

Numerical Analysis of Projectile Impact Towards Flax Plate with Different Orientation

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Abstract

The study seeks to replicate and assess the effect of gunshots on flax composite plates used in body armor. The study uses ANSYS for velocity impact testing and SOLIDWORKS for model building to assess how various mesh systems and flax plate topologies effect energy dissipation, damage propagation, and plate disintegration. The study aims to better understand the ballistic resistance of flax composites, emphasizing its potential to increase body armor performance. The findings give critical insights into improving composite materials for increased protection, making major contributions to materials science and military equipment developments. This study underlines the practical use of flax composites in the development of lightweight, high-strength protection equipment.

1. Introduction

The use of composite materials in ballistic applications, particularly body armor design, has received a lot of interest because of its ability to provide protection while reducing weight. Flax fiber-based composites have emerged as potential options, with distinct mechanical qualities and environmental benefits. This thesis looks at the ballistic impact behavior of flax fiber composites, with the goal of better understanding their energy dissipation, damage propagation, and overall performance under high-velocity projectile impacts. The introduction chapter presents an account of the project's history, emphasizing the significance of producing composite materials with higher ballistic resistance. The issue statement emphasizes the need of understanding how bullets interact with body armor materials to reduce penetration rates and protect troops.

A projectile and a target interact dynamically during a ballistic impact [1]. The study is to assess the effect of projectiles on flax sandwich plates at various velocities and to analyze the failure patterns of multi-ply flax composite materials. The study covers velocity impact testing with simulation software, geometric modeling, and detailed data analysis. Furthermore, the study's relevance stems from its ability to improve body armor design, contribute to developments in protective equipment, and advance the area of materials science in ballistic application. The objectives of this study are to evaluate the effect of projectile impact towards flax sandwich plate at different velocity impact and too analyse the profile of failure of multiple ply flax with sandwich honeycomb plate when subjected to different velocity impact.

2. Method

The methodology used in this thesis is a complete approach to simulating and analyzing the ballistic impact behavior of flax fiber composites. Initially, geometric models of the projectile, honeycomb plate, and woven flax materials are created with Solidworks software. The velocity impact tests are then conducted using Ansys simulation software [2,3,4], which collects data on energy dissipation and damage propagation.

The FEA features of Ansys allow to simulate and assess the dynamic structural behaviour of mechanical components [5]. The impact resistance of honeycomb constructions and flax fiber arrangements is investigated using various orientations. The data from ANSYS simulations is rigorously evaluated to determine the performance of flax composites at various impact velocities. The impact of projectile towards target plate will results on the deformation of impacted plate at various range of impact velocities [6].

The methodologies used in this study are intended to offer a thorough knowledge of how flax fiber composites respond to ballistic impacts, eventually contributing to the optimization of body armor design and the improvement of protective materials in ballistic applications.

