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Finite Element Simulations of Ballistic Impact on Glass Fiber Composite

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***Abstract*: Conventional layup technique is used for manufacturing laminated polymer composite. By using this technique composite structures are prone to edge delamination. Wrap around technique is used for suppressing edge lamination problems. By using this technique composite properties will increase and delamination can be minimized. This results in increased life for the composite. Impact analysis is conducted on Glass Fiber composite under three different velocity on wrap around composites. From the results check whether the glass fiber composite can withstand at applied velocities. According to the analysis results implement glass fiber in the manufacturing of body armors**

I. INTRODUCTION

Interlaminar fracture or Delamination of polymeric based structural composites is generally caused by high interlaminar stresses, that occurs due to mismatch in elastic properties between free edge and plies. Laminated composite structures manufactured by conventional lay-up technique are subjected to edge delamination. The presence and growth of delamination in composite laminates may lead to safety problems, such as reduction of stiffness, fatigue life and strength etc. Therefore, understanding the behavior of stress and delamination have critical importance in the analysis of structural behavior of composite materials and structures. Many investigators have studied free edge effects with delaminated composite laminates subjected to load because of the negative effect of delamination on the structural integrity. The delamination is found to be sensitive to laminate stacking sequence, fiber orientation, and ply thickness.

In present scenario all vests manufactures are trying to build them at minimum manufacturing cost as well as light weight. For this many experiments are being carried out for finding out a best solution. The above can be achieved by introducing good materials, good design concept and effective manufacturing process. Kevlar is a material commonly used to make bullet proof vests. Kevlar is not a economic product. This will cause high manufacturing cost.

II. PROBLEM STATEMENT

Conventional layup technique is used for manufacturing laminated polymer composite. By using this technique composite structures are prone to edge delamination. Wrap around technique is used for suppressing edge lamination problems.

By analyzing stresses on glass fiber composite and use this material as alternative one for the manufacturing of civilian ballistic vests. Ballistic vests made by Kevlar and other types of bullet proof materials are very costly. In order to reduce this manufacturing cost and make vests more familiar to the civilians, a low cost vest material is to be introduced. Compared to military purposes civilian ballistic vests have low strength. The objective of this project is to replace the material used in manufacturing of civilian vest which will ensure safety and can be produced at low cost and easy manufacturing methods.

III. OBJECTIVE

Composite material plate was analyzed using FEM technique to know high velocity impact analysis of plate. Ansys software was used to find out the result. The analysis of composite materials with high cost and limited amount of data from impact testing has lead to ballistic tests expensive and time consuming. In order to ignore this issue, finite element analysis can be used as a method to find out the response of ballistic composite material and to obtain parameters affecting impact phenomena. The main focus of this research work is to study the response of thick plate made of composite material at a high velocity impact by using finite element analysis.

IV. MATERIALS AND METHODS

A composite material is defined as a combination of two or more chemically or physically distinct constituents in a macroscopic level. The constituents present in the composite material should maintain their individual identities and properties, but together they produce a new material, the properties which are to be superior to those of the constituent materials.

A. Glass Fiber

Fiberglass is a type of fiber reinforced material where the fiber reinforcement is glass fiber. The glass fiber may be flattened into a sheet, randomly arranged or woven into a fabric. The most often plastic matrix are epoxy, polyester resin or vinyl ester. Depending upon uses of glass fiber various types are manufactured. These glasses all contain boron, silica or silicate and sometimes with varying amounts of oxides of calcium, magnesium, . To be used in body amour, glass fibers have to be made with very low amount of defects.

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B. Properties of Glass Fiber

A structural glass fiber is both strong and stiff in tension and compression along its axis. Although the glass fiber is weak in compression, it is due to the long aspect ratio of the fiber. A typical fiber is long and narrow and also buckles easily. On the other hand, across its axis the glass fiber is weak in shear.

By laying multiple layers of fiber oriented in various preferred directions and top of one another, with each layer , by this stiffness and strength can be easily controlled. In fiberglass, the properties depending upon the directions chosen by the designer. With woven fabrics stiffness and strength can be more efficiently controlled within the plane

Table 1 Glass Fiber Properties

Density (g/cm3)	2.55-2.6
Tensile strength (GPa)	3.445
Young's Modulus(Gpa)	72.3
Elongation at Break (%)	4.6-4.9
Poisson ratio	0.2

C. Optimization Technique In Designing Composite Layer

The composite manufactured have 15 layers and each layers are to be placed in different angles. This is to ensure equal strength in all directions. Glass fiber chosen is woven type. In order to find out superior angles for the layers, optimization technique is used with the help of Ansys software.

