RESEARCH ARTICLE OPEN ACCESS

DYNAMIC ANALYSIS OF HONEY COMB STRUCTURE

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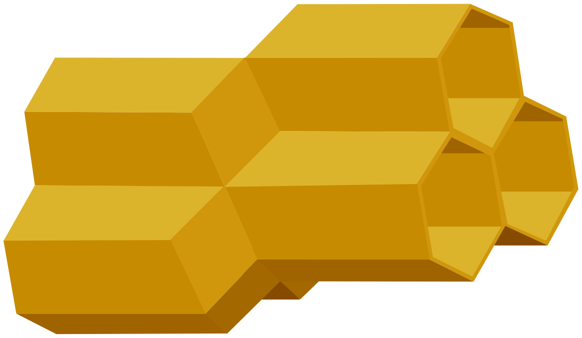
ABSTRACT

A honeycomb structure is a geometric arrangement of hexagonal cells, similar to the pattern found ina beehive. In engineering and materials science, honeycomb structures are typically composed oflightweight materials arranged in a hexagonal grid, creating a rigid and strong structure with minimalmaterial usage. These structures are known for their high strength-to-weight ratio, making themadvantageous in various applications. Materials like aluminum, composites, and even paper can beshaped into honeycomb structures. The design mimics the efficiency seen in natural honeybee hives,wherehexagonalcellsprovide strengthandstability withminimal use ofresources.
Inthis,weareanalysingtheperforationofcompositesandwichstructuresunderhigh-velocityimpact.we are using a three-dimensional finite element model modelled in Creo and implementing in Ansysto simulate sandwich panels with carbon/epoxy skins and an aluminium honeycomb core. We areevaluatingtheimpactofindividualcomponentsonthebehaviourofthesandwichpanelanddetermining the contribution of various failure mechanisms to the absorption of projectile kineticenergy. This project aims to provide insights into the present and future prospects of compositesandwichstructuressubjected to high-velocity impact.

INTRODUCTION

1.1 ABOUTHONEYCOMBSTRUCTURE



Figureno.1.1.1: Honeycombstructure

Honeycomb structures are natural or man-made structures that have the geometry of a honeycomb to allow theminimization of the amount of used material to reach minimal weight and minimal material cost. The geometryofhoneycombstructurescanvarywidelybutthecommonfeatureofallsuchstructuresisanarrayofhollowcellsformed between thin vertical walls. The cells are often columnar and hexagonal in shape. A honeycomb-shapedstructureprovidesamaterialwithminimaldensityandrelativehighout-of-planecompressionpropertiesandout-of-planeshearproperties.

Man-made honeycomb structural materials are commonly made by layering a honeycomb materialbetween two thin layers that provide strength in tension. This forms a plate-like assembly. Honeycomb materialsarewidelyusedwhereflatorslightlycurvedsurfacesareneededandtheirhighspecificstrengthisvaluable.They are widely used in the aerospace industry for this reason, and honeycomb materials in aluminum, fiberglass andadvancedcompositematerialshavebeenfeaturedinaircraft androcketssincethe1950s.Theycanalsobefoundin many other fields, from packaging materials in the form of paper-based honeycomb cardboard, to sportinggoodslike skis and snowboards.

LITERATUREREVIEW

1. **Akhil Garg:** An experimental study was conducted to investigate the impact of design parameters (wallthickness and cell size) on the mechanical properties, specifically yield strength and modulus of elasticity(stiffness),ofhoneycombcellularstructuresproducedthroughfuseddepositionmodelling(FDM).Additionally,threecomputationalintelligence(CI)basednumericalmodellingmethods—geneticprogramming (GP), automated neural network search (ANS), and response surface regression (RSR)—wereemployed. The performance of these models in predicting the mechanical properties was compared, withstatisticalanalysisrevealingthattheANSmodelexhibitedthehighestperformance,followedbyGPandRSRmodels. The validity of the experimental findings was confirmed through 2D and 3D surface analysesconductedon modelsformulated usingANS.

