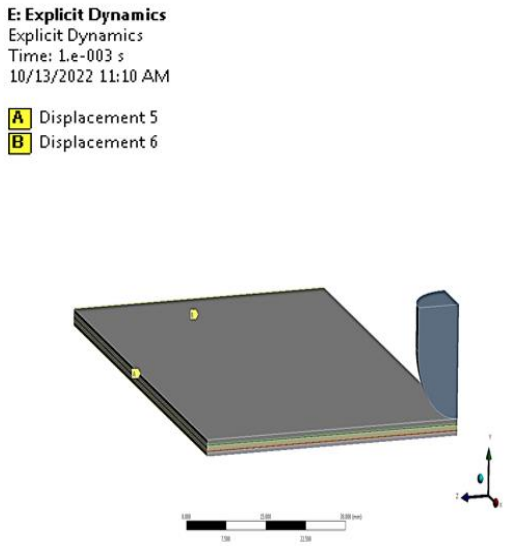


Fig. 3. FEA Model for Impact Simulation in ANSYS

Table 1

Metal elastic material properties for simulation

Material	AA 2024-T3
Young's Modulus (GPa)	73.8
Poisson's ratio ν	0.33
Yield Strength (MPa)	290MPa

FML type, has a lay plan of (0.5AL, 0/90/±45 GW,0.5-AL,0/90/±45 GW, and 0.5-AL). Elastic properties of Glass Epoxy was described below.

Table 2

Glass epoxy orthotropic properties used in simulation

Materials	Parameters value GPa					
Glass Epoxy	E11 55	E22 9.5	G12 5.5	G23 3	ν12 0.33	ν23 0.33

2.2 Meshing

3D model of FML was meshed with Solid 185 elements as shown in Fig. 4. Solid 185 is eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, hyper elasticity, stress stiffening, creep, large deflection, and large strain capabilities. Impactor had elements 2161 and number of nodes was 2200 and material was selected was default Steel. Element size was kept 0.67. FML plate was also meshed with Solid 185 because for modelling plastic deformation in impactor and number of elements 2106 and no of nodes were 3500. Plate material in GLARE 6A was selected as Aluminium for metal sheets and Glass Epoxy for composite sheets sandwiched between metal sheets. Elements size was kept 3mm and 2 layers of elements along thickness of plate.

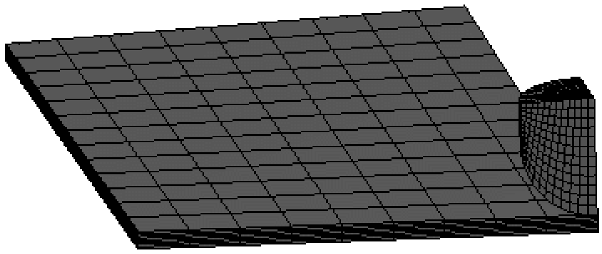


Fig. 4. 3D Meshed Model of GLARE 6A with Impactor

2.3 Boundary Conditions and Loading

Constraints applied by constraining x and y direction upper edges of laminate plate and lower edges in all directions and symmetry BC was applied on right and bottom faces of plate and impactor. As shown in Fig. 3. Loading cases used in simulation were depicted in table 4.

Table 4

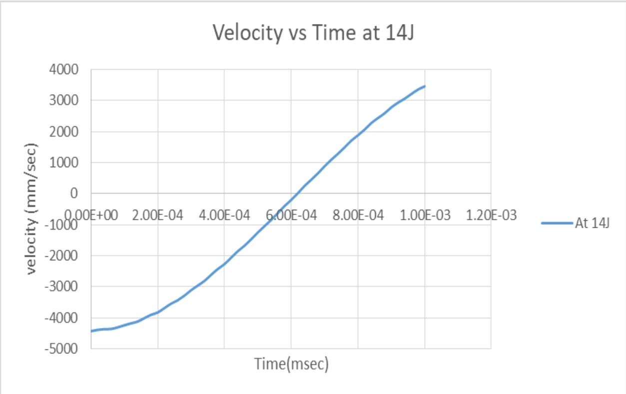
03 x impact loading cases of FEA simulation