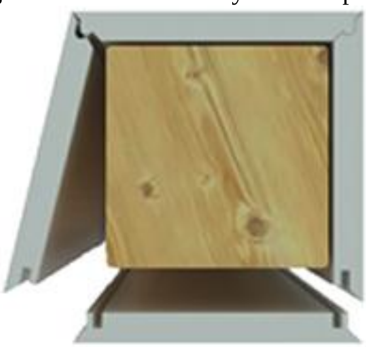
D. Optimization Method

The optimization method used here is Screening optimization. In this method simple approach based on sampling and sorting. It supports multiple objectives and constraints as well as all types of input parameters. Usually it is used for preliminary design, which may lead you to apply other methods for more refined optimization results.

In this method, 20 samples are generated and find 3 candidates after 20 evaluations.

E. Wrap-Around Technique

Wrap-Around Technique is nothing but, process of giving an outer cover for a layered composite product which is being manufactured by any one of manufacturing methods being used in the industries. The purpose of outer covering is to resist edge delamination in a layered composites.



F. Bullet Resistant Soft Body Armor Vests

Although soft body armors are used to prevent penetration by specified small arms projectiles, deformations in the form of indentations can occur to the extent that further life-threatening injuries remain possible. Impact deformation limits are often specified to help minimize indentation depths, which are also known as BFSs

To maximize energy absorption levels, therefore, one must understand the materials and mechanics of the

1. fiber bundles within the yarns.
2. Type of woven architecture that forms the layers, and
3. Stacking arrangement and stitching patterns of the layers that form the ballistic packs.

Engineers and scientists must consider the woven armour as a system of subsystems that span multiple dimensional scales to maximize protection levels. Stages behind the preparation of woven fabrics are multiple fibers (or filaments) are bundled to form a yarn, yarns are woven to form a fabric layer, and fabric layers are stacked and joined to form body armors.

G. Use of Soft Bullet Proof Material

Bullet resistant panels are specified in many design situations. The more common applications include judge's benches, courtroom protection for the witness box and the jury area, within the wood work of teller's cages or in banks counters, as a bullet proof barrier within government buildings, police stations, guard houses, control rooms within prisons, convenience stores, check cashing stores.

V. SOLID MODELLING AND FEM ANALYSIS

The two dimensional drawing of the test specimen is fixed at first. From main menu we go to 'Geometry'. Then select the required plane. Then the required lines are drawn by using the 'sketch' option. In between them usage of necessary steps are followed for obtaining the desired model from the 'mechanical design' menu option.

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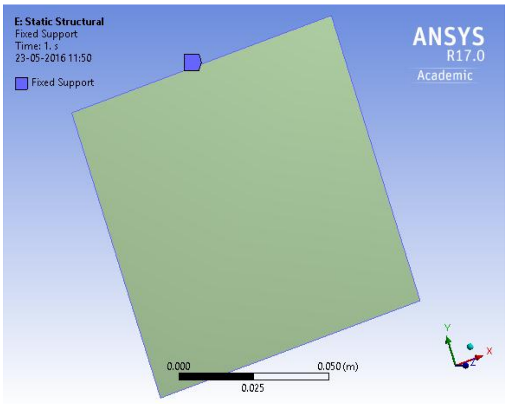
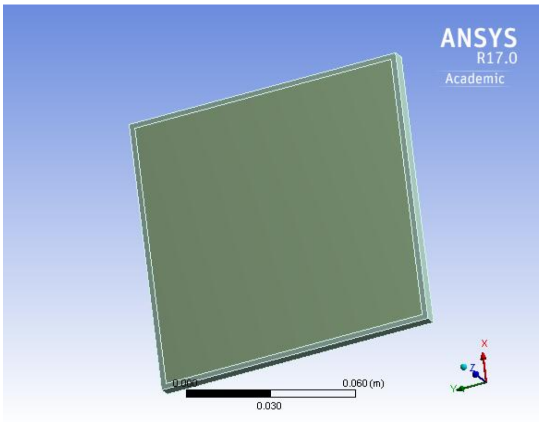


The first FEA model was developed to understand the basics of the model development sequence in Ansys. The execution helped to identify necessary modules and results that could be used to improve the observed result qualitatively and quantitatively. These models also helped to find methods of trouble shooting errors incurred and software options for better efficiency leading to second generation models. These second generation models helped to identify drawbacks in meshing, material modeling and established the need for better material inputs and progressive damage models.



