© February 2022| IJIRT | Volume 8 Issue 9 | ISSN: 2349-6002

# Deformation studies of Bullet proof vest designed with various composite materials

M.S.Prabhu[1], V.Ganesan[2]
[1,2] *Assistant Professor, Department of Aeronautical Engineering, Hindusthan Institute of Technology*

***Abstract* - The manuscript focuses on investigation of various composite materials used to make bulletproof vests, thereafter, to analyze their effectiveness and to identify the optimum material based on directional deformation, total deformation, shear stresses and principal stresses by using ANSYS.**

**When a bullet strikes body armor, it is caught in a web of a very strong fiber. These fibers absorb and disperse the impact energy that is transmitted to the vest from the bullet causing the bullet to deform or mushroom. Additional energy is absorbed by each successive layer of the material in the vest, until such time as the bullet has been stopped.**

**The fiber helps the bullet from penetrating into the body by distributing bullet's force uniformly. Hence after comparison of different properties of the fibers, a bulletproof vest would be designed using Ansys software. These vests will be tested for penetration and hence its effectiveness would be determined.**

***Index Terms* - bulletproof, ansys, anti-ballistic, armor, shear stresses.**

## I.INTRODUCTION

A composite material is defined as a material comprising of two or more chemically and or physically distinct constituents (phases) combined on a macroscopic scale. The constituents present in the composite material retain their individual identities and properties, but together they produce a material system, the properties of which are designed to be superior to those of the constituent materials acting independently. A composite material consists of two phases one is called reinforcement and other is called matrix. These two phases are separated by distinct interfaces.

The design of composite armor is a very complex task as compared to conventional single-layer metallic armor, due to the exhibition of coupling among membrane, torsion and bending strains, weak transverse shear strength and discontinuity of the mechanical properties along the thickness of the composite laminates. This has drawn attention of several researchers to study the penetration phenomenon in composite amours. The first protective clothing and shields were made from animal skins.

As civilizations became more advanced, wooden shields and then metal shields came into use. Eventually, metal was also used as body armor, what we now refer to as the suit of armor associated with the knights of the Middle Ages. However, with the invention of firearms around 1500, metal body armor became ineffective. In general, the battlefield demands durable, reliable, light, maneuverable and fast vehicles which, at the same time, can provide the required level of protection for the vehicle occupants. The traditional steel armor, while providing the required level of protection for the on-board personnel and do it at a relatively low cost, contributes a prohibitively large additional weight to the battle vehicles, often increasing the loads beyond the levels anticipated during the vehicle design. In this review, a brief account of response of thick plate made of composite materials when impacted at high velocity by using finite element analysis, the effect of simulation on different materials to find high velocity impact on their structures and the analysis of deformation of thick plate when struck by bullet at high velocity has been done. These two phases are separated by distinct interfaces. The most useful properties of composites are high specific strength and specific stiffness, good corrosion resistance and good fatigue resistance.

On account of these highly desirable characteristics, composites have rightfully emerged as important engineering materials for applications where weight of the components or structure is an important consideration. Advanced composite materials, typically consisting of reinforcing fibers (e.g. carbon fibers) in a resin matrix (e.g. epoxy), are progressively replacing metals in the transport and defence industries. Due to their high strength to weight ratios, laminated composite materials have found extensive applications in the construction of mechanical, aerospace, marine, protective gear and automotive structures.

As we have to analyze the composite material for bullet-proof material we will now give a brief introduction regarding ballistic material. The purpose of the ballistic protective materials is not to just stop the speeding bullets but to protect the individual from fragmenting devices as well, i.e. from grenades, mortars, artillery shells, and improvised explosive devices. We should note that the injury caused to the civilians is mainly due to two factors: High velocity bullets from rifles, machine guns which are mainly shot from a long range and low velocity bullets from hand guns which are shot from close range.

## II. OBJECTIVE

The objective of the work is to find out the impact analysis of bullet on different type of bulletproof materials to design better safe body vests, having high impact energy absorbing capacity. The armor should be as light as possible, while still providing protection against the threat that is most prevalent in the geographical area of use. To evaluate ballistic materials in relation to the levels of safety, to design and optimize the material configuration for bulletproof vest, the analyze were performed by using Ansys software explicit dynamics over the different bulletproof materials having dimensions of 100 mm x 100 mm.

## III. LITERATURE SURVEY

There is significant interest within the engineering community to better understand and predict the damage sustained by composite structures under high energy ballistic impact. Ballistic survivability requirements are common in applications were structural integrity following high energy impact threats is critical to maintaining mission capability. A number of researchers have investigated the ballistic impact response of composite materials using a variety of numerical models and framework. Song-XueSha, Yan Chen and Xiao-Yu Liu assessed the mechanical protective performance of Kevlar yarns and fabrics. Simulation of impact has been done in Ansys Autodyn. By Vaibhav Dangwal, SaurabhGairola. The finished product after modeling and assembly in Catia V5 was imported as geometry in Ansys Explicit Dynamics Workbench. After selection of materials from material library, it was opened in Autodyn for loading of impact conditions. Both the lead core and outer shell are connected and are given a velocity of 700 m/s. The bullet is initially touching the assemblage of sheets. As the high velocity impact phenomenon is of localized nature, the boundary conditions do not influence the results and therefore only a square region of all the sheets (200 X 200 mm) was modeled. After finalizing the loading conditions, and output as total Deformation and Equivalent (von-Mises) Stress, solver was run. An impact phenomenon is considered as low velocity impact if the contact period of the impact is longer than the time period of the lowest mode of vibration of the structure. Apart from that, the support condition is critical since the stress waves generated during the impact will have enough time to reach the edges of the structure and causing full vibrational response. Conversely, ballistic impact or high velocity impact is involved with smaller contact period of the impact on the structure than the time period of the lowest vibrational mode. The response of the structure is localized on the impacted area and it is usually not dependent on the support conditions (Naik and Shrirao, 2004). However, there is also a threshold velocity which distinguishes low and high velocity impact. As implied by Cartie and Irving (2002), 20 m/s is a transition velocity between two different types of impact damage and it allows a definition of high and low velocity impacts. Similarly, the transition to a stress wave-dominated impact arises at impact velocities between 10 and 20 m/s especially for general epoxy matrix composites (Abrate, 1998).

