Design and Analysis of Bulletproof Vest made from Fiber Reinforced Composite

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Abstract - *This research aims to optimize the construction of the panels for soft body armor by hybridization in order to achieve the improvement of ballistic performance. The analysis of the composites panels as a replacement for the presently used bulletproof, panel is studied in this work. The work focuses on three natural fiber composites and their suitability to the application. The Bullet was modeled as per the standard design of a 9 mm bullet used in several other studies. The velocity was fixed for the bullet and the impact analysis was performed individually for all the panels.*

Three hybrid panels were designed and evaluated. In the performance ballistic tests, the jute fiber panel was more likely to stop the projectile compared to Coir sheath and PALF fiber panels with the same areal density. In the non-perform ballistic tests, the hybrid panel achieve the improvement of ballistic performance and light weight. Such hybrid design makes best use of different available materials to achieve the improvement of ballistic performance and light weight of a panel. It has a practical significance for the soft armor panel design.

Key Words: Composites, Bulletproof, Key Impact Ballistic, Armour

1. INTRODUCTION

The consequence of 2nd world war leads the Army and defense industries to implement the huge and constrained body armors into more prominent protectors. Days have come with the gradual growth in terrorism storms and battle. The requirement of foremost good ballistic safeguard for soldiers and defense, officers and also the self safeguarding, , which is faced by the engineers and scientists to counter this consequence of ballistic protection field to counter the attacks [5].

Today's world, technologies are utilised for good protection, and one of the most essential is to reduce weight by developing tools for armour that results in foremost protection, lower armour mass. Blast protection, as it has been called for decades, is a type of sandwich with excellent energy absorption properties. [6].

1.2 Earlier Body Armor

Earlier Armours were to heavey and constrained as shown in figure. Medieval armours were to heavy such that it weighed more than 26 kg. These were taken into account for thier head, chest, leg and hand safety from sharp weapons such as sword also arrows. Besides they were heavy, a man worn this feel uncomortable.

Fig 1. Earlier Body Armor [4]

These have been now replaced with well modified armours as shown below figure 1. These are convenient to wear, easy to carry and isn't heavvy as Medieval Armor. Which can perevent gunfire and save the men's lives. Present study is focused on Civil officers, political leaders, V.I.P. These are now known as "Bulletproof Vest" well modified to save the lives as mentioned above

2. Literature review

Onyechi, Pius C et.all [1], Authors used finite element analysis (FEA) to study the stress-strain magnitude on body armor composites made of glass fiber reinforced polyester (GFRP) when they collide with ogival and conical nosed bullets. The plain stress study revealed that the composite is harder along the longitudinal axis. It is supported by the fact that the highest stress in the X direction was 328.125 Mpa, whereas the maximum stress in the Y direction was 57.726

Mpa, The study also reveals that the highest stress manipulation occurred around the event hole and the least occurred near the sample's exterior boarders.

Yohannes Regassa et al. [2], in this research authors carried out modeling and simulation by means of solid work and Abqus. Kelvar-29 fiber and polyester resin were used in the modeling of composite body armor. Since a matrix indicates no penetration through the modeled composite body panel with a projectile of 7.62x39mm bullet impact load at 10m and 50m and the mass of the modeled composite body was 1.5kg, the simulation results imply for 20 layers of woven Kevlar-29 fiber through polyester resin. The findings were compared to published findings and found to be in good agreement. There is also an effort to localize the product using local materials while transferring technologies at a low cost. By taking into account the present thickness and mass of modeled and simulated composite body bullet resistance.

Shashi Kant et al [3], in this research, advanced techniques like as Ansys were utilized to improve the vest's efficiency and as a result the bullet's control. This review attempts to discuss the properties of the manual made fiber and polymers from which these types of vests are made in order to identify the greatest one based on directional deformation, total deformation, shear stresses, and principal stresses for a variety of types of work wear (in particular Bullet proof vests).

3. METHODOLOGY

•Preparation of CAD Model for the selected composite panels using CATIA V5

•Generation of FE Model for prepared CAD model using ANSYS.

•Apply the materials and their properties for the generated FE model.

•Apply Loads and Boundary conditions depends on the selected impact conditions.