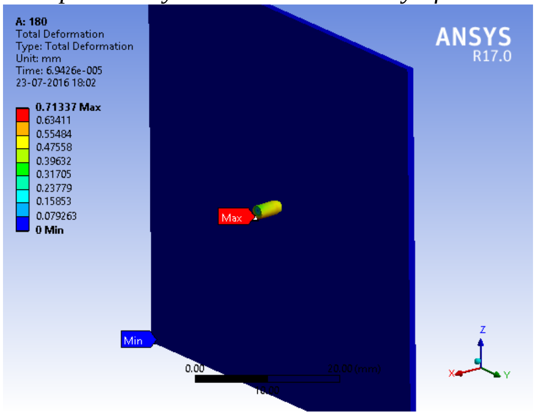
A. Finite Element Analysis

The model created was analyzed with the help of ansys software. From engineering data proper material is selected, material properties like Poisson's ratio, mass density and Young's modulus are checked. Next step is to give meshing to the obtained glass fiber block. . This analysis is based on static structural type analysis. After this, has to apply the boundary condition.

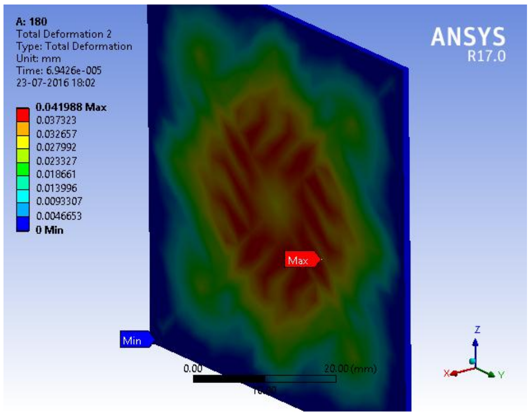
VI. RESULTS AND DISCUSSION

Finite element analysis is carried out on models at three different velocity of 180,250.350m/s. To check whether the composite can withstand at specific impact velocities.

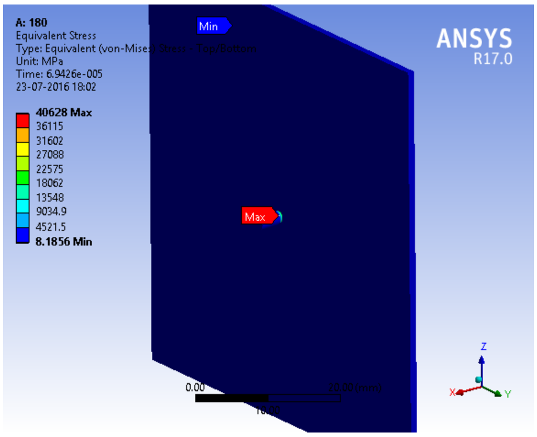
A. Impact Analysis at a Bullet Velocity of 180m/s



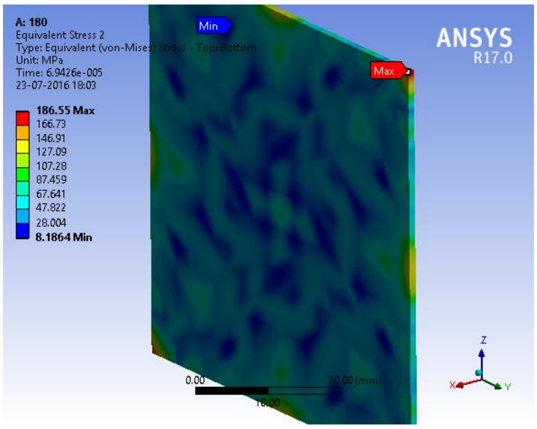
The deformation value recorded is 0.7133mm for the bullet.