2. **Enrique Barbero:** This study focused on analysing the perforation of composite sandwich structures whensubjected to high-velocity impact. The sandwich panels under investigation featured carbon/epoxy skins andan aluminium honeycomb core. The analysis was carried out using a three-dimensional finite element modelimplemented in ABAQUS/Explicit. The model's accuracy was verified through experimental tests, wherenumericalresultswerecomparedwithexperimentaldataforresidualvelocity,ballisticlimit,andcontacttime.

   The primary objective of the model was to assess the impact of individual components on the behaviour of thesandwich panel when exposed to impact loads. Furthermore, the study aimed to determine the contribution ofvarious failure mechanisms to the energy absorption of the projectile's kinetic energy within the sandwichstructure.

3. **B.CASTANIE:**Intheaeronauticalfield,sandwichstructures,commonlyusedforsecondarycomponentslikeflaps or landing gear doors, face a significant challenge in modelling low-velocity/low-energy impacts, whichcan reduce structural strength by up to 50%. As these impacts have a similar effect to quasi-static indentation,thestudyprimarilyfocuseson understandingthebehaviourofhoneycombcores undercompression.

   To unravel the crushing mechanism, various honeycomb test specimens made of materials such as Nomex,aluminium alloy, and paper were examined. Observations during crushing, captured by a CCD camera,revealed rapid buckling of the cell walls. The peak load recorded during tests corresponded to the buckling ofthecommonedgeofthreehoneycombcells.Additionaltestsoncornerstructures,simulatingonlyoneverticaledgeof ahoneycombcell,exhibitedasimilarbehaviour,withdifferencesattributedtomaterial 3properties.Based on this phenomenological study, it was hypothesized that the vertical edge primarily bears the loadsduring compression of a honeycomb core. Consequently, a simple analytical model using a grid of nonlinearsprings was developed and validated through tests on Nomex™ honeycomb core indented by sphericalindenters of different sizes. The analytical model demonstrated good correlation with experimental results,providingabasisforeffectivelymodellingtheindentationonasandwichstructurewithametallicorcompositeskinand honeycombcore usingfinite elementanalysis.

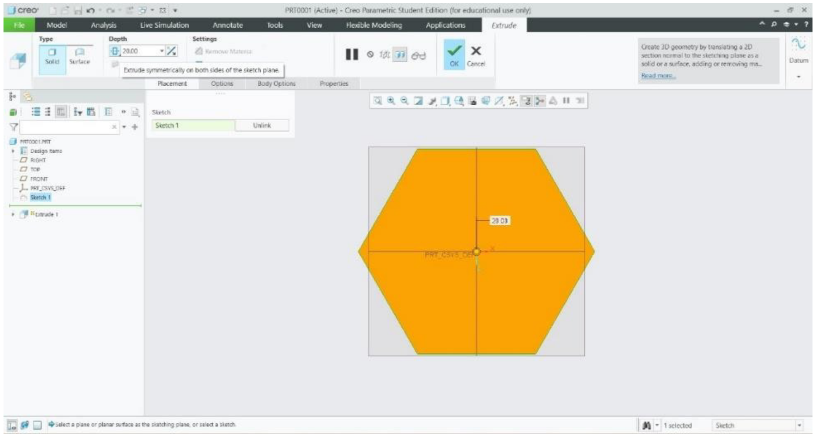
4. **Boudjemai:** This paper explores honeycomb panels used in the structural design of satellites, focusing onclamped-free boundary conditions. The study involves creating and analysing detailed finite element modelsfor honeycomb panels. Experimental tests were conducted on a honeycomb specimen to compare modalanalysisresultsobtained throughfiniteelementmethods andexistingequivalentapproaches.

   Theresultsindicateastrongagreementbetweenfiniteelementanalysis,equivalentapproaches,andexperimentaltests.Thedifferencesinthefirsttwofrequenciesarelessthan4%,andlessthan10%forthethirdfrequency. The equivalent model used in the analysis provides accurate results. The research also investigatesvariousaspectsofhoneycombplatemodalanalysis,includingtheimpactofstructuralgeometricvariationsandthe influence of dimension parameters on modal frequency. Additionally, the study explores how changes inthe core and skin materials of the honeycomb affect modal frequency. The results suggest that geometryparameters and material types indeed affect the honeycomb plate's modal frequency, providing promisinginsights.

