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Numerical Investigation on Medium Velocity Impact Response of Hybrid Metal Matrix Composite Laminate

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Abstract

The current investigation centers on examining the numerical analysis of a hybrid metal matrix composite laminate resulting from impacts inflicted by diverse projectiles on the composite structure. Composite materials are chosen based on their inherent properties and compatibility in terms of bonding with other materials, forming the layers for the hybrid metal matrix composite. The fiber taken for the research paper was Kevlar and Sisal because they both bear good impact resistance compared to other existing fibres, the aluminium metal sheets were used for as laminates. The aluminium sheets are choosen for their lightweight and their resistance to corrosion. The Hybrid metal matrix Composite laminate is laminated with different orientation and the laminate is subjected to impacts from projectiles with varying velocities, and measurements are taken for normal stress, equivalent stress, and total deformation. Within this research, two laminates with distinct materials and orientations of hybrid metal matrix composite, are devised and assessed using Ansys software. Various bullet types are employed to strike the composite laminate at different Velocities. Subsequent to each impact, the physical attributes of the composite laminates, including equivalent stress, normal stress, total deformation, and strain, are scrutinized. The values obtained for each composite after different impact velocities are compared to determine the most favorable outcomes.

Keywords: Hybrid metal matrix composite, impact analysis, Ansys software, bullets, stresses and deformation

INTRODUCTION

A hybrid metal matrix composite is a type of material with two or more different reinforced matrices to enhance physical properties. The energy absorption of the composites demonstrated a positive correlation with the escalating initial velocity [1]. Notably, the Al back stacking sequence plate emerged as the optimal structural configuration for effectively withstanding impact loading. This finding underscores the significance of considering the stacking sequence in enhancing the composite material's ability to absorb energy under varying velocities [2]. The modelled composite laminate structures incorporate fibre-cement, Kevlar woven fabric, and steel layers to assess the technical viability of an armour design. Subsequent experimental testing of samples was conducted for validation purposes [3]. The outcomes indicate that an 8 mm thick fibre-cement layer, a total Kevlar29 layer thickness of 2.4 mm, and a 3 mm thick steel 1006 plate collectively demonstrate the capability to effectively halt a 9 mm FMJ bullet with minimal deformation. This underscores the promising potential of the proposed composite laminate configuration as a reliable armour solution [4]. In the flexural test, the initiation of top skin failure is characterized by localized wrinkling on the compressed side of the panel. Notably, carbon fibre sandwich structures exhibit higher fracture stress compared to glass or Kevlar counterparts [5]. Interestingly, the

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incorporation of higher modulus carbon fibre does not notably impact flexural strength or modulus. In contrast, Kevlar fibre sandwich structures demonstrate a lower deformation-to-break, while the wrinkling fracture of the top skin is gradual, and delamination occurs in the sandwich samples [6]. Utilizing the commercial ANSYS code, Finite Element Method (FEM) analysis was employed to simulate static mechanical tests, effectively approximating the elastic zone behavior of the composite structure through numerical simulations [7]. The drop test machine is certified for subjecting components and structures, such as segments of vessels, tanks, and containers, to dynamic impact and bending [8]. Its primary goals include assessing impact resistance and crashworthiness while incorporating material and structural parameters into advanced finite element models. Additionally, it facilitates the analysis of reference structures to enhance overall understanding and predictive capabilities [9]. The utilization of sisal fibres to reinforce composite materials presents numerous applications in industries requiring plates or thin structures, as evidenced by compelling results [10]. Optimal mechanical properties are achieved in specimens with a high-volume fraction of sisal and a lower volume fraction of polyester, leading to enhanced modulus of elasticity and maximum load, as demonstrated in tensile tests [11]. Notably, there exists a disparity between the longitudinal modulus of elasticity and the transverse modulus, with the latter registering a reading lower than the former in the final recorded measurements [12]. The paper provides pioneering perspectives on the examination of energy dynamics and stress field behaviors in the context of high-velocity impacts on heterogeneous materials. These revelations stand poised to propel advancements in comprehending and modeling the responses of materials to dynamic forces, presenting significant ramifications for diverse applications within the realms of engineering and material science [13]. Ballistic performance and energy absorption assessments were conducted through both quasi-static and impact perforation tests on metallic sandwich panels. These panels featured a composition comprising two skins of aluminum alloy and a core constructed from aluminum foam [14]. The experimentation involved subjecting the sandwich specimens to impact from three distinct projectiles, each possessing varied shapes flat ended, hemispherical nosed, and conical nosed. This comprehensive examination aimed to evaluate the panels' resilience and absorption capabilities under different projectile shapes and impact conditions [15]. The integration of experimental testing and numerical simulation for natural composites in aerospace applications offers significant insights. The amalgamation of real-world experimentation and virtual modeling results in a thorough comprehension of the material's performance in aerospace conditions. This comprehensive approach enables the extraction of meaningful data, empowering the improvement of aerospace applications through well-informed design and engineering choices [16]. The strains experienced at points equidistant from the impact point differ based on varying initial striking velocities, with higher velocities resulting in larger strains. Throughout the penetration process, notable local deformations occur, characterized by a steep deformation gradient around the impact point. This gradient diminishes rapidly as one moves away from the point of impact, leading to a reduction in the impact effect area with increasing initial striking velocity [17]. For bullets of identical size and material, the energy absorption capacities of all three target types exhibit corresponding increases with rising initial striking velocity. Moreover, at the same initial striking velocity and stacking sequence, thick plates demonstrate greater energy absorption than thin plates due to their higher strain rate. Upon penetration, thick plates exhibit a more significant release of fiber fragments compared to their thinner counterparts [18]. innovative approach to studying the impact behavior of a unique composite structure combining Aluminum, Kevlar, and Sisal. This research explores the synergistic effects of these materials within a hybrid laminate, specifically under medium velocity impact conditions, which is less commonly addressed in existing studies [19]. The use of a metal matrix composite (MMC) with natural and synthetic fibers like Sisal and Kevlar is particularly novel, as it aims to achieve an optimal balance between mechanical performance, weight reduction, and cost-effectiveness [20]. The integration of Sisal, a biodegradable and sustainable material, adds an environmental dimension to the study, while Kevlar provides superior impact resistance. Additionally, the study's focus on medium velocity impacts, rather than the more commonly studied high or low velocity impacts, fills a gap in the literature, providing insights that are directly relevant to real-world applications such as automotive and aerospace components [21]. The numerical modeling and simulation techniques employed offer a detailed understanding of the impact response, enabling the design of more efficient, durable, and lightweight composite materials.