Impactor energy(J)	Mass of impactor (kg)	Impactor Height(m)	Impactor velocity(m/sec)
14	1.43	1	4.4287
19	1.95	1	4.4287
24	2.45	1	4.4287

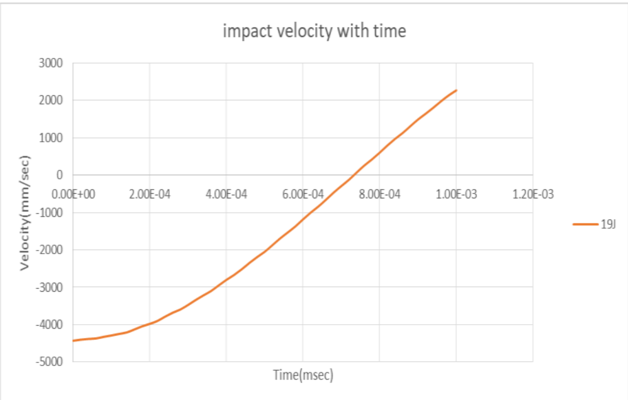
Body interactions were penalty based using proximity based algorithm in ANSYS explicit Dynamics. Initial velocity and impact velocity was adjusted for specific energy levels using height parameter. It was assumed that impactor was dropped from prescribed height and transferred predefined potential energy to plate. Default contact was used between laminates Aluminium sheets and Glass Epoxy.

2.4 Results and Discussion

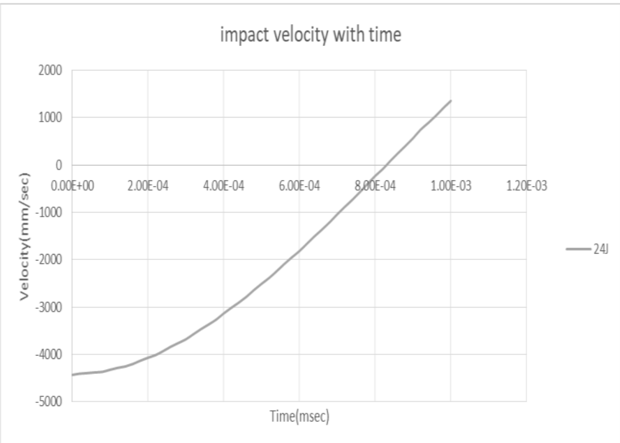
In this section stresses and deformation produced in the GLARE plate are presented. The velocity vs time and force vs time graphs are shown for each case. Impact force simulations results clarified that impact force decay was rapid and calculated by hertz was found close to simulation results. Reaction force results in fig 6 (a), (b) and (c) had sinusoidal behaviour about mean position. It showed that energy absorbed in simulation completely by boundary. Introduction of damage model can produce more realistic simulation. Energy pattern depicted in fig 7 (a), (b) and (c) that impactor stopped and rebounded due to flexural deformation of FML.



(a)

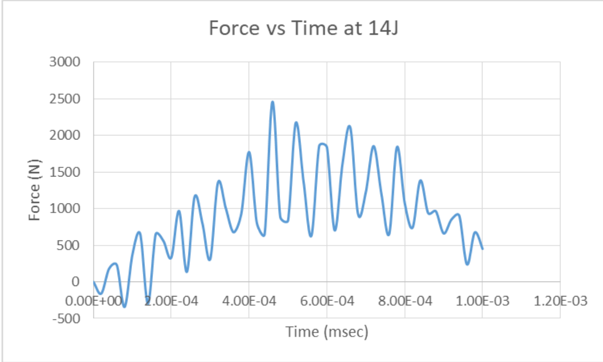


(b)