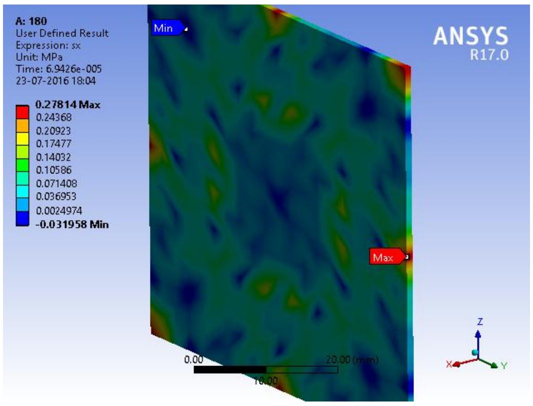
In static analysis, fibre which is subjected to boundary conditions such as the plate has been fixed and given a bullet velocity as 180 m/sec indented on a plate. The maximum deformation value recorded on the fiber plate is 0.041mm.



The above figure shows the Von Mises Stress Distribution in case of bullet. Von Mises Stress Distribution of the bullet is 40628Mpa.

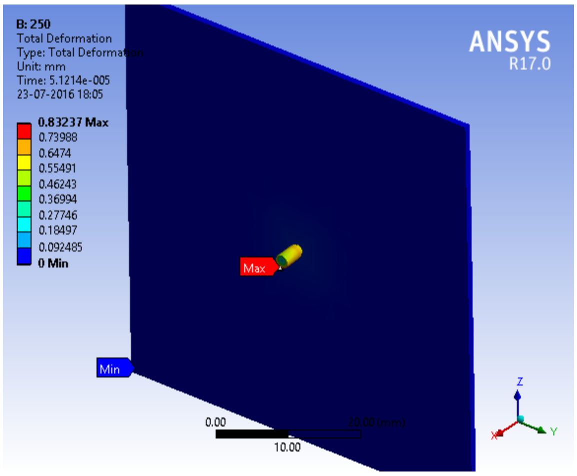


The above figure shows the Von Mises Stress Distribution for fiber plate. Von Mises Stress Distribution of the fiber plate is 186.55Mpa.

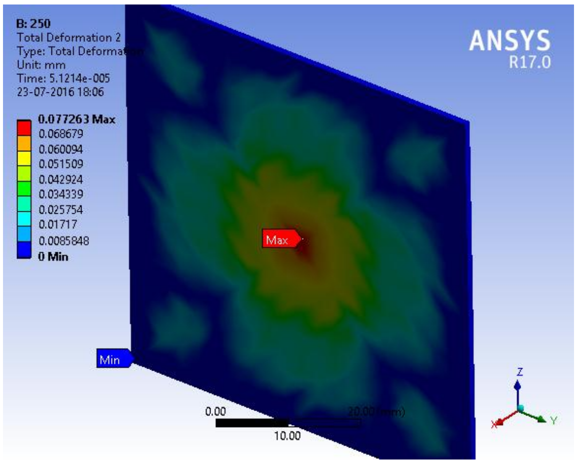


The above figure shows the inter laminar stress distribution between layer 1&15 for fiber plate. The inter laminar stress distribution between layer 1&15 for the fiber plate is 0.27814Mpa.

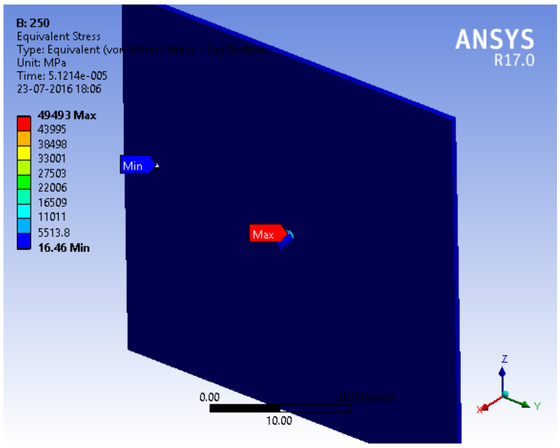
B. Impact Analysis at a Bullet Velocity of 250m/s