METHODOLOGY

CREOPARAMETRIC

Step-11: GiveDepthas20mminSymmetric.



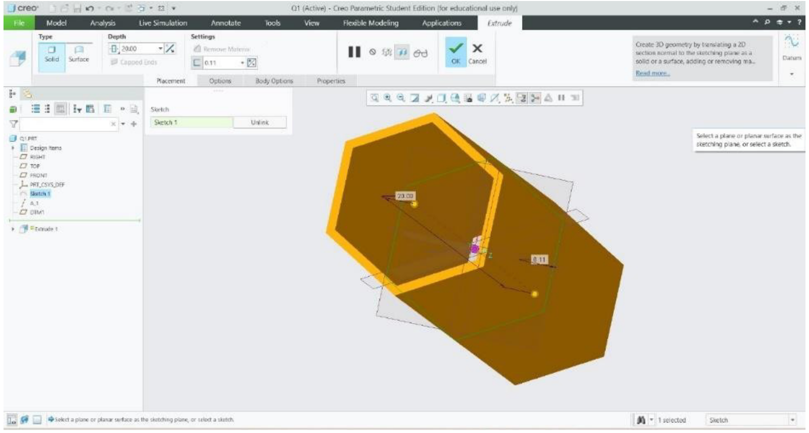
Extrude symmetrically on both sides of the sketch plane.

Create 3D geometry by translating a 2D section normal to the sketching plane as a solid or a surface, adding or removing ma...
Read more...

Select a plane or planar surface as the sketching plane, or select a sketch.

Figureno. 4.1.11: Extrudecommandselection

Step-13: ClickonOK**.**



Create 3D geometry by translating a 2D section normal to the sketching plane as a solid or a surface, adding or removing ma...
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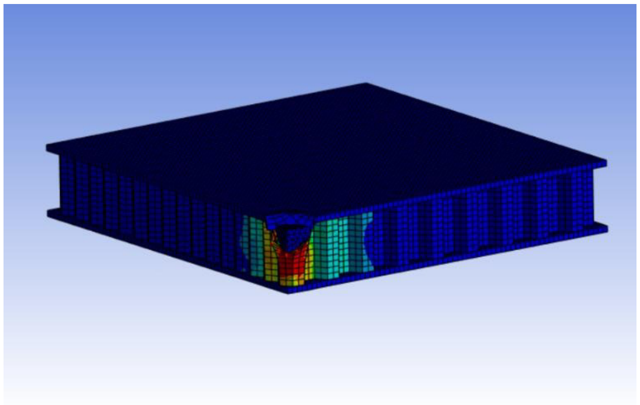
Select a plane or planar surface as the sketching plane, or select a sketch.

Figure no. 4.1.13:clickonok

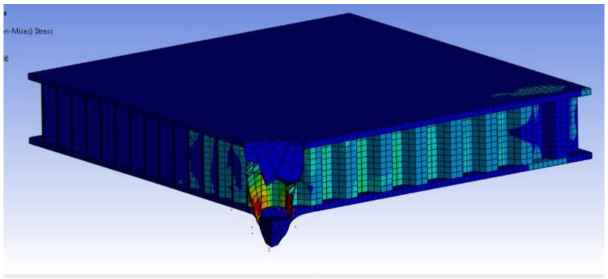
RESULTS

6.1 Evaluationoftimefromfiberfailurecriterion.



Figureno6.1.1:Fiberfailurecriterionattopplate.