MATERIALS AND METHODS

Material Selection

The primary objective of this investigation centres on comprehending the aftermath of impact tests on a hybrid metal matrix composite. The selection of materials with elevated tensile strength plays a pivotal role in this study, with a strategic combination of Aluminium, Kevlar and Sisal integrated into a five-layered composite laminate based on specific requirements. Aluminium, renowned for its lightweight yet robust characteristics, contributes to structural stability. Kevlar, acknowledged for its exceptional tensile strength and impact resistance, enhances the composite's overall performance. Sisal, chosen for its natural fibre properties, introduces unique mechanical features to the composite, collectively creating a dynamic and resilient hybrid metal matrix structure for in-depth impact analysis. Aluminum, Kevlar, and Sisal are chosen for hybrid metal matrix composite laminates in medium velocity impact studies due to their complementary properties. Aluminum serves as a lightweight, strong, and ductile matrix, offering a good balance of structural integrity and energy absorption. Kevlar contributes exceptional impact resistance and high tensile strength, preventing crack propagation and enhancing the laminate’s toughness [22]. Sisal, a natural fiber, provides additional impact resistance, cost-effectiveness, and environmental sustainability. Its natural damping properties help absorb vibrations and shocks, further reducing stress on the composite during impact [19]. This material combination is selected to optimize performance under medium velocity impacts, where balancing strength, weight, and cost is crucial. Aluminum’s compatibility with reinforcements, Kevlar’s superior toughness, and Sisal’s sustainable and economic advantages make this trio ideal for applications requiring efficient impact energy management without significantly increasing the laminate's weight. Other materials, like steel or carbon fiber, are less suitable due to their higher density, brittleness, or cost, making this specific selection optimal for achieving the desired balance of properties in impact-resistant composite structures. Required few properties of the material are shown in Table 1.

Modelling

Two varieties of composite laminates are simulated, each featuring distinct stacking sequences of identical materials positioned at varying orientations.

Composite material model 1

The laminate configuration comprises five layers arranged in the following sequence: Aluminium, Kevlar, Aluminium, Sisal, and Aluminium. Notably, all sheets, except for Kevlar and Sisal, are oriented at 0 degrees, contributing to the structural integrity. The Kevlar layer assumes a 45-degree positive orientation, while the Sisal layer is positioned at a 45-degree negative orientation, introducing a deliberate arrangement that enhances the composite material's mechanical properties and resilience as shown in Figure 1. This meticulous layering and orientation strategy contributes to the overall strength and performance of the laminate under varying conditions.

Composite material model 2

Likewise, this composite structure is configured as a five-layered laminate, featuring Aluminium, Kevlar and Sisal Sheets in the sequence of Aluminium, Sisal, Kevlar, Sisal and Aluminium. The orientation of all sheets, excluding Kevlar and Sisal, is consistently set at 0 degrees to ensure uniformity in the structure. Notably, the Sisal layers introduce a deliberate orientation strategy, with one oriented at 45 degrees in the positive direction and the other at 45 degrees in the negative direction as shown in Figure 2. This thoughtful arrangement enhances the overall mechanical properties and resilience of the laminate, showcasing a strategic design to optimize performance under various conditions.

Table 1. Properties of Material used in Composite Laminate. (Ramadhan.A et.al).

Properties	**Aluminum**	**Kevlar**	**Sisal**
Density(g/cm$^{3)}$	2.7	1.44	1.3
Sheet Thickness(mm)	0.4	0.2	0.6
Modulus of Elasticity (Gpa)	71.7	62	9.4-15.8
Poisson’s Ratio	0.33	0.44	0.32
Yield Stress (Mpa)	100	2758	568-640

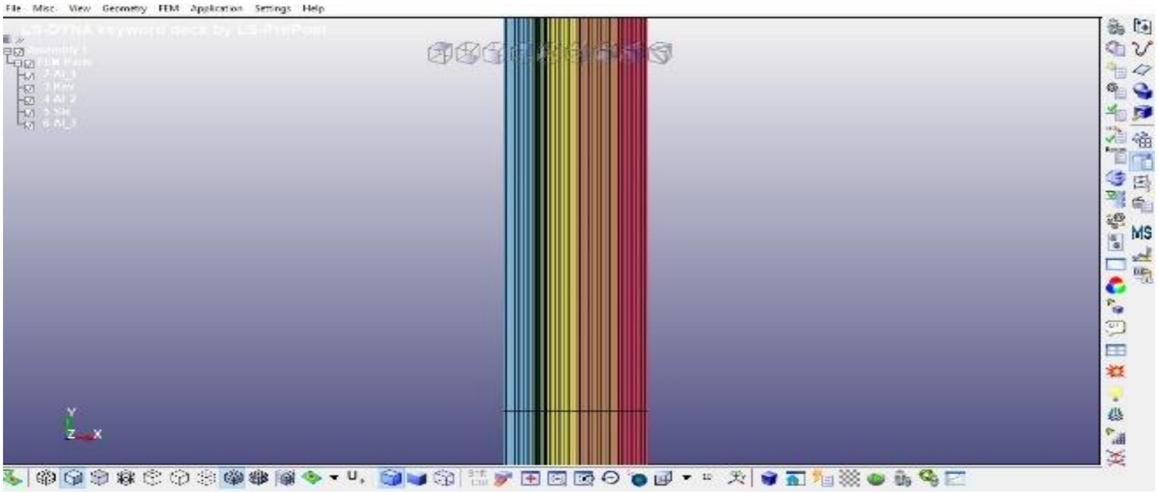


Figure 1. Al-K-Al-Si-Al composite laminate.

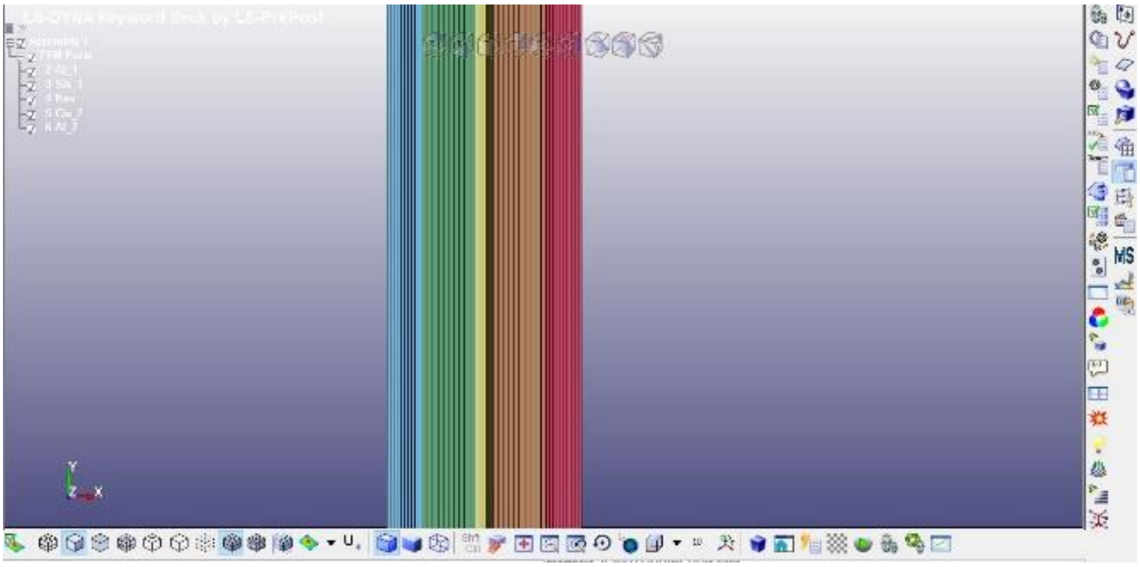


Figure 2. Al-Si-K-Si-Al composite laminate.