•Analyzing the FE Model using ANSYS.

•Obtain the results after completion of analysis...

4. FINITE ELEMENT ANALYSIS

4.1 GEOMETRIC MODELING

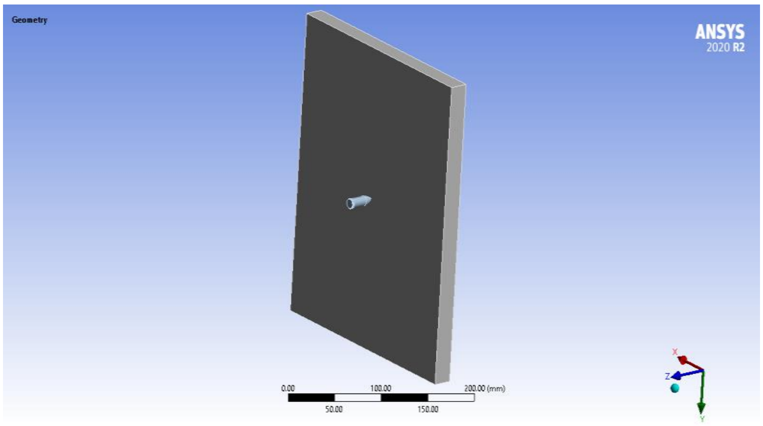

Fig 4.1: 3D CAD Model of the natural fiber bulletproof panel

Figure 4.3 gives the 3D representation of the bullet and the panel given in Figure 4.1 and 4.2. The bullet model is modeled based on literature review. The software used for modeling the panel and the bullet is CATIA v5 (Part modeling and assembly modeling)

4.2 NUMERICAL MODELING

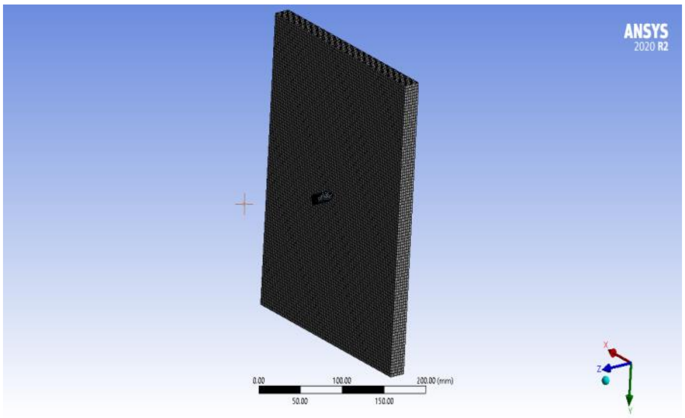

Fig 4.2: 3D Discretized model of the bulletproof composite panel and bullet

The 3D CAD model is then discretized to be able to solve the interaction between the bullet and the panel. The Discretization was done by using 1mm element. This Discretization helps the numerical methods in solving and accurately predict the results required by the user.

4.3 MATERIAL PROPERTIES

4.3.1 Jute

Jute is one of the types of textile fiber produce from jute crop. It crop is considered as commercial crop also many type verities of botanical jute can be seen among this Corchorud olitorius are main specie which are used to produce white jute. But co chorus capsular is (toss jute) is specie of jute and referred to be the superior besides it is harder to cultivate. Jute is in second in natural fiber while cotton stands in the first position jute are not grown in the first world countries and these are mainly grown in India and its surroundings countries this plant grows up to 10 feet and it is longest textile fiber.

Table 4.1: Mechanical Properties of jute fiber

Properties	Value	Unit
Density	1.5	g/ cm3
Tensile strength	393 – 773	MPa
Young's modulus	26.5	GPa
Poisson's Ratio	0.38	-
Elongation of break	3	%

4.3. Coir Sheath

Coir sheath: Another important natural fibre is coir. Coir is being choosen for its good strength and tough material. This is taken from the ripe coconut fruit husk. It is prepared by the husk of coconut these are largely found in south Asia countries such as India, Bangladesh, Sri Lanka and Vietnam Etc. Every year around forty million metric tons coconut is grown in the world. Coconut husk contains approximately 76 percent of the fibre remaining 24 percent includes "coir pith" 15. And coir fibres contain 35 & 44 percent cellulose 32.25 percent lignin and it also includes 15.17 percent hem cellulose similar to various natural grown fibres.