- Heightofplate1(h1)=2mm =0.002m
- Velocityof ball @h1 (v1)=362.11
- Time1@h1(t1)=$\frac{h1}{v1}=\frac{0.002}{362.11}$ =5.5*10^{-6} s = 5.5μs



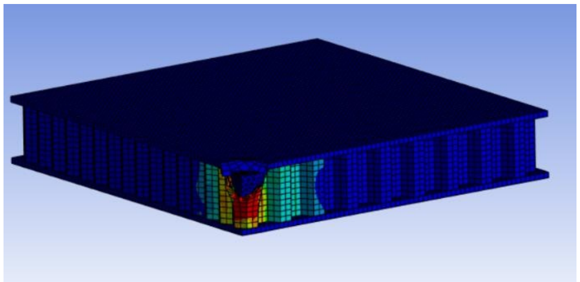
Figureno.6.1.2:Fiberfailurecriterionatbottom plate

- Heightofsandwichstructure(h2)=24mm=0.024m
- Velocityofball@h2(v2)=363
- Time2@h2(t2)=$\frac{h2}{v2}=\frac{0.024}{363}$=6.6*$10^{-5}$s=66.1μs

Tableno6.1.1: Obtainedtimefrom fiberfailurecriterion

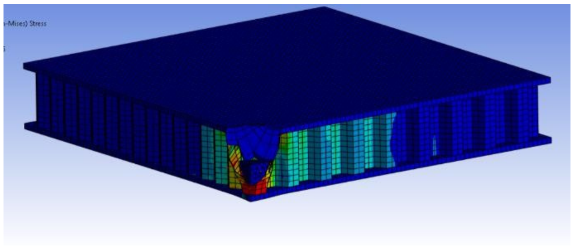
S.no	Time	Obtainedtime
1	T_1	5.5 μs
2	T_2	66.1μs

Evaluatingresultsfromplasticstrainduringthesandwichperforation



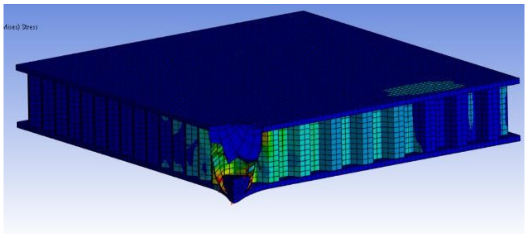
Figureno6.2.1:Plasticstrainat topplate.

- Heightofplate1(h1) =2mm = 0.002m
- Velocityofball@h1(v1)=363.11m/s
- Time1@h1(t1)==$\frac{h1}{v1}$=$\frac{0.002}{363.11}$=5.5*10-6s=5.5µs



Figureno6.2.2: Plasticstrainat honeycombstructure.

- Heightofhoneycombstructure(h2)=24mm =0.024m
- Velocityof ball@h2(v2)= 363m/s
- Time2@h2(t2)==$\frac{h2}{v2}$=$\frac{0.012}{363}$=3.3*10-5s=33µs



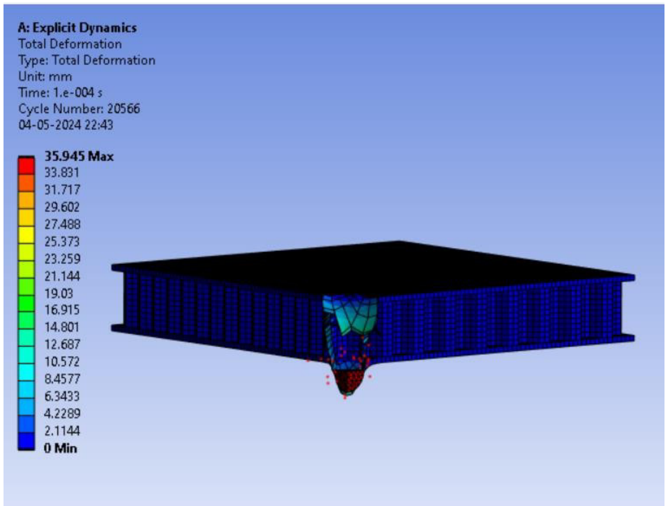
Figureno6.2.3:Plasticstrainatbottomplate.