Bullet types

An analysis of the impact on the composite laminate involves the utilization of bullets in various sizes. The bullets employed in this study encompass a diverse range, including the following configurations:

- Spherical Bullet (Figure *3*)
- Blunt Nosed Bullet (Figure *4*)
- Needle Tip Bullet (Figure *5*)

This comprehensive exploration of different bullet sizes enhances the breadth and depth as shown in *Table 2*. of the impact assessment on the composite laminate, providing valuable insights into the material's response under a variety of projectile shapes and characteristics.

Table 2. Bullets and their dimensions.

Bullet Shapes	**Diameter (mm)**	**Length(mm)**
Spherical	9	-
Blunt	9	19
Needle Tipped	9	19

These bullets are specifically designed to impact the laminate at three distinct velocities, namely 30 m/s, 60 m/s, and 90 m/s. This deliberate variation in impact velocities serves to create a comprehensive and systematic analysis, allowing for a thorough examination of the composite laminate's performance under different kinetic conditions. The incorporation of these diverse velocities enhances the scope of impact testing, providing a deeper understanding of how the material responds to varying degrees of force and speed.

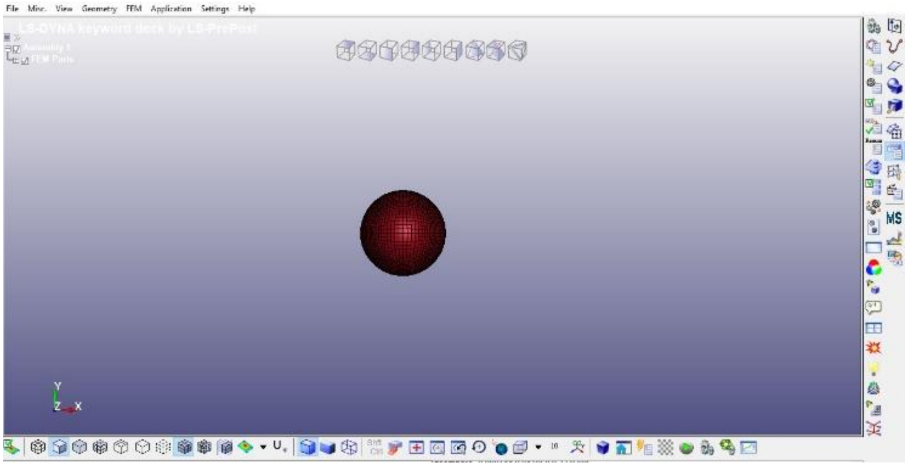


Figure 3. Spherical bullet design.

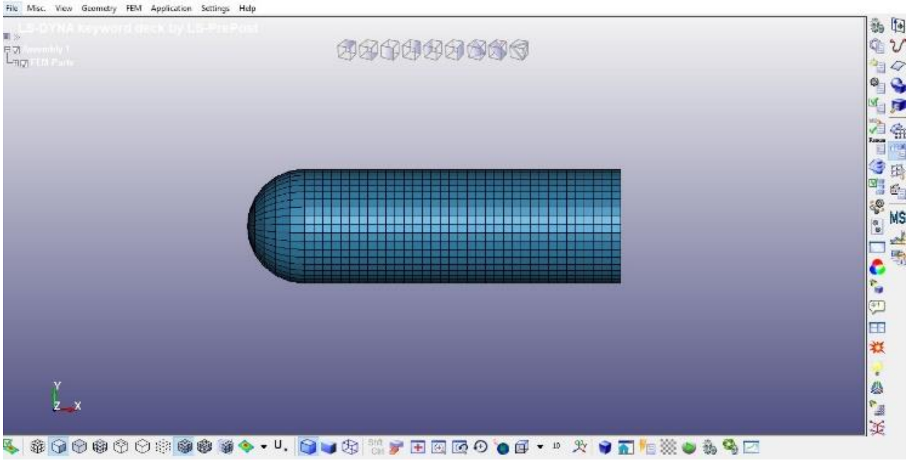


Figure 4. Blunt nosed bullet design.

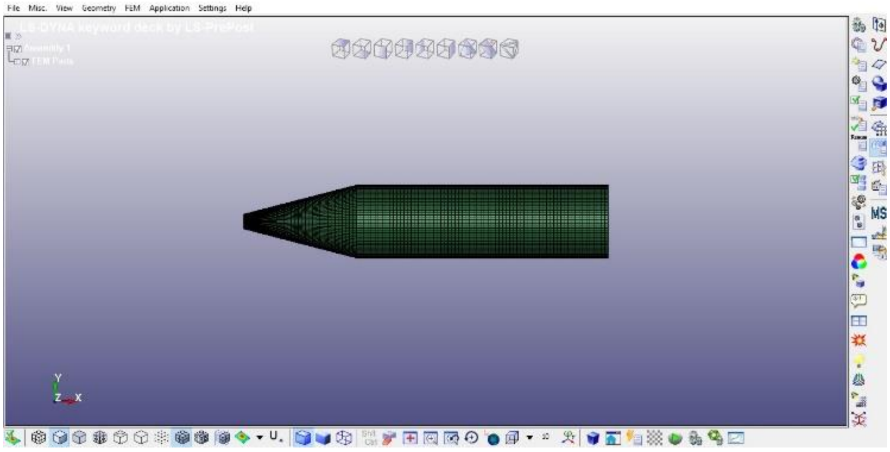


Figure 5. Needle nosed bullet design.

The bullet designs are done using the dimensions shown in Table 2. using LS- Dyna software, which is then imported into Ansys Software for the analysis part.

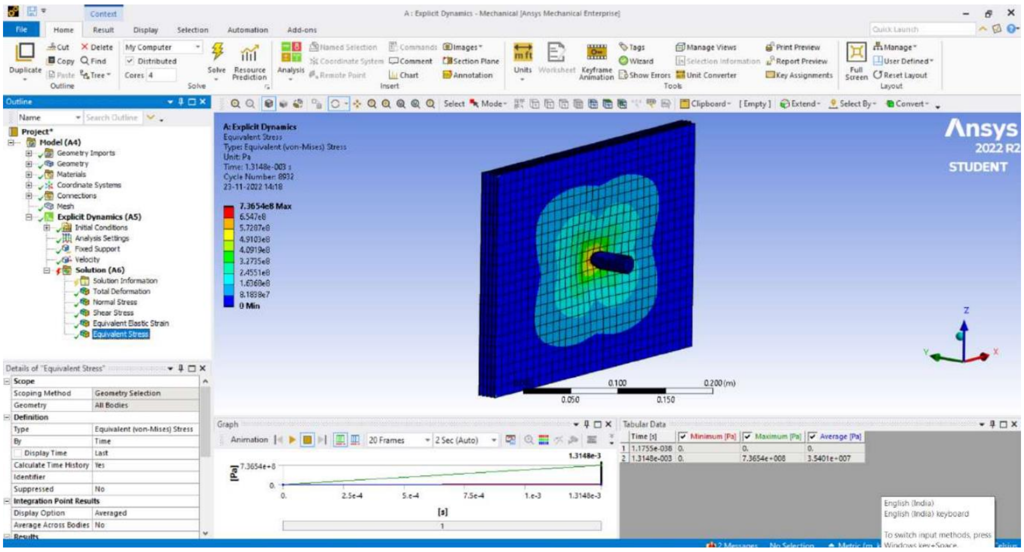
RESULTS

Subsequently, the models are uploaded to the Ansys Workbench platform, where a series of impact tests are conducted at varying velocities, specifically at 30 m/s, 60 m/s, and 90 m/s. These tests involve the utilization of different bullet shapes, including sphere, blunt, and needle configurations, providing a comprehensive examination of the structural responses under diverse impact conditions. This meticulous approach allows for a thorough exploration of the composite material's performance across a spectrum of projectile shapes and velocities, contributing valuable insights to the overall assessment of impact resistance.