One of the important facts of this type of natural fiber is low gradation rate due its high lignin content 17, 18. Advantages of coir compared to different naturally grown fiber are, less expensive, low elastic modules 19, 20

Table 4.2 : Material properties of Coir.

Properties	Value	Unit
Density	1.1 to 1.5	g/ cm3
Tensile strength	105 – 593	MPa
Young's modulus	6	GPa
Poisson's Ratio	0.39	-
Elongation of break	3	%

4.4. PALF

PALF extracts multi-cellular and lignocelluloses materials from the leaves of the plant Ananas cosmos which belongs to the Bromelaaceae family, by retting (separating the fabric bundles from the cortex). PALF has a ribbon-like form and is held together by lignin, pentosan like materials, which provides the fiber its strength like other vegetables fiber, PALF fiber has multcellular fiber. PALF has comparably good potential for reinforcement in thermoplastic composites.

Table 4.2 Mechanical Properties of PALF

Properties	Value	Unit
Density	1.526	g/cm^3
Softening point	104	°C
Tensile strength	170	MPa
Young's modulus	6260	MPa
Specific modulus	4070	MPa
Elongation of break	3	%
Moisture gain	12	%

4.4 Loads and boundary conditions

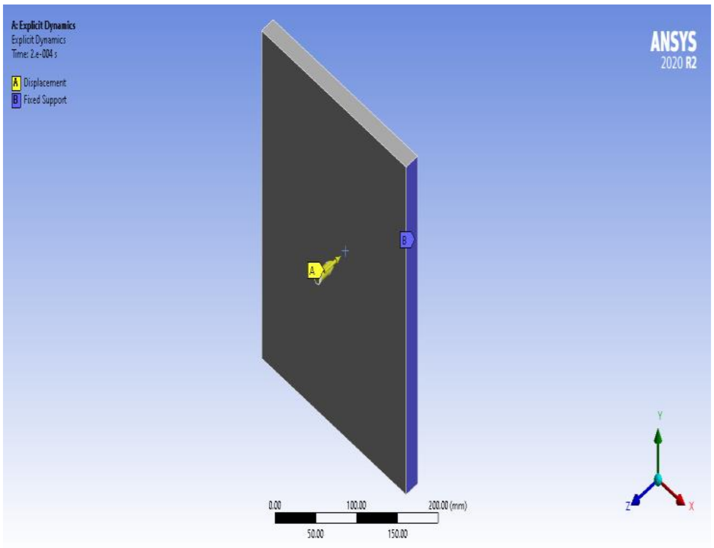

Fig 4.3: Loads and Boundary conditions for impact analysis

The loads and boundary conditions for the analysis is setup as given in the figure 4.3. The bullet model is allowed to move in the z-direction and constrained in the X and Y irections. The Bullet model is given a displacement of 50mm to occur in 0.0002s which equals to the velocity of 250m/s. The bullet is considered as rigid and the material properties are applied. The panel is modeled as PMC and fixed at both end and the material properties are applied as per requirements.

5. Results and Discussion

5.1 Von Misses Stress

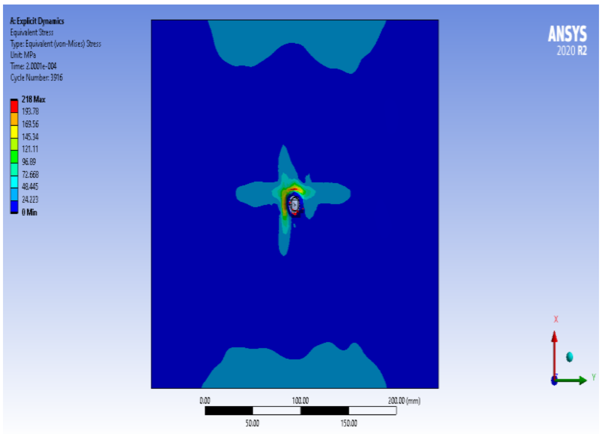

Fig 5.1: Von Misses stress plot for impact analysis of jute fiber composite

Figure 5.1 gives the representation of the von misses stress developed in the composite panel made of jute fiber during impact analysis. The plot shows that the maximum stress developed in the panel is 389Mpa. The plot also shows that the majority of the energy is absorbed around the impact area and the remaining areas remain unaffected by the impact of the bullet. This also shows that the stress propagation if horizontal in the panel indicating that the energy absorption does not affect a large portion of the composite panel.