- Heightoftheplate2(h3) =2mm= 0.002m
- Velocityof ball@h3(v3)= 363m/s
- Time3@h3(t3)==$\frac{h2}{v2}$=$\frac{0.022}{363}$=6.6*10-5s=66µs

Tableno6.2.1:Obtainedtimefrom plasticstraincriterion

S.no	Time	Obtainedtime
1.	T_1	5.5 µs
2.	T_2	33 µs
3.	T_3	66 µs

6.2 Totaldeformation



Figureno.6.3.1:Total deformation

Tableno.6.3.1:Total deformationvalues

S.No	Totaldeformationvalues (mm)	Color band
1	0	
2	2.1144	🟦
3	4.2289	🟦
4	6.3433	🟦
5	8.4577	🟦
6	10.572	🟩
7	12.687	🟩
8	14.801	🟩
9	16.915	🟩
10	19.03	🟩
11	21.144	🟨
12	23.259	🟨
13	25.373	🟨
14	27.488	🟧
15	29.602	🟧
16	31.717	🟧
17	33.831	🟥
18	35.945	🟥

Equivalentstress

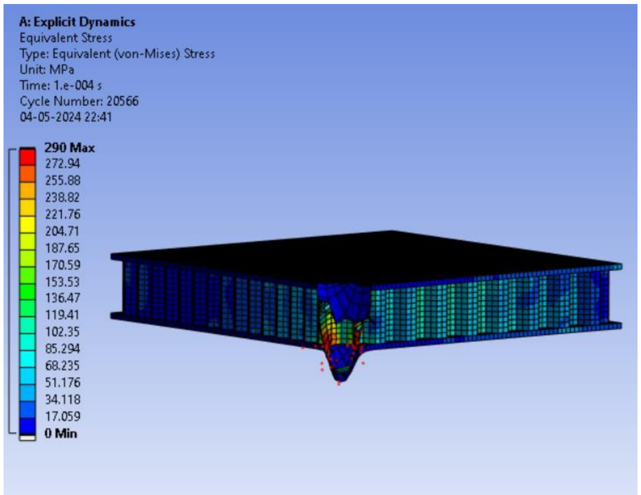


Figure no. 6.4.1: Equivalent stress

6.3 EquivalentElasticstrain

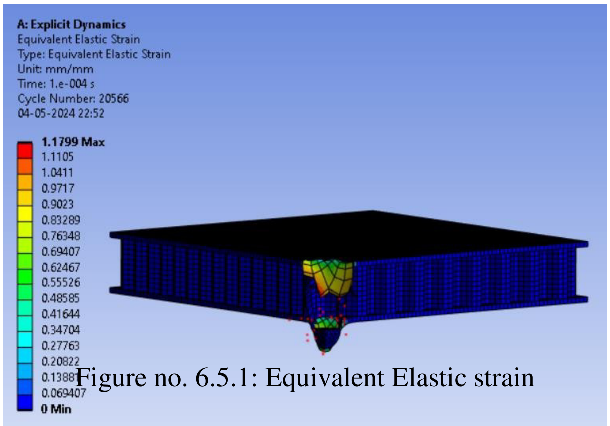
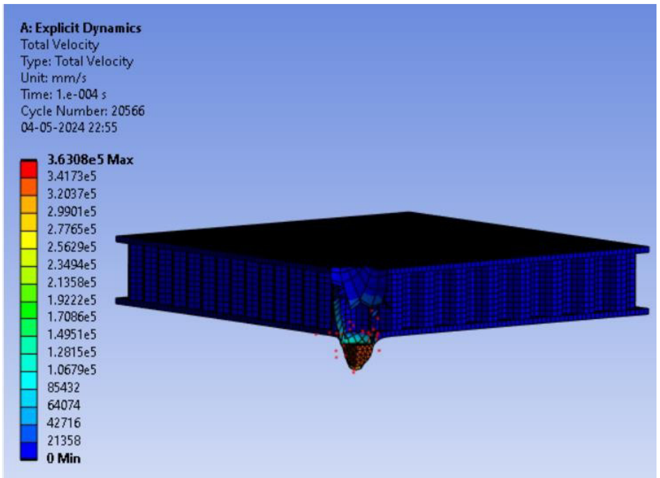