Analysis

Blunt bullet of velocity 30m/s composite material 1

An analysis of alterations in the mechanical properties of Composite Material 1 (Al-K-Si-K-Al) is conducted by subjecting it to impact from a blunt-tipped bullet traveling at a velocity of 30 m/s. Figure 6, 7 and 8 represents the equivalent stress, normal stress and total deformation for the velocity of 30m/s.



A : Explicit Dynamics - Mechanical [Ansys Mechanical Enterprise]

A: Explicit Dynamics
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: Pa
Time: 1.3148e-003 s
Cycle Number: 8932
23-11-2022 14:18

7.3654e8 Max
6.547e8
5.7287e8
4.9103e8
4.0919e8
3.2735e8
2.4551e8
1.6368e8
8.1838e7
0 Min

Details of "Equivalent Stress"

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Equivalent (von-Mises) Stress
By	Time
☐ Display Time	Last
Calculate Time History	Yes
Identifier	
Suppressed	No
Integration Point Results	
Display Option	Averaged
Average Across Bodies	No
Results	

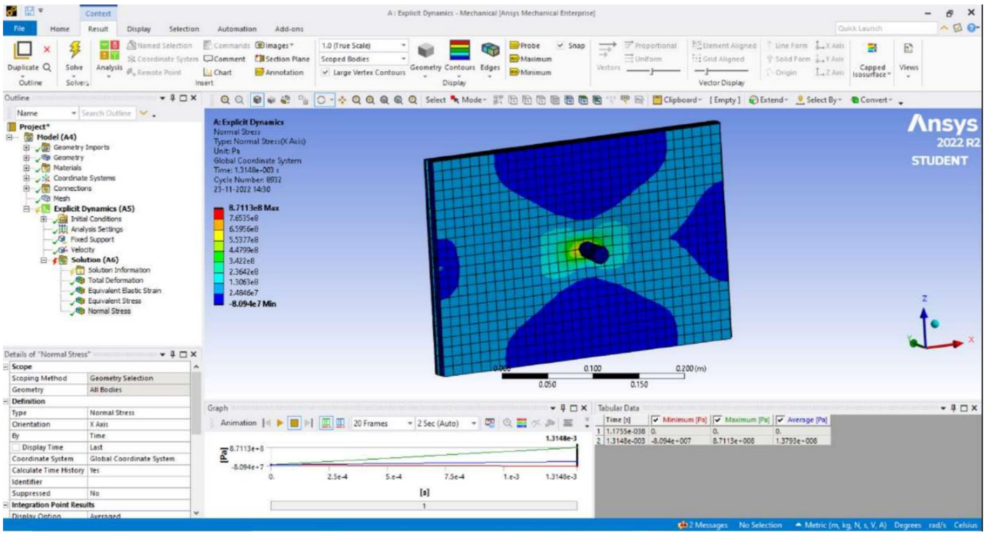
Tabular Data

	Time [s]	☑ Minimum [Pa]	☑ Maximum [Pa]	☑ Average [Pa]
1	1.1755e-038	0.	0.	0.
2	1.3148e-003	0.	7.3654e+008	3.5401e+007

English (India)
English (India) keyboard

To switch input methods, press Windows key+Space.

Figure 6. Equivalent stress for 30m/s.



A : Explicit Dynamics - Mechanical [Ansys Mechanical Enterprise]

A: Explicit Dynamics
Normal Stress
Type: Normal Stress(X Axis)
Unit: Pa
Global Coordinate System
Time: 1.3148e-003 s
Cycle Number: 8932
23-11-2022 14:30

8.7113e8 Max
7.6535e8
6.5956e8
5.5377e8
4.4799e8
3.422e8
2.3642e8
1.3063e8
2.4846e7
-8.094e7 Min

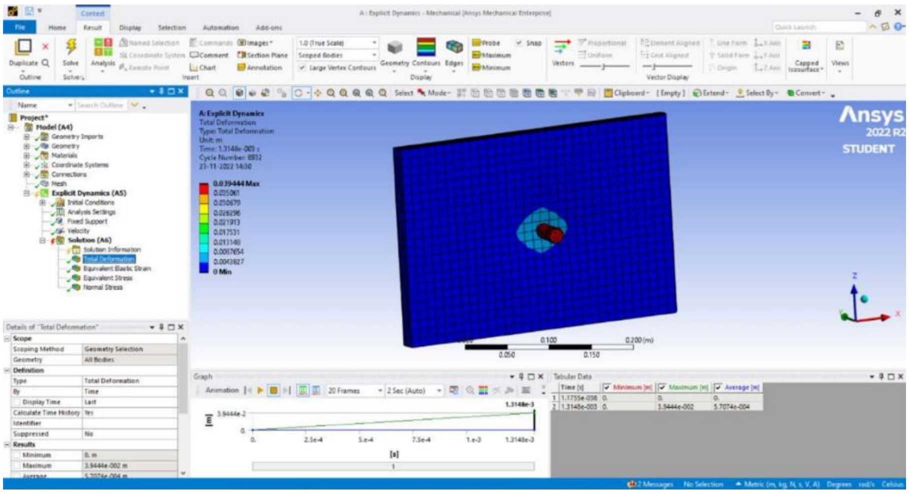
Details of "Normal Stress"

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Normal Stress
Orientation	X Axis
By	Time
☐ Display Time	Last
Coordinate System	Global Coordinate System
Calculate Time History	Yes
Identifier	
Suppressed	No
Integration Point Results	
Display Option	Averaged

Tabular Data

	Time [s]	☑ Minimum [Pa]	☑ Maximum [Pa]	☑ Average [Pa]
1	1.1755e-038	0.	0.	0.
2	1.3148e-003	-8.094e+007	8.7113e+008	1.3793e+008

Figure 7. Normal stress for 30m/s.