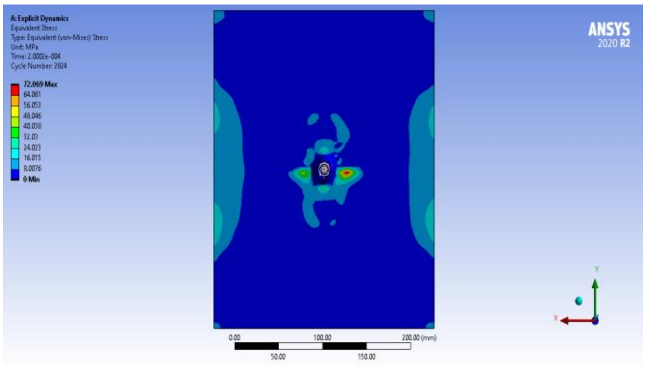

Fig 5.2: Von Misses stress plot for impact analysis of Coir fiber composite

Figure 5.2 gives the representation of the von misses stress developed in the composite panel made of coir sheath fibers during impact analysis. The plot shows that the maximum stress developed in the panel is 179 Mpa. The plot also shows that the majority of the energy is absorbed around the impact area and the remaining areas remain unaffected by the impact of the bullet. This also shows that the stress propagation if vertical in the panel indicating that the energy Absorption does not affect a large portion of the composite panel.

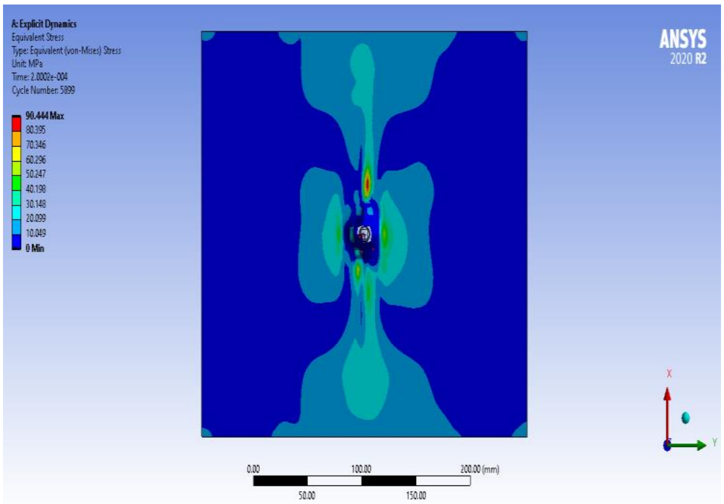

Figure 5.3 gives the representation of the von misses stress developed in the composite panel made of PALF during impact analysis.

The plot shows that the maximum stress developed in the panel is 155Mpa. The plot also shows that the majority of the energy is absorbed around the impact area and the remaining areas remain unaffected by the impact of the bullet. This also shows that the stress propagation is both horizontal and vertical in the panel indicating that the energy absorption affects a large portion of the composite panel.

Table 5.1: Stress variation in the composite panels during Impact analysis according to time

Sl No	Time (s)	Jute (MPa)	Coir Sheath (MPa)	PALF (MPa)
1	1.18E-38	0	0	0
2	1.01E-05	166.31	120.39	111.76
3	2.02E-05	197.41	79.019	57.97
4	3.01E-05	233.58	49.842	58.784
5	4.01E-05	253.43	80.697	57.918
6	5.00E-05	280.95	106.6	91.463
7	6.00E-05	389.23	169.38	155.2
8	7.00E-05	261.77	179.56	154.5
9	8.01E-05	222.78	104.88	95.83
10	9.01E-05	196.64	114.54	81.458
11	1.00E-04	276.2	99.055	83.928
12	1.10E-04	168.47	106.77	93.975
13	1.20E-04	151.96	111.84	79.107
14	1.30E-04	194.29	103.36	86.261
15	1.40E-04	256.59	83.946	87.303
16	1.50E-04	285.32	86.88	77.919
17	1.60E-04	287.19	91.903	67.342
18	1.70E-04	274.21	89.469	65.328
19	1.80E-04	266.48	91.138	69.439
20	1.90E-04	245.48	86.128	69.683
21	2.00E-04	218	90.444	72.069