2.1 Modal and arrangement

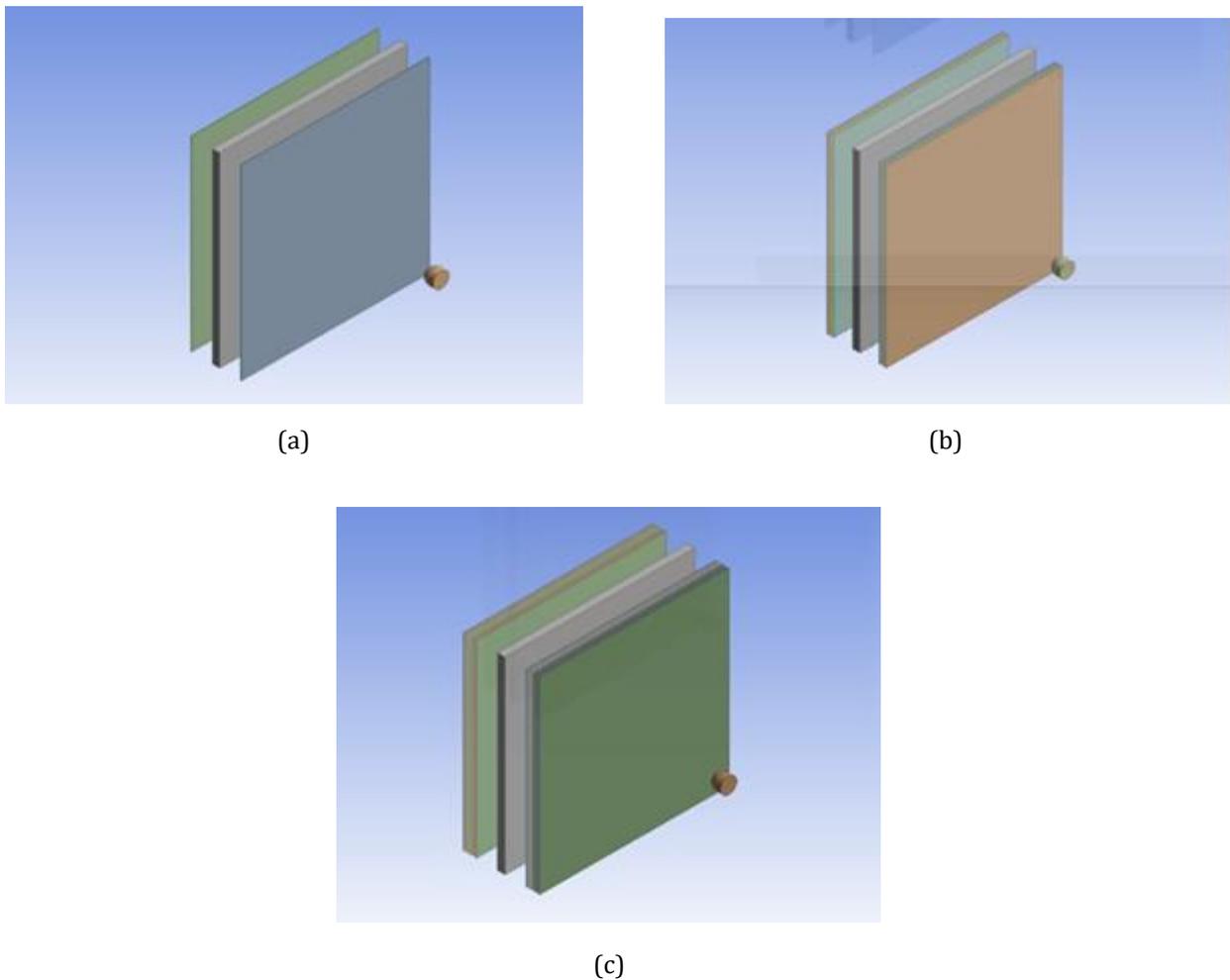


Fig 1 Modal arrangement, (a) Modal A, (b) Modal B, (c) Modal C

Table.1 Modal and arrangement

Modal	Arrangement	Arrangement of configuration
A	1	1 ply of flax plate with honeycomb
	2	1 ply of unidirectional flax with honeycomb
B	3	3 ply of flax plate with honeycomb
	4	3 ply of unidirectional flax with honeycomb
C	5	5 ply of flax plate with honeycomb
	6	5 ply of unidirectional flax with honeycomb

2.2 Bullet

The projectile component of firearms, bullets, is essential to the operation of contemporary weapons and understanding of bullets must take into account the physics of their trajectory, as well as their design and composition [7]. Ammunition typically consists of a bullet, casing, propellant, and primer [8]. In this study, the bullet utilised in the simulation had a diameter of 12.5 mm and a maximum velocity of 5 and 10 m/s, lead, with a density of 11340 kg/m³, a shear modulus of 8.6 GPa, and a mass of 12.75 g.

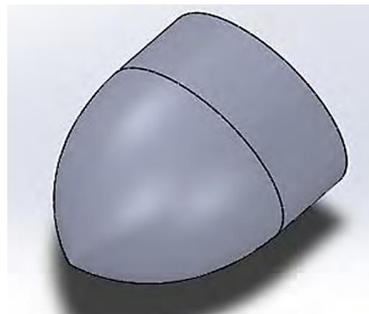


Fig 2 Bullet profile

3. Material

In this research, a family of composite constructions known as sandwich plate systems is made up of two thin, highly-strengthened face sheets that are divided by a lightweight core material. By combining the low density of the core material with the strength and stiffness of the face sheets, this design gives the structure exceptional mechanical qualities. In the fields of aerospace, automotive, marine, and civil engineering, where it's critical to strike a balance between strength, weight efficiency, and structural integrity, these systems are widely used. Because of their outstanding stiffness-to-weight ratio, sandwich plate systems are highly recommended for situations where weight is a crucial consideration. A gap between the face sheets is provided by the core material, which is frequently composed of lightweight materials like foam or honeycomb. The sandwich plate size is 150mm*150mm. This helps the structure endure shear, torsion, and bending stresses.