A: Explicit Dynamics
Total Deformation
Type: Total Deformation
Unit: m
Time: 1.3148e-003 s
Cycle Number: 8932
23-11-2022 14:30

Details of "Total Deformation"

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Total Deformation
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	
Suppressed	No
Results	
Minimum	0. m
Maximum	3.9444e-002 m
Average	5.7074e-004 m

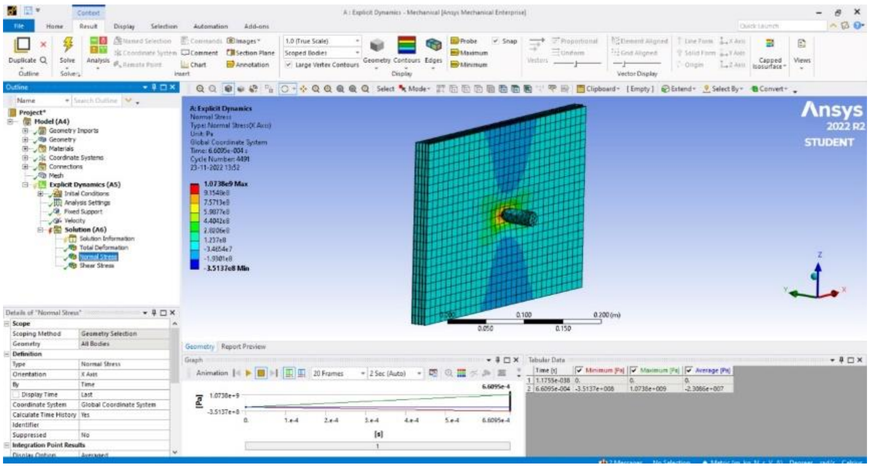
Tabular Data

	Time [s]	☑ Minimum [m]	☑ Maximum [m]	☑ Average [m]
1	1.1755e-038	0.	0.	0.
2	1.3148e-003	0.	3.9444e-002	5.7074e-004

Figure 8. Total Deformation for 30m/s.

Blunt bullet of velocity 60m/s composite material 1

Similarly, an analysis of alterations in the mechanical properties of Composite Material 1 (Al-K-Si-K-Al) is conducted by subjecting it to impact from a blunt-tipped bullet traveling at a velocity of 60 m/s. Figure 9, 10 and 11 represents the normal stress, total deformation and equivalent stress for the velocity of 60m/s.



A: Explicit Dynamics
Normal Stress
Type: Normal Stress(X Axis)
Unit: Pa
Global Coordinate System
Time: 6.6095e-004 s
Cycle Number: 4491
23-11-2022 13:52

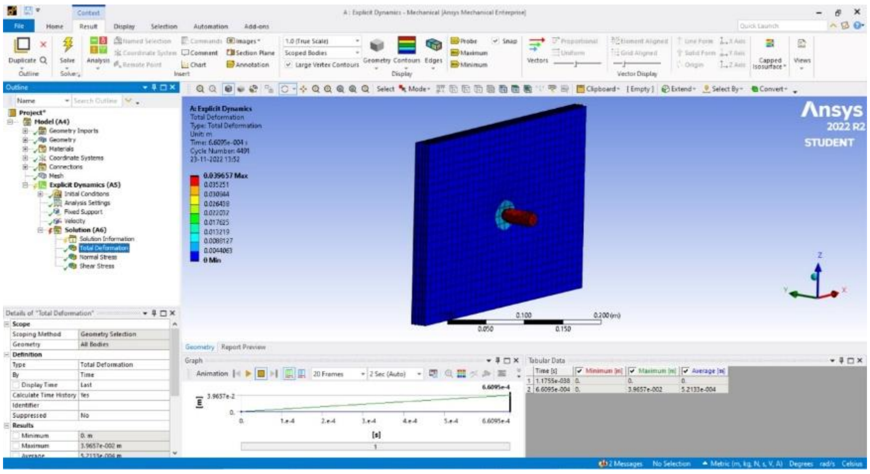
Details of "Normal Stress"

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Normal Stress
Orientation	X Axis
By	Time
Display Time	Last
Coordinate System	Global Coordinate System
Calculate Time History	Yes
Identifier	
Suppressed	No
Integration Point Results	
Display Option	Averaged

Tabular Data

	Time [s]	☑ Minimum [Pa]	☑ Maximum [Pa]	☑ Average [Pa]
1	1.1755e-038	0.	0.	0.
2	6.6095e-004	-3.5137e+008	1.0738e+009	-2.3066e+007

Figure 9. Normal stress for 60m/s.



A: Explicit Dynamics
Total Deformation
Type: Total Deformation
Unit: m
Time: 6.6095e-004 s
Cycle Number: 4491
23-11-2022 13:52

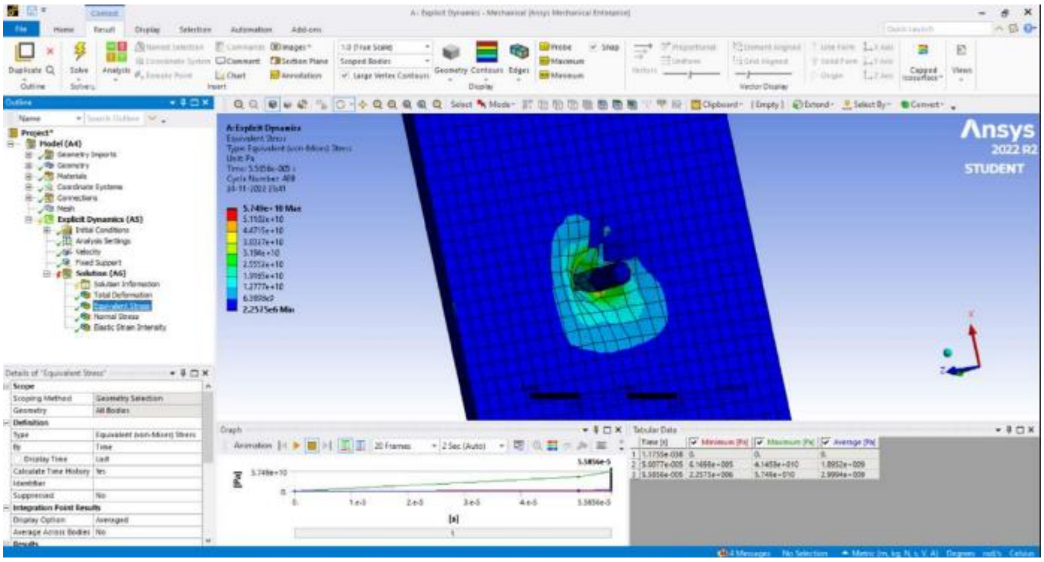
Details of "Total Deformation"

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Total Deformation
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	
Suppressed	No
Results	
Minimum	0. m
Maximum	3.9657e-002 m
Average	5.2133e-004 m

Tabular Data

	Time [s]	☑ Minimum [m]	☑ Maximum [m]	☑ Average [m]
1	1.1755e-038	0.	0.	0.
2	6.6095e-004	0.	3.9657e-002	5.2133e-004

Figure 10. Total deformation for 60m/s.