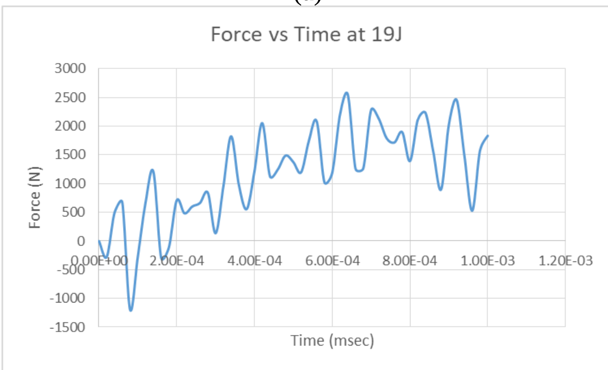


(c)

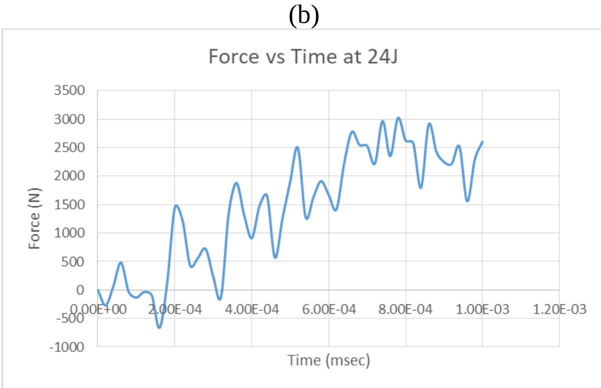
Fig. 5. Reaction Forces Recorded on Boundary Condition in Drop Testing FEA Simulation



(a)

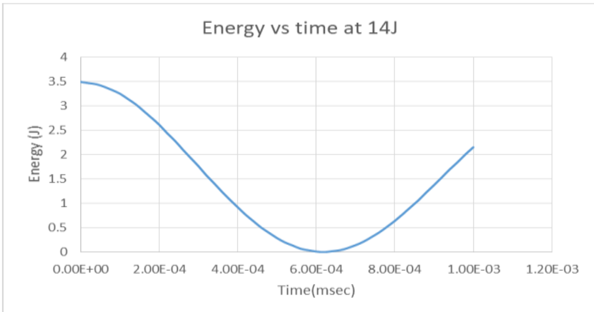


(b)

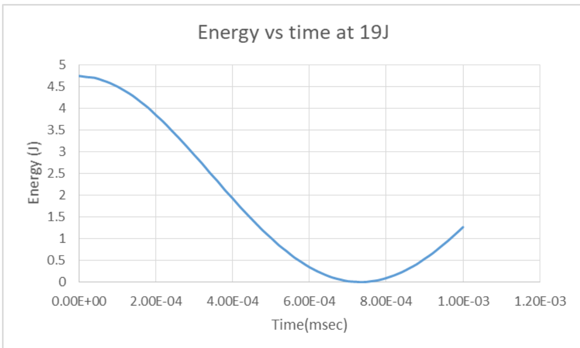


(c)

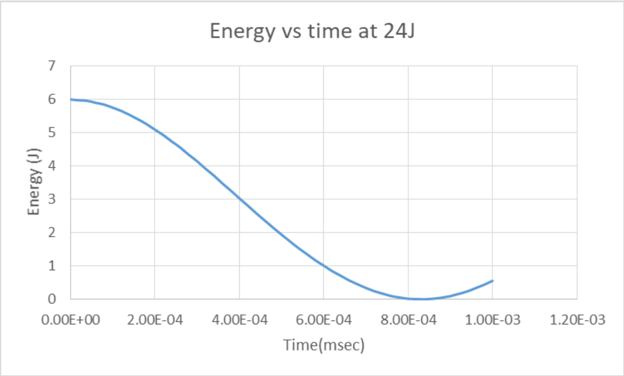
Fig. 6. Impact force Vs Time in drop testing FEA simulation



(a)



(b)



(c)

Fig. 7. Kinetic Energy Variation with Time in Impact Simulation

The following figures show the maximum deformation of plate during impact at different 14J, 19J and 24J. It is mentioned to that plate has maximum deflection at centre of plate.