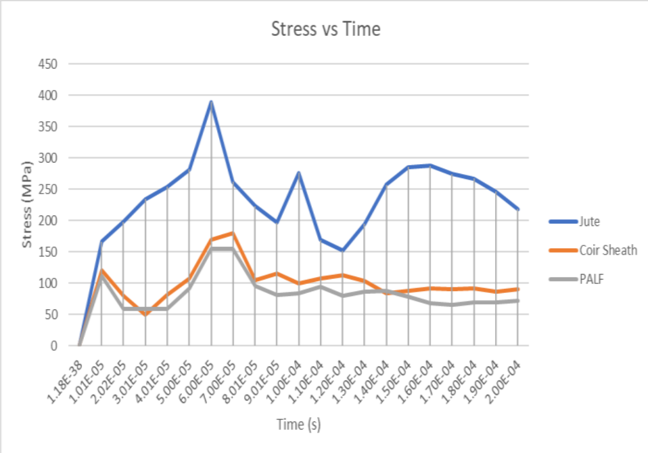

Fig 5.4: Graphical representation of the stress variation in the composite panels

Table 5.1 and Figure 5.4 show the graphical representation of the stress variation in the entire three composite panels with respect to the total Impact time. The graph shows that the highest stress development is in the jute fiber composite and the lowest is seen in the PALF composite panel.

5.2 Forces at Entry

Table 5.2 and Figure 5.5 give the graphical representation of the force induced in the composite panel by the bullet at the entry face. The variation in force between the three materials shows that the highest variation is seen for the jute fiber and the lowest is seen for the PALF fiber which indicates that the jute fibers have a higher tendency to absorb the impact energy than the other fibers

Table 5.2: Variation of force of bullet impact at the entry of the composite panel

Sl NO	Time (s)	Jute (N)	Coir Sheath (N)	PALF (N)
1	1.18E-38	0	0	0
2	1.01E-05	0	0	0
3	2.02E-05	0.29415	0	134.52
4	3.01E-05	123.75	90.979	372.22
5	4.01E-05	209.92	62.185	182.83
6	5.00E-05	989.99	130.11	144.58
7	6.00E-05	353.17	200.35	289.55
8	7.00E-05	224.29	488.42	293.28
9	8.01E-05	555.18	395.82	595.17
10	9.01E-05	845.8	558.72	520.92
11	1.00E-04	913.12	247.32	717.7

12	1.10E-04	414.51	381.6	546.75
13	1.20E-04	705.93	227.73	755.07
14	1.30E-04	1487	593.11	847.56
15	1.40E-04	2421.6	701.05	1105.7
16	1.50E-04	2802	1022.4	1250
17	1.60E-04	2859.4	1402.8	1283.6
18	1.70E-04	2402.8	1387.7	760.22
19	1.80E-04	2251	1186.2	325.32
20	1.90E-04	1834.4	708.97	150.26
21	2.00E-04	1639.7	644.14	102.59

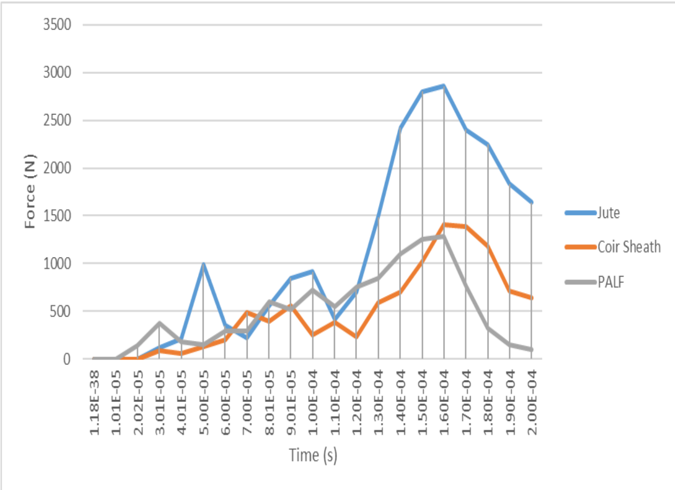

Fig 5.5: Graphical representation of the variation of force of bullet impact at the entry of the composite panel.