A: Explicit Dynamics
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: Pa
Time: 5.5856e-005 s
Cycle Number: 409
24-11-2022 15:41

Details of "Equivalent Stress"	
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Equivalent (von-Mises) Stress
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	
Suppressed	No
Integration Point Results	
Display Option	Averaged
Average Across Bodies	No

Tabular Data

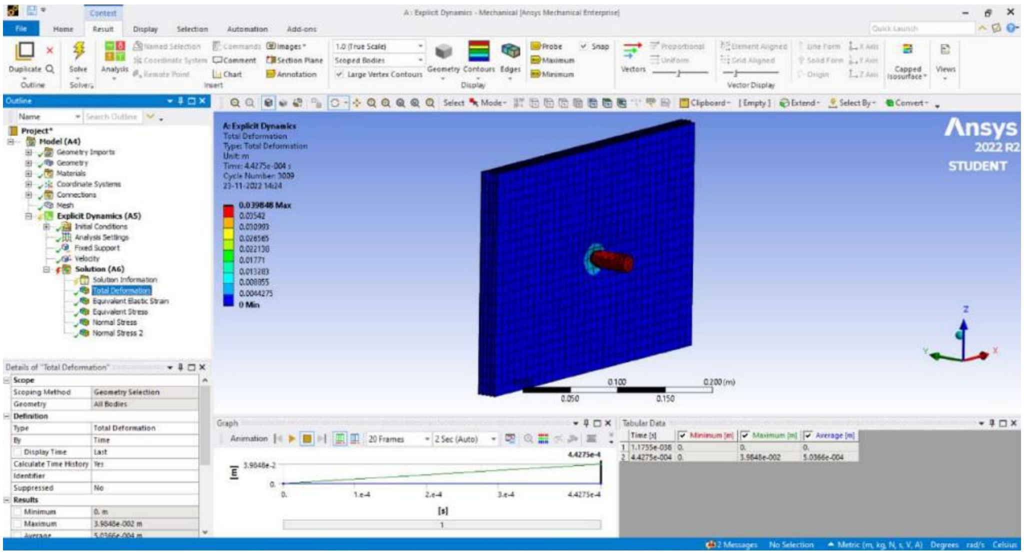
	Time [s]	☑ Minimum [Pa]	☑ Maximum [Pa]	☑ Average [Pa]
1	1.1755e-038	0.	0.	0.
2	5.0077e-005	4.1698e+005	4.1459e+010	1.8952e+009
3	5.5856e-005	2.2575e+006	5.749e+010	2.9994e+009

Figure 11. Equivalent stress for 60m/s.

Blunt bullet of velocity 90m/s composite material 1

An analysis of alterations in the mechanical properties of Composite Material 1 (Al-K-Si-K-Al) is conducted by subjecting it to impact from a blunt-tipped bullet traveling at a velocity of 90 m/s is also analysed and noted. Figure 12 , 13 and 14 represents the total deformation, equivalent stress and normal stress for the velocity of 90m/s.

The images depict impact simulation of a composite laminate. The laminates, shown as a rectangular plate, are subjected to a medium velocity impact, with the resulting stress distribution visualized through color contours. Red areas indicate regions of maximum stress or deformation at the point of impact, while blue areas show minimal stress farther from the impact site. The mesh grid on the laminate indicates that the structure has been discretized into finite elements for detailed numerical analysis. The left panel displays the simulation setup, including materials and boundary conditions, while a graph at the bottom likely tracks the time-history response of the laminate during the impact event. After analysing the models, the required data like equivalent stress, normal stress and total deformation are noted for both composite laminates under different projectiles. Similarly values for equivalent stress, normal stress and total deformation is done for composite material 2, the values are noted and analysed.



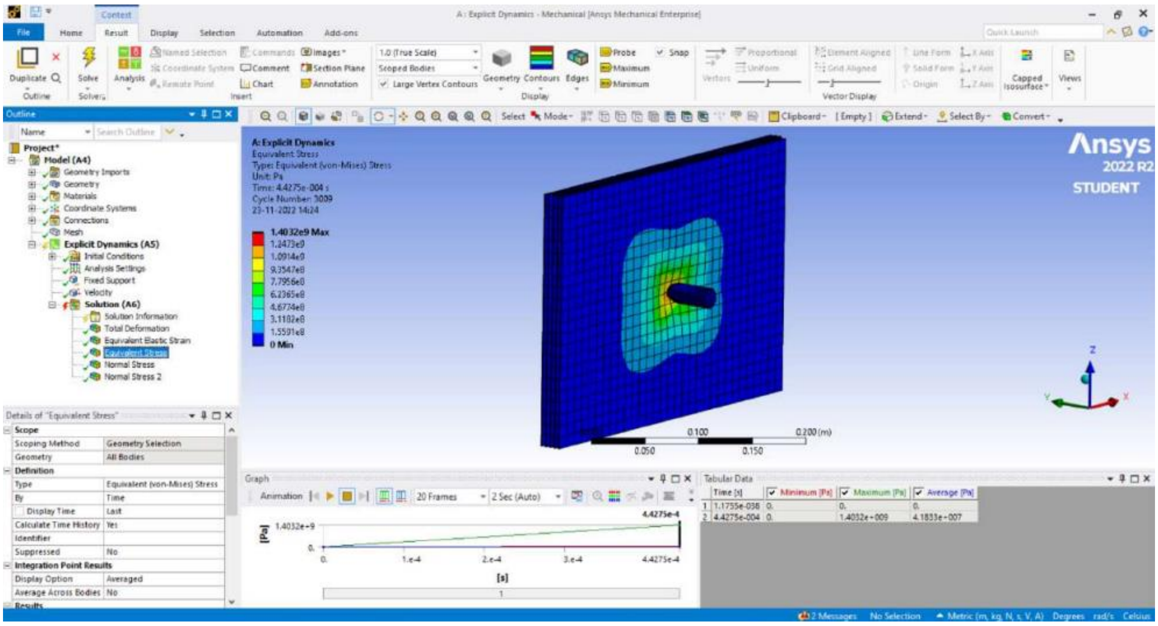
A: Explicit Dynamics
Total Deformation
Type: Total Deformation
Unit: m
Time: 4.4275e-004 s
Cycle Number: 3009
23-11-2022 14:24

Details of "Total Deformation"	
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Total Deformation
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	
Suppressed	No
Results	
Minimum	0. m
Maximum	3.9848e-002 m
Average	5.0366e-004 m

Tabular Data

	Time [s]	☑ Minimum [m]	☑ Maximum [m]	☑ Average [m]
1	1.1755e-038	0.	0.	0.
2	4.4275e-004	0.	3.9848e-002	5.0366e-004

Figure 12. Total deformation for 90m/s.



A: Explicit Dynamics
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: Pa
Time: 4.4275e-004 s
Cycle Number: 3009
23-11-2022 14:24

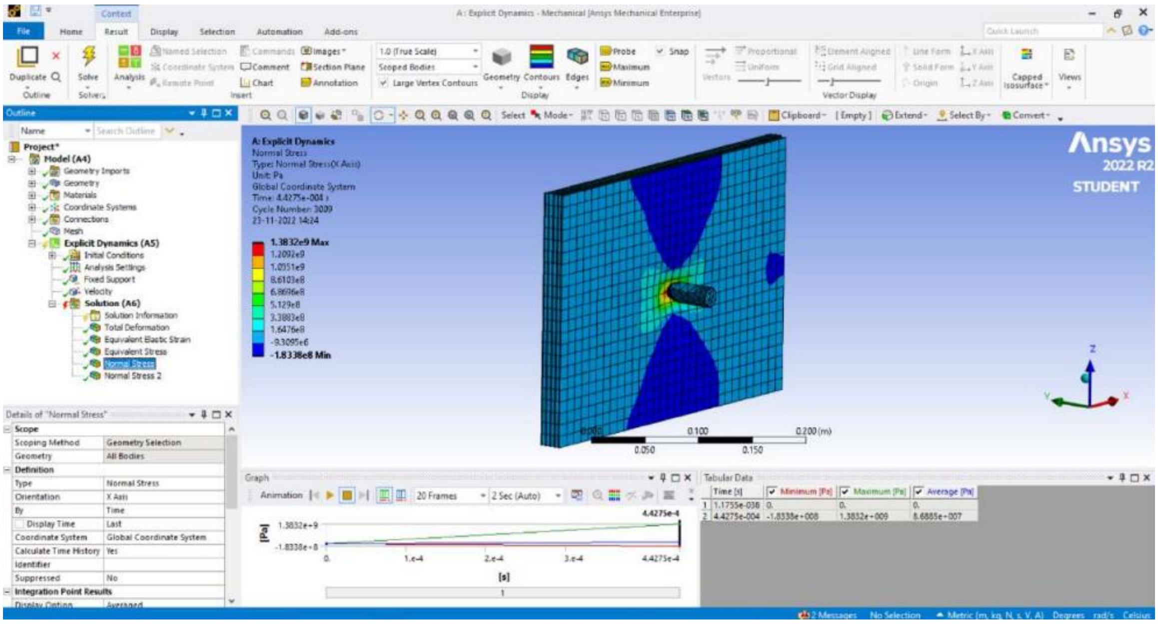
Details of "Equivalent Stress"