The simulation makes use of several flax plies. In order to investigate the various effects of ballistic hit, a different type of flax plywood was employed. The four types of plates are honeycomb with honeycomb as the core material, woven, unidirectional, and regular flat.

Table.2 *Materials properties*

Material	Density (g/cm ³)	Young Modulus (GPa)	Poisson Ratio	Thickness (mm)	Shear Modulus (GPa)
Woven Flax	1.20	10.00	0.3	0.75	4.0
Unidirectional flax	1.22	10.20	0.3	0.45	4.10
Honeycomb	0.08	0.225	0.001	6.00	0.070

4. Result

4.1 Velocity Impact Using a Similar Mesh Configuration

In Combination 5, which had five layers of woven flax and one layer of honeycomb, had the greatest capacity to slow down the bullet, lowering its velocity to 1.5386 m/s. In comparison, combination 6, which had five layers of unidirectional flax and one layer of honeycomb, produced a higher velocity impact value of 3.1031 m/s. This suggests that braided flax has a higher probability of stopping the projectile. The bullet deflected at 7.5×10^{-4} s for combination 5 at 5 m/s and 10.0×10^{-4} s for combination 6 at the same rate. At 10 m/s, combination 5 deflected 6.5 times, whereas combination 6 deflected 8.5 times, indicating that weaved flax is superior. Penetration or deflection varied with simulation duration, particularly evident in combinations 1, 2, 3, and 4 at 5 m/s and combinations 1 and 2 at 10 m/s.

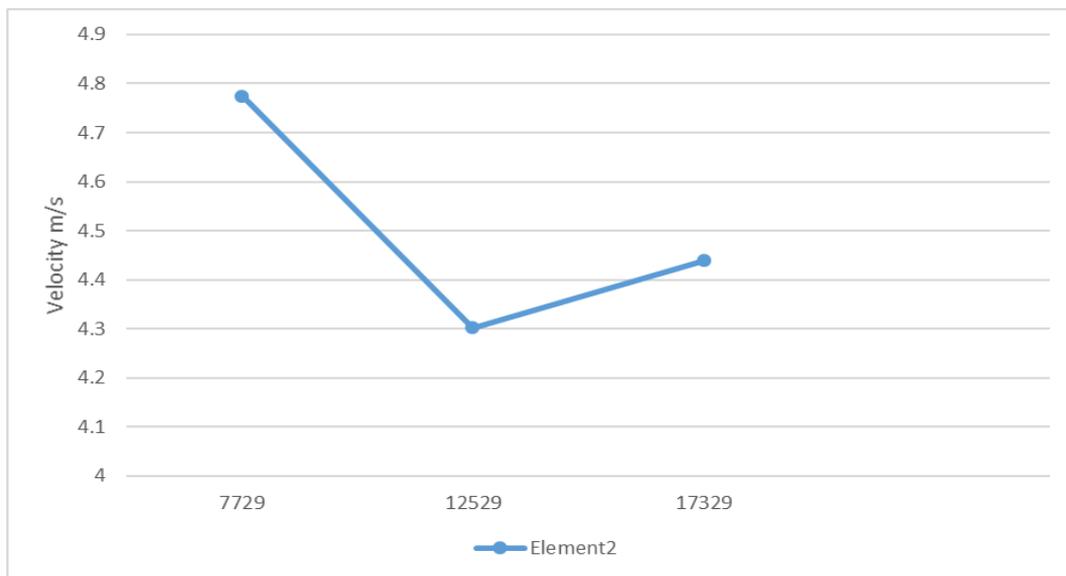
Table.3 *Result velocity Impact Using a Similar Mesh Configuration*

Combination	Initial velocity (m/s)	Velocity impact(m/s)	Time cycle of simulation(s)	Deflection time(s)	Penetration time(s)
1	5	4.7724	0.001	Not occur	Not occur
	10	9.6005	0.001	Not occur	Not occur
2	5	4.8034	0.001	Not occur	Not occur
	10	9.6869	0.001	Not occur	Not occur
3	5	3.2111	0.001	Not occur	Not occur
	10	5.5439	0.001	8.5×10^{-4}	Not occur
4	5	4.5889	0.001	Not occur	Not occur
	10	9.1601	0.001	10.0×10^{-4}	Not occur
5	5	1.5386	0.001	7.5×10^{-4}	Not occur
	10	2.6264	0.001	6.5×10^{-4}	Not occur
6	5	3.1031	0.001	10.0×10^{-4}	Not occur
	10	5.3040	0.001	8.5×10^{-4}	Not occur