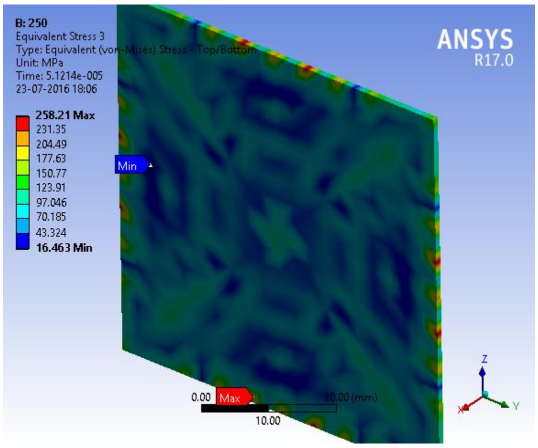
In static analysis, fibre which is subjected to boundary conditions such as the plate has been fixed and given a bullet velocity as 250 m/sec indented on a plate. The maximum deformation value recorded on the bullet is 0.8323mm



The above figure shows the total deformation occurred to fiber plate. The maximum deformation value recorded on the fiber plate is 0.077mm.



The above figure shows the Von Mises Stress Distribution in case of bullet. Von Mises Stress Distribution of the bullet is 49493Mpa.



The above figure shows the Von Mises Stress Distribution for fiber plate. Von Mises Stress Distribution of the fiber plate is 258.21Mpa

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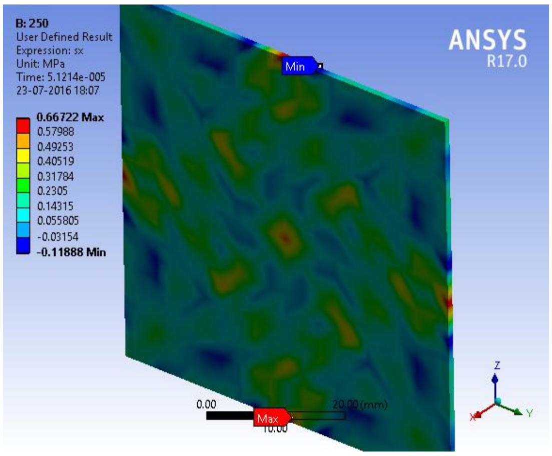
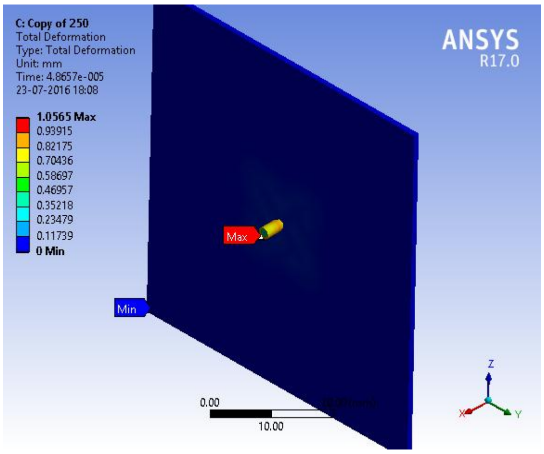
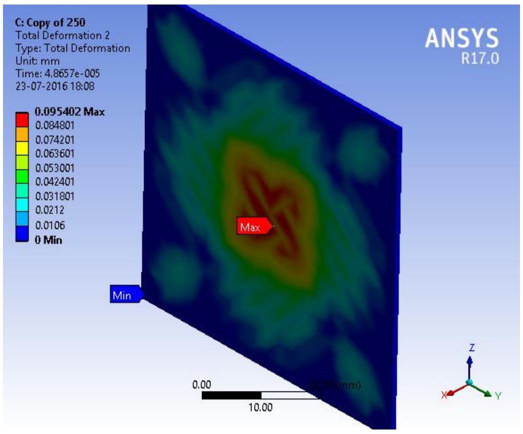


The above figure shows the inter laminar stress distribution between layer 1&15 for fiber plate. The inter laminar stress distribution between layer 1&15 for the fiber plate is 0.6672Mpa.