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Equivalent (von-Mises) Stress
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	
Suppressed	No
Integration Point Results	
Display Option	Averaged
Average Across Bodies	No

Tabular Data

	Time [s]	☑ Minimum [Pa]	☑ Maximum [Pa]	☑ Average [Pa]
1	1.1755e-038	0.	0.	0.
2	4.4275e-004	0.	1.4032e+009	4.1833e+007

Figure 13. Equivalent stress for 90m/s.



A: Explicit Dynamics
Normal Stress
Type: Normal Stress(X Axis)
Unit: Pa
Global Coordinate System
Time: 4.4275e-004 s
Cycle Number: 3009
23-11-2022 14:24

Details of "Normal Stress"

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Normal Stress
Orientation	X Axis
By	Time
Display Time	Last
Coordinate System	Global Coordinate System
Calculate Time History	Yes
Identifier	
Suppressed	No
Integration Point Results	
Display Option	Averaged

Tabular Data

	Time [s]	☑ Minimum [Pa]	☑ Maximum [Pa]	☑ Average [Pa]
1	1.1755e-038	0.	0.	0.
2	4.4275e-004	-1.8338e+008	1.3832e+009	8.6885e+007

Figure 14. Normal stress for 90m/s.

Equivalent Stress

In the context of the various bullets utilized in the study, a consistent pattern emerges composite material 1 consistently manifests higher values of equivalent stress compared to its counterpart, composite material 2. This divergence in equivalent stress levels prompts a deeper exploration into the mechanical characteristics inherent in each composite material, unravelling the distinct ways in which they respond to applied forces.

Zooming in on the velocity-dependent dynamics, it becomes apparent that the optimal values of normal stresses for composite material 2 are consistently achieved through the use of blunt-nosed bullets. This holds across a spectrum of velocities, whether it be at 30m/s, 60m/s, or 90m/s. The resilience and efficacy of the blunt-nosed bullet in optimizing equivalent stress values for composite 2 underscore its importance in tailoring material responses under varying impact scenarios.

Table 3. Equivalent stress (Pa).

Type of bullet	Velocity(m/s)	Composite material 1		Composite material 2	
		Min	***Max***	***Min***	***Max***
i) Blunt	30	12718	4.5229e+10	3.1354e+006	4.4975e+009
	60	2.2575e+06	5.749 e+10	2.5548e+006	6.2654e+009
	90	9.4805e+05	6.1788e+10	5.5519e+006	6.4025e+009
ii) Spherical	30	0	7.3654e+08	8.1238e+005	7.4044e+009
	60	0	1.9916e+08	2.1201e+005	2.7168e+009
	90	0	1.4032e+09	4.6991e+006	1.0723e+010
iii) Needle	30	5.913 e+06	2.5706e+09	1.4308e+008	1.2397e+007
	60	0	4.2238e+09	4.7814e+006	4.0894e+009
	90	3.5543e+06	4.5428e+09	2.5744e+006	5.0499e+009

The acquired values for equivalent stress for both composite materials are tabulated as shown in Table 3.

Normal Stress

In comparing the different types of bullets employed in the study, a discernible pattern has emerged composite material 1 consistently exhibits a higher stress loading capacity than its counterpart, composite material 2. This intriguing revelation prompts further exploration into the inherent mechanical properties of each composite material and their respective responses to applied forces.

Diving deeper into the velocity-dependent variations, it becomes evident that the optimal normal stress values for composite material 2 are achieved consistently with the use of blunt-nosed bullets. Regardless of the velocity parameter be it 30m/s, 60m/s, or 90m/s the blunt-nosed bullet consistently yields superior normal stress values for composite 2.

The acquired values for normal stress for both composite materials are tabulated as shown in Table 4.

Total Deformation

Notably, our findings reveal a significant discrepancy in deformation between composite material 1 and composite material 2, with the latter exhibiting lesser deformation. This implies that composite material 2 possesses a higher resistance to external loads, suggesting its superior structural integrity compared to composite material.

Table 4. Normal stress (Pa).

Type of bullet	Velocity(m/s)	Composite material 1		Composite material 2	
		Min	***Max***	***Min***	***Max***
i) Blunt	30	-1.3079e+010	4.6324e+010	-3.683e+08	1.1447e+09
	60	-3.9128e+010	2.8251e+010	-5.5568e+09	6.0869e+09
	90	+9.4805e+005	6.1788e010	-8.9671e+09	5.9312e+09
ii) Spherical	30	-8.094e+007	8.7113e+008	-1.5488e+08	1.937e+09
	60	-3.5137e+008	1.0738e+009	-4.9753e+08	2.446e+09
	90	-1.8338e+008	1.3832e+009	-4.3288e+09	1.07e+10
iii) Needle	30	-4.0723e+09	3.0279e+09	-2.4289e+08	1.1838e+06
	60	-5.2697e+09	4.749e+09	-6.6924e+09	4.1796e+09
	90	-4.9774e+09	4.618e+09	-3.2905e+09	5.0349e+09

Table 5. Total Deformation(m).

Type of bullet	Velocity(m/s)	Composite material 1	Composite material 2
i) Blunt	30	3.4412e-002	1.1912e-002
	60	5.5871e-002	1.2844e-002
	90	5.9998e-002	1.3759e-002
ii) Spherical	30	3.9444e-002	1.2621e-002
	60	3.9657e-002	1.3585e-002
	90	3.9848e-002	1.3714e-002
iii) Needle	30	2.3478e-002	1.6411e-002
	60	2.4504e-002	2.566e-002
	90	2.6181e-002	2.665e-002

Further dissecting the results based on various bullet types, it becomes evident that composite material 2 consistently outperforms its counterpart. Specifically, at a velocity of 30m/s, the needle-nosed bullet exhibits the least deformation for composite 2. At 60m/s, the blunt-nosed bullet emerges as the optimal choice, demonstrating minimal deformation. Notably, when the velocity increases to 90m/s, both the blunt and spherical-nosed bullets yield comparable and reduced deformation values that may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

The acquired values for total deformation for both composite materials are tabulated as shown in Table 5

DISCUSSION

In essence, the comprehensive examination of these impact analyses not only underscores the superior deformation resistance of composite material 2 but also provides nuanced insights into the specific bullet types that optimize performance at varying velocities. These findings are paramount for informing material and design choices in applications where structural integrity and deformation resistance are critical considerations

Through a comprehensive examination of impact analysis data obtained via Ansys simulations, our focus has honed in on the critical parameter of equivalent stress. This form of stress analysis is particularly illuminating when the deforming force acts perpendicular to the cross-sectional area of the body. The insights garnered from these analyses have brought forth significant revelations, notably about the comparative equivalent stress levels exhibited by composite materials 1 and 2.