4.2 Velocity Impact with Different Mesh Setups

Table.4 Result velocity impact with different mesh setup

Case	Combination	Element	Time of deflection ($\times 10^{-3}$ s)	Final velocity(m/s)
1	1	7729	1.125	4.7745
2	1	12529	1.375	4.3022
3	1	17329	1.625	4.4395
4	2	7653	1.625	4.6671
5	2	12453	1.625	3.9694
6	2	17253	1.875	2.9063

**Fig.3** The final velocity of combination 1 with various number of elements.

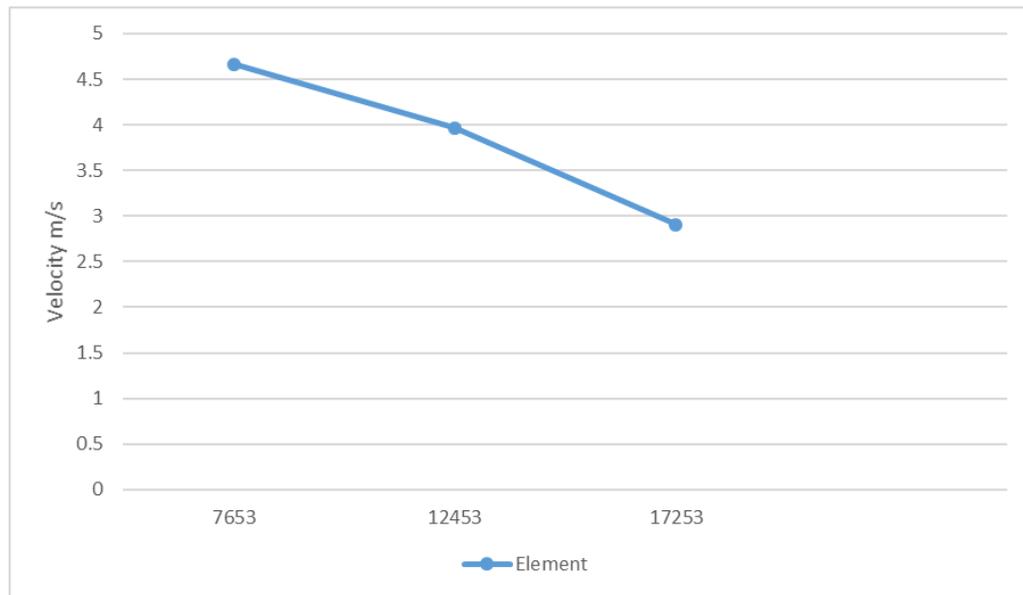


Fig. 4 The final velocity of combination 2 with various number of elements.

The amount of time required for the bullet to begin to deflect increased as the number of elements as shown in Table 4. The time of deflection in cases 1 through 3 increases from 1.125×10^{-3} s to 1.625×10^{-3} s, whereas the time of bullet before deflection in cases 4 through 6 increases from 1.625×10^{-3} s to 1.875×10^{-3} s. The final velocity of the bullet at time 2.5×10^{-3} s decreased as the number of elements increased. In Fig. 3, there is a rapid variation in final velocity at element 17329, but in Fig. 4, the velocity is steadily decreasing.

5. Conclusion

In this study, two types of simulations were conducted: velocity impact with the default meshing option, and various meshing settings that increased the number of elements in the plate combination. The plate was made up of 1ply woven honeycomb, 1ply unidirectional honeycomb, 3ply woven honeycomb, 3ply unidirectional honeycomb, 5ply woven honeycomb, and finally 5ply unidirectional honeycomb. Each plate underwent velocity impact simulation with bullets at beginning speeds of 5m/s and 10m/s. The results showed that the deflection time for the woven plate combination was substantially superior to the unidirectional plate combination for deflecting the bullet. The second simulation utilized a mix of plate 1ply woven with honeycomb and 1ply unidirectional with honeycomb. The simulation failed because the number of divisions increased to four owing to a mistake. One of the reasons for the inaccuracy is that penetration occurs at the fourth division, yet the material parameters do not contain maximum main strain and maximum shear strain. The second reason for the simulation's failure is that in the analysis setting in Ansys software under erosion control, the setting does not select "Yes" on material failure, but the different meshing settings show that the number of elements affects the time for the bullet to deflect due to velocity distribution that spreads more uniformly, even though the simulation failed.

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Conflict of Interest

The authors declare that there are no conflicts of interest concerning the publication of this paper.

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