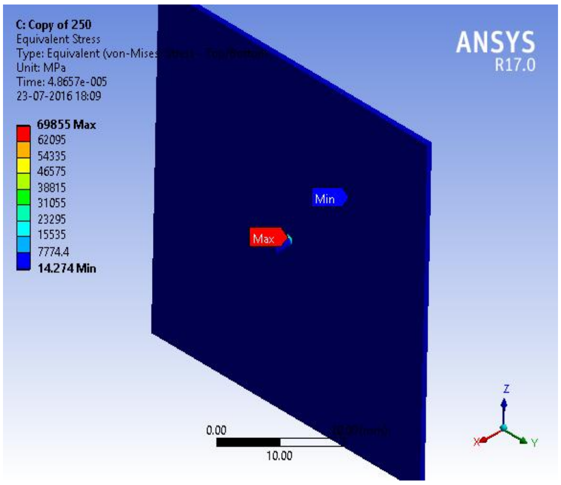
C. Impact Analysis at a Bullet Velocity of 350m/s



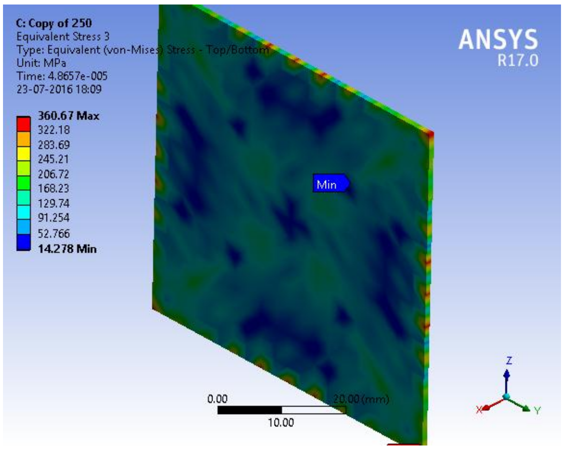
Total deformation obtained for bullet with wrap during static analysis is shown in above figure. The maximum deformation value recorded on the bullet at a velocity of 350 m/sec is 1.0565mm.



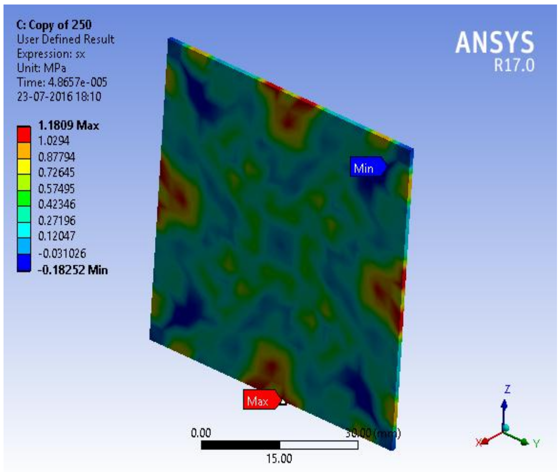
The above figure shows the total deformation occurred to fiber plate. The maximum deformation value recorded on the fiber plate is 0.0954mm.



The above figure shows the Von Mises Stress Distribution in case of bullet. Von Mises Stress Distribution on the bullet is 69855Mpa.



The above figure shows the Von Mises Stress Distribution for fiber plate. Von Mises Stress Distribution of the fiber plate is 360.67 Mpa.



The above figure shows the inter laminar stress distribution between layer 1&15 for fiber plate. The inter laminar stress distribution between layer 1&15 for the fiber plate is 1.180Mpa.

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Table 2 Comparison of Deformation at Different Velocities on Bullet and Fiber

Speed	Bullet Deformation(mm)	Fiber Plate Deformation(mm)
180m/s	0.7133	0.0419
250m/s	0.8323	0.0772
350m/s	1.056	0.0954

Table 3 Comparison Between Von Misses Stress Distribution at Different Velocities

Speed	Bullet(Mpa)	Fiber Plate(Mpa)
180m/s	40628	186.55
250m/s	49493	258.21
350m/s	69855	360.67

VII. CONCLUSION

Detailed study about glass fiber composite materials are done. Solid Modeling and Impact analysis are Completed. Wrap around composites are tested using Ansys software.

Wrap around composite shows improved properties. Finite element analysis is carried out on model at three different velocity of 180,250.350m/s. From the analysis Glass fiber composite can with stand up to a bullet velocity of 350m/s.

From the results wrapped model shows minimum deformation in case of material and maximum deformation to the bullet. Thus the Glass Fiber Composite can be used for manufacture soft ballistic amours.

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