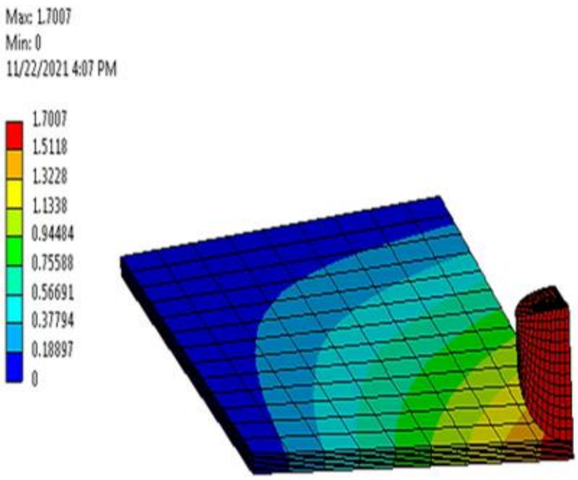


Fig. 8. Total Deformation in GALRE FML at 14J

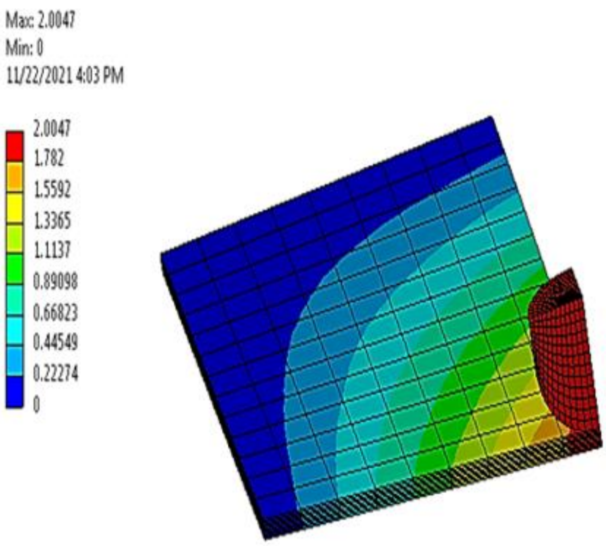


Fig. 9. Total Deformation in GLARE at 19J

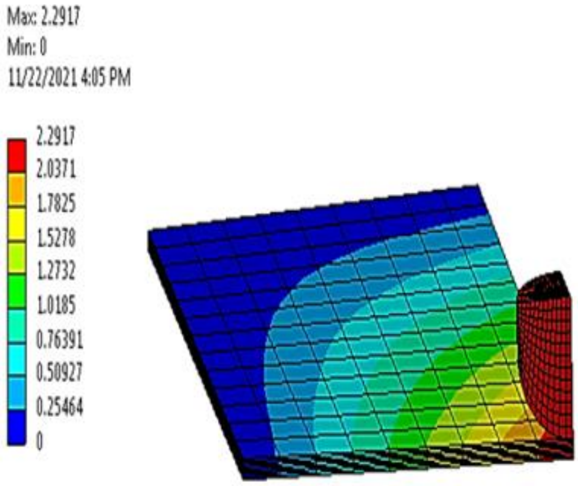


Fig. 10. Total Deformation in GLARE at 24J

3. Conclusion

In this paper, ANSYS explicit dynamics simulation was performed at three energy levels and impact results were analyzed to assess the impact-prone response of GLARE. It was clear that impact force was absorbed by GLARE. The energy and force decay plot showed an absorption pattern of impact force and it became zero after transferring all energy to the plate. Impact force decay emphasized the need for a damage model and made simulation more realistic for testing for future work. Model analysis can be used to determine the required metal and composite combination to produce a more damage-tolerant design for FML. Additionally, material and damage modeling using cohesive zone elements can be opted for incorporating damage modes of GLARE such as delamination, debonding, and fiber-matrix cracking. Development of an analytical model that covers all damage patterns in FML should be developed for a complete understanding of damage mechanisms in single and multiple impacts of FML.

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