Figure no. 6.5.1: Equivalent Elastic strain

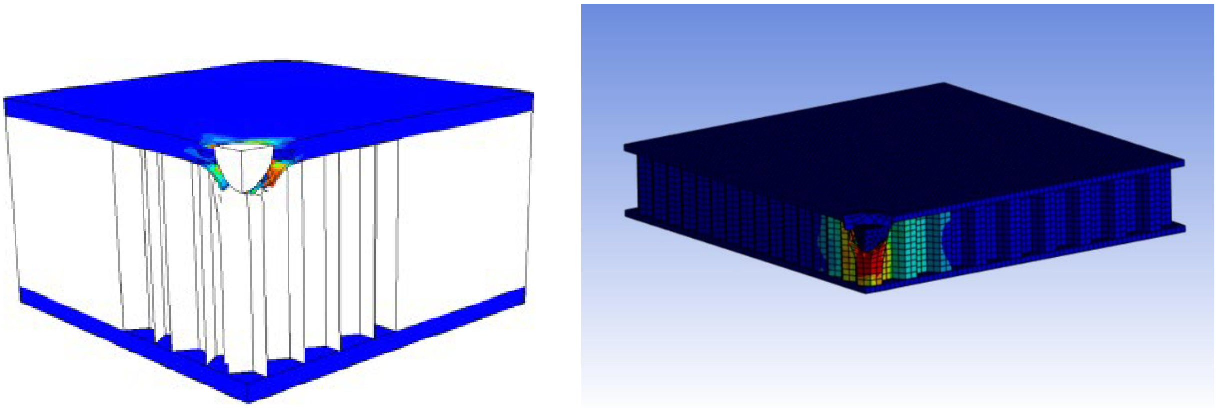
6.4 Totalvelocity



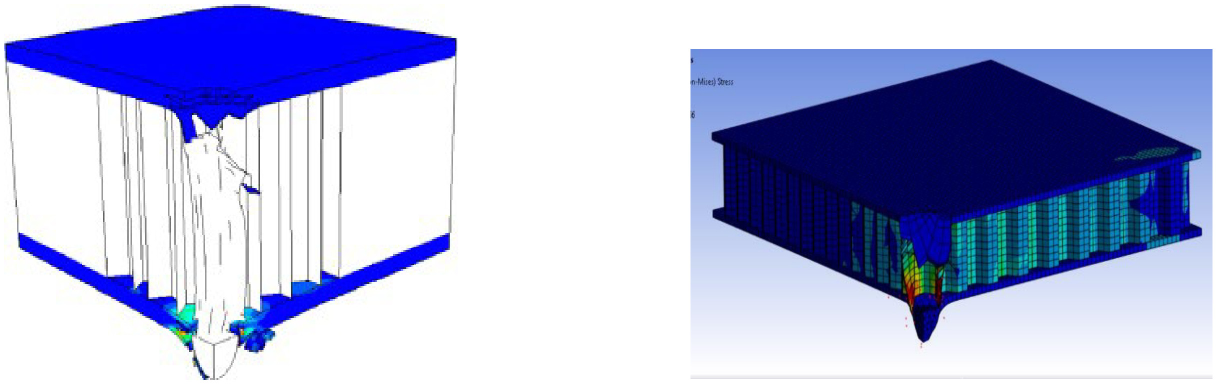
Figureno. 6.6.1:Total velocity

VALIDATIONOFRESULT

7.1 Fiber-failurecriterionduringthesandwich perforation



Figureno.7.1.1:Fiber failurecreationtopplate

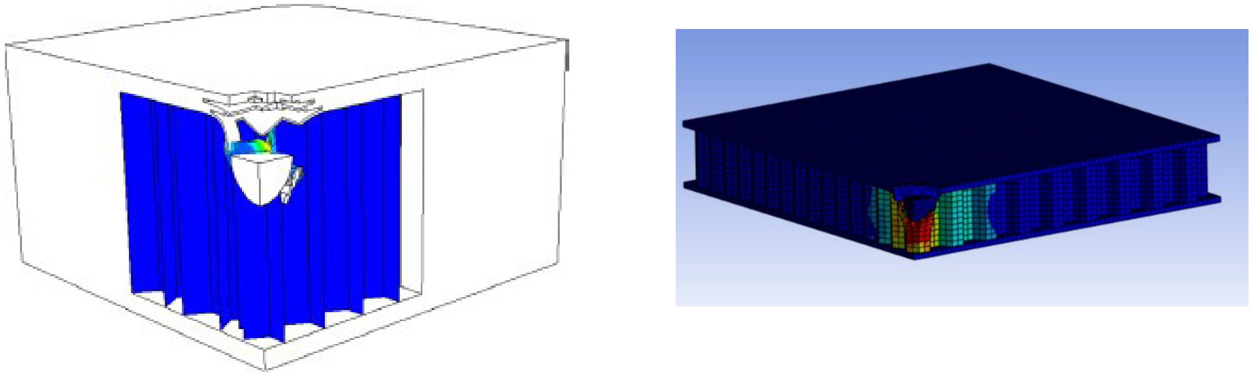