CONCLUSIONS

In conclusion, the impact analyses conducted through Ansys simulations have yielded valuable insights into the mechanical behavior of composite materials under varying conditions. The examination of total deformation revealed a notable advantage for composite material 2, showcasing its superior resistance to external loads when compared to composite material 1. This observation carries implications for material selection, suggesting that composite material 2 may be better suited for applications demanding heightened structural integrity.

Moving on to normal stress considerations, the findings unveiled a consistent trend wherein composite material 1 exhibited higher stress loading capacities than its counterpart, composite material 2. This prompts a deeper exploration into the intrinsic mechanical properties of each material, providing critical information for scenarios where normal stress resistance is a primary concern.

The assessment of equivalent stress further corroborates the superiority of composite material 1, as it consistently demonstrated higher values compared to composite material 2. However, the role of the blunt-nosed bullet in optimizing normal stresses for composite 2 across various velocities introduces a nuanced dimension to the analysis. This underscores the importance of considering specific projectile types in tandem with material properties for tailored responses to external forces.

In the broader context, these findings collectively contribute to a holistic understanding of how composite materials respond to impact, offering valuable insights for material selection and design optimization. The nuanced interplay between material composition, bullet type, and impact velocity underscores the need for a meticulous approach in engineering applications where structural integrity, stress resistance, and deformation characteristics are pivotal considerations.

Upon scrutinizing the comprehensive dataset, a discernible trend emerges, indicating that composite material 1 exhibits superior load-bearing capabilities in comparison to composite material 2. While the latter demonstrates commendable strength in total deformation, a crucial facet of structural integrity, it is surpassed by the former in terms of stress loading capacities. Consequently, in a holistic evaluation of specifications, composite material 1 emerges as the preferred choice for applications demanding robust and rigid structures.

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REFERENCES

1. Ramadhan, A. A., Talib, A. A., Rafie, A. M., & Zahari, R. High velocity impact response of Kevlar-29/epoxy and 6061-T6 aluminum laminated panels. Materials & Design. 2013; 43, 307-321.
2. Soydan, A. M., Tunaboylu, B., Elsabagh, A. G., Sarı, A. K., & Akdeniz, R. Simulation and experimental tests of ballistic impact on composite laminate armor. Advances in materials science and engineering. 2018; 1-12.
3. Borsellino, C., Calabrese, L., & Valenza, A. Experimental and numerical evaluation of sandwich composite structures. Composites Science and Technology. 2004; 64(10-11), 1709-1715.
4. Müller, K., Quercetti, T., & Musolff, A. Characterisation of shock-absorbing components under impact loading. In Proc. 9th International Conference on the Mechanical and Physical Behaviour of Materials under Dynamic Loading. 2009; DYMAT (pp. 569-574).
5. Ali, Z. A. A. A. Sisal natural fiber reinforcement influenced with experimental and numerical investigation onto vibration and mechanical properties of composite plate. International Journal of Energy and Environment. 2016; 7(6), 497.
6. Bayless, T., Downey, J., Lucon, P., & Coguil, S. High velocity impact conditions: A novel approach to energy analysis and stress fields in inhomogeneous materials. International Journal of Impact Engineering. 2023; 179, 104634.
7. Hou, W., Zhu, F., Lu, G., & Fang, D. N. Ballistic impact experiments of metallic sandwich panels with aluminium foam core. International journal of impact engineering. 2010; *37*(10), 1045-1055.
8. Kumar, G. R., Vijayanandh, R., Kumar, M. S., & Kumar, S. S. Experimental testing and numerical simulation on natural composite for aerospace applications. In AIP conference proceedings. 2018, May; (Vol. 1953, No. 1). AIP Publishing.
9. Zhao, G., Cho, C., Lu, S., & Wang, Z. Experimental study on impact resistance properties of T300/epoxy composite laminates. Journal of composite materials. 2010; 44(7), 857-870.
10. Venkateswarlu, S., & Rajasekhar, K. Modelling and analysis of hybrid composite joint using fem in Ansys. IOSR Journal of Mechanical and Civil Engineering. 2013; *6*(6), 1-6.
11. Neto, J., Queiroz, H., Aguiar, R., Lima, R., Cavalcanti, D., & Banea, M. D.A review of recent advances in hybrid natural fiber reinforced polymer composites. Journal of Renewable Materials. 2022; 10(3), 561.
12. Cantwell, W. J., & Morton, J. The impact resistance of composite materials—a review. Composites. 1991; 22(5), 347-362.
13. Ravid, M., Bodner, S. R., & Holcman, I. Penetration into thick targets—refinement of a 2D dynamic plasticity approach. International journal of impact engineering. 1994; 15(4), 491-499.
14. Ravid, M., & Bodner, S. R. Dynamic perforation of viscoplastic plates by rigid projectiles. International Journal of Engineering Science. 1983; 21(6), 577-591.
15. Silva, M. A., Cismaşiu, C., & Chiorean, C. G. Numerical simulation of ballistic impact on composite laminates. International Journal of Impact Engineering. 1983; 31(3), 289-306.

16. Kumar, S., Gupta, D. S., Singh, I., & Sharma, A. Behavior of kevlar/epoxy composite plates under ballistic impact. Journal of Reinforced Plastics and Composites. 2010; 29(13), 2048-2064.
17. Grujicic, M., Pandurangan, B., Zecevic, U., Koudela, K. L., & Cheeseman, B. A. Ballistic Performance of Alumina/S-2 Glass-reinforced Polymer-matrix Composite Hybrid Lightweight Armor Against Armor Piercing (ap) and Non-AP Projectiles. Multidiscipline Modeling in Materials and Structures. 2010; 3(3), 287-312.
18. Weinberg, A., & Schwartz, P. Effect of fibre volume fraction on the strength of Kevlar-29/epoxy strands. Journal of materials science letters. 1987; 6(2), 183-184.
19. Robertson, N., Hayhurst, C., & Fairlie, G. Numerical simulation of impact and fast transient phenomena using AUTODYN™-2D and 3D. Nuclear Engineering and Design. 1994; 150(2-3), 235-241.
20. Mutasher, S. A. Evaluation of mechanical properties of hybrid aluminium/fiber-reinforced composites (Doctoral dissertation, Universiti Putra Malaysia). 2006.
21. Silva, M. A., Cismaşiu, C., & Chiorean, C. G. Numerical simulation of ballistic impact on composite laminates. International Journal of Impact Engineering. 2005; 31(3), 289-306.
22. Saleh, M., Edwards, L., & Crouch, I. G. Numerical modelling and computer simulations. In The science of armour materials. 2017; (pp. 483-579). Woodhead Publishing.