5.3 Forces at Exit

Table 5.3: Variation of force of bullet impact at the exit of the composite panel

Sl No	Time (s)	Jute (N)	Coir Sheath (N)	PALF (N)
1	1.18E-38	0	0	0
2	1.01E-05	0	0	0
3	2.02E-05	7.46E-02	0	54.867
4	3.01E-05	61.23	57.84	35.858
5	4.01E-05	330	184.59	20.272
6	5.00E-05	246.71	42.183	45.543
7	6.00E-05	958.98	166.66	186.18
8	7.00E-05	86.467	120.17	369.78
9	8.01E-05	585.62	369.76	571.05
10	9.01E-05	800.67	542.09	578.18
11	1.00E-04	817.99	165.23	623.1
12	1.10E-04	336.57	194.51	512.76
13	1.20E-04	680.48	139.77	786.96
14	1.30E-04	1543.4	574.08	823.87
15	1.40E-04	2121.5	700.25	1029.8
16	1.50E-04	2749.1	1050.6	1174.9
17	1.60E-04	3039.9	1137.4	1310.2
18	1.70E-04	2375.7	1405.2	833.03
19	1.80E-04	2012	1293.3	350.82
20	1.90E-04	1791.6	873.11	184.77
21	2.00E-04	1519.7	694.82	141.82

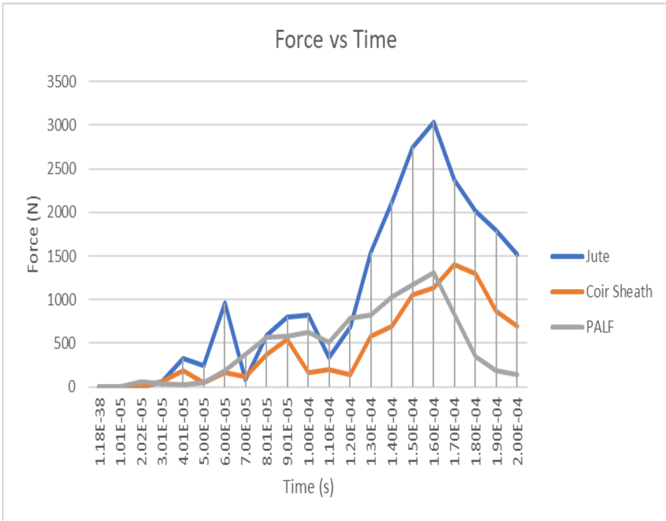

Fig 5.6 : Graphical representation of the variation of force of bullet impact at the exit of the composite panel

Table 5.3 and Figure 5.6 gives the graphical representation of the force induced in the composite panel by the bullet at the exit face. The variation in force between the three materials show that the highest variation is seen for the jute fiber and the lowest is seen for the Coir sheath fiber which indicates that the jute fibres have a higher tendency to absorb the impact energy than the other fibers. The comparison between the forces in the entry and exit faces show that the force applied by the bullet on the composite panels is higher at the entry face as compared to the force applied at the exit face

6. CONCLUSIONS

The analysis of the composite panels as a replacement for the presently used bullet proof panels is studied in this work. The work focuses on three natural fiber composites and their suitability to the application. The bullet was modeled as per the standard design of a 9 mm bullet used in several other studies. The velocity was fixed for the bullet and the impact analysis was performed individually for all the panels. The analysis of the results obtained for the three panels indicate that

•The force distribution of the three panels showed a large force variation in the jute fiber panel for both entry and exit faces.

•The jute fiber composite panel has the highest energy absorption capacity .

•This indicates that the force transfer from the bullet to the panel is highest for the jute fiber composite panel and hence can beconsidered as th eoptimum selection for the given conditions.

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