Figureno.7.1.2:Fiberfailurecreationbottomplate

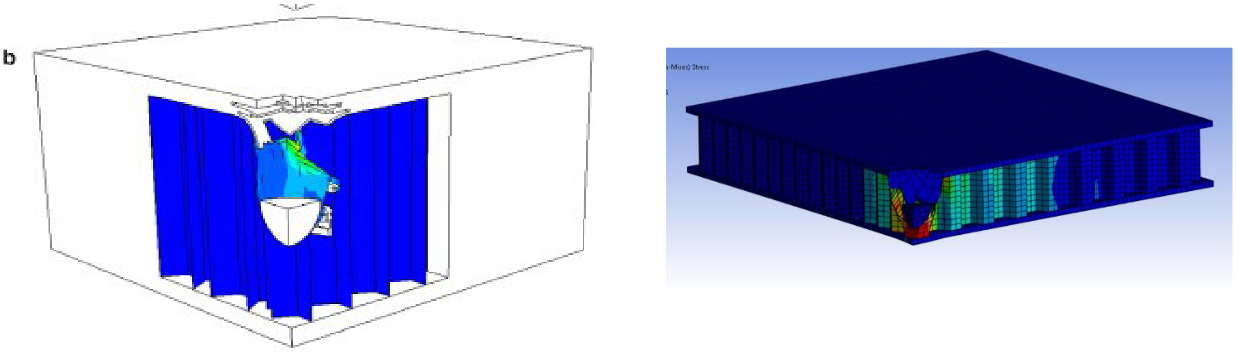
Tableno.7.1.1:comparisonbetweenobtainedandjournalvaluesduringfiberfailure.

Time	ReferenceValues	Obtainedvalues
T1	7.2 µs	5.5 µs
T2	78.5 µs	66.1 µs

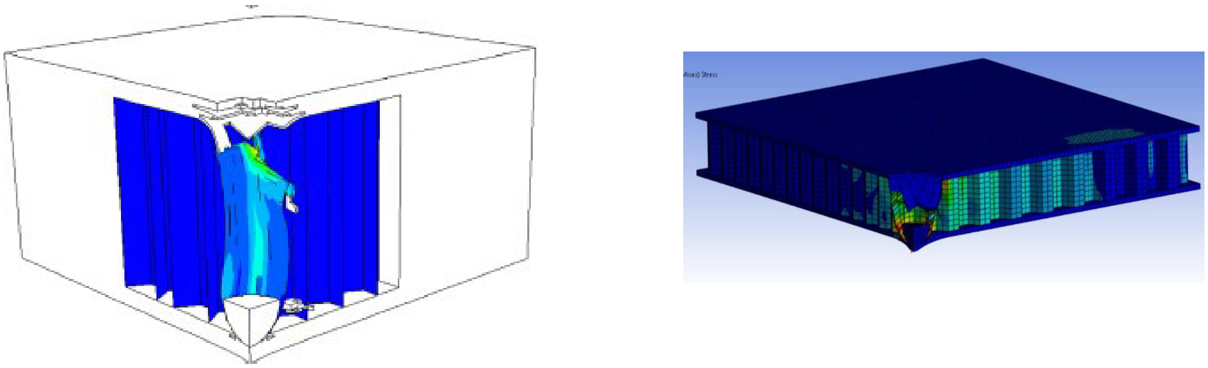
Evaluationofresultsfromplasticstrainduringsandwichperforation



Figureno. 7.2.1: Plastic strainattop plate



Figureno.7.2.2: Plasticstrainat honeycombstructure



Figureno.7.2.3:Plasticstrainat bottom plate

Tableno.7.2.1: Comparisonbetweenobtainedandjournalvaluesduringplasticstrain

Time	Referencevalues	Obtainedvalues
T1	7.2	5.5
T2	41	33
T3	78.5	66.1

7.2 ComparisonbetweenContacttimevsImpactvelocity

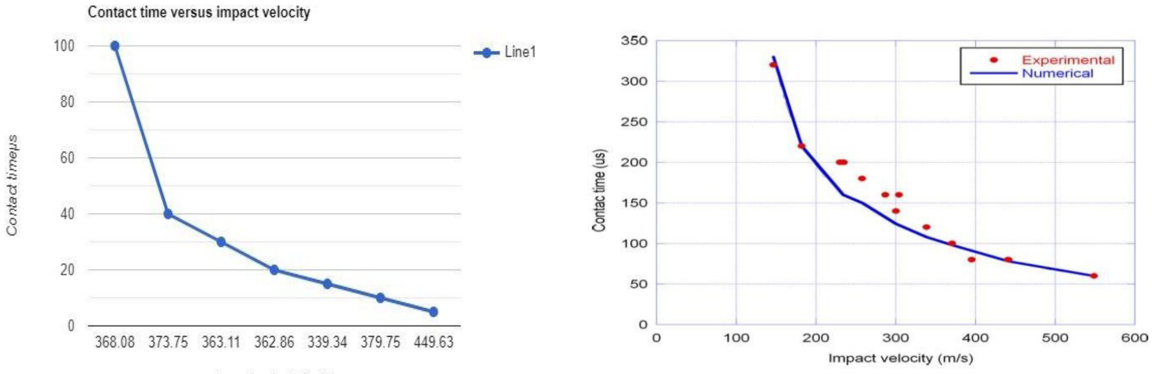


Fig. 4. Contact time versus impact velocity.

Figureno.7.3.1Contacttimevsimpact velocity

CONCLUSION

Inthisstudytheperforationofcompositesandwichpanelshoneycombstructuresubjectedtohigh-velocityimpactwasanalyzedusingathree-dimensionalfiniteelementmodelimplementedinANSYS.Impacttest wascarriedouttovalidatethe journalmodel.Goodagreement wasfoundbetweenjournal resultsandexperimentalresults.

The influence of both plates and core in the energy-absorption capabilities of the honeycomb sandwich panel wasstudied in a broad range of impact velocities. Most of the impact energy was absorbed by plates. For impactvelocities 339 m/s, the impact energy was absorbed by the top plate and bottom plate. On the contrary thehoneycomb core absorbed impact energy by plastic strain, at all the impact velocities analyzed. Also, the energy-absorption mechanisms in both plates and the core were studied. The main mechanism in the plate was fiberbreakage whereas in the core the mechanism was the plastic deformation of the aluminum core. Both in the platesandthe core,thedamage was concentratedina smallareaaround the impactpoint.

8.1 FUTUREPROSPECTS

Whileourstudyprovidesvaluableinsights,furtherresearchiswarrantedtoexploreadvancedmaterials,innovativemanufacturingtechniques,andmulti-scalemodelingapproachesforpredictingballisticperformance.Additionally,investigating the long-term durability and environmental sustainability of honeycomb-based composite materialsiscrucialfor their widespread adoption.
Ourfindingsunderscoretheefficiencyofhoneycombstructuresascompositematerials,offeringsuperiorprotectionagainsthigh-velocityprojectiles.Byadvancingourunderstandingoftheirbehaviorandoptimizingtheirdesign,wecanenhancethesafet

y andsecurityofindividualsin high-riskenvironments.Sustainabilityofhoneycomb-basedballisticmaterialsiscrucialfor theirwidespread adoption.

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