## IV.OPTIMUM BULLET STUDY

Bullets are made of a variety of materials. Lead or a lead alloy (typically containing antimony) is the traditional bullet core material. Traditional bullet jackets are made of copper or gilding metal, an alloy of copper and zinc. There are many other materials that are used in bullets today, including aluminum, bismuth, bronze, copper, plastics, rubber, steel, tin, and tungsten. J. hub along with his team members presented a numerical model of expansion pistol hollow point bullet penetrating the block of simulator representing the organic material (tissue). The hollow point bullet has an expansion ability to increase its wound potential, but only in case of exceeding the specific limit impact velocity.

Experiments and simulations done upon the gel block and the fuselage structure targets have shown a significant difference in piercing ability of the bullet Action 5 under various target conditions. In case of firing directly to the secondary target that is fuselage structure, the bullet penetrates all parts of the fuselage structure easily with high surplus of energy. After the simulated penetration of thin and thick parts of the human body that can be represented by the arm above the elbow and thighs of the leg, penetration ability of the bullet decreases significantly partly due to the expansion of the bullet and increasing the cross section of the bullet and partly due to lower velocity of the bullet impact as a result of deceleration in the test gel block. When considering a possible damage of the fuselage skin, the least favorable situation corresponds to the firing through gel block of the thickness less than 150 mm. In this case a large damage could occur due to tear of the skin caused by low impact energy and expanded bullet, which could have negative consequences in real flight.

Kolibri 2.7mm

The cartridge weighs 5.3 grams (82 grains), measures 3 millimeters (0.12 in) at its widest point, and 11 mm (0.43 in) from the base of the primer to the tip of the bullet. The cartridge is head spaced on the mouth of the case. The bullet itself masses 0.2g (3 grains), and is estimated to have a normal muzzle velocity of 200 meters per second (660 ft/s), resulting in a muzzle energy of 4.0J (3 ft-lbs).

The round was not well accepted. The 2mm Kolibri's small size makes handling and loading individual cartridges difficult, and the bullet itself is fairly weak, with literature at the time suggesting the round was capable of penetrating only 10–40 millimeters (0.39–1.57 in) of pine board. The round also suffers some accuracy issues, since the technology of the time was incapable of applying rifiling to the bore of such a small caliber, resulting in no spin on the bullet.

Fig.4.1 Kolibri bullet (forums.gunboards.com)

## V METHODOLOGY

- Dimension of fiber materials
- Thickness of fiber material = 10mm
- Dimension of bullet proof material = 100mm x 100mm
- BoronCarbi, Kevlar149, Structured steel and Spectra900 fibers are taken for the analysis
- Dimension specification of bullet 2.7mm
- Diameter of bullet = 2.7mm
- Velocity of bullet = 200m/sec
- Thickness of the fibers = 10mm
- Velocity of bullet = 200m/sec
- End time = 0.00005000sec

## VI RESULTS AND DISCUSSION

1. Total Deformation of Boron fiber

In dynamics analysis, the model has been extracted in IGES format. Here the material chosen is boron fiber which is subjected to boundary conditions such as the plate has been fixed and given a bullet velocity as 200 m/sec indented on a plate. Fig.1 shows the total deformation along Y-axis. It is found that maximum Deformation in the plate is 10.329mm.

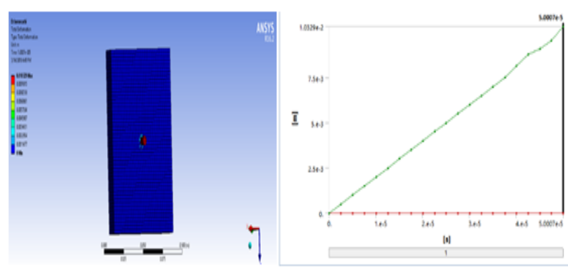

*Fig 1 Total Deformation of Boron fiber*

2. Total deformation of kevlar149 fiber

In dynamics analysis, the model has been extracted in IGES format. Here the material chosen is kevlar149 fiber which is subjected to boundary conditions such as the plate has been fixed and given a bullet velocity as 200 m/sec indented on a plate. The fig.2 shows the total deformation along Y-axis. It is found that maximum Deformation in the plate is 10.066mm

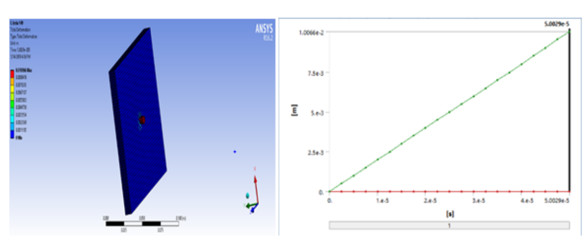

*Fig 2 Total Deformation of kevlar149 fiber*

3. Total deformation of spectra900 fiber

In dynamics analysis, the model has been extracted in IGES format. Here the material chosen is Spectra900 fiber which is subjected to boundary conditions such as the plate has been fixed and given a bullet velocity as 200 m/sec indented on a plate. The Fig.3 shows the total deformation along Y-axis. It is found that maximum Deformation in the plate is 10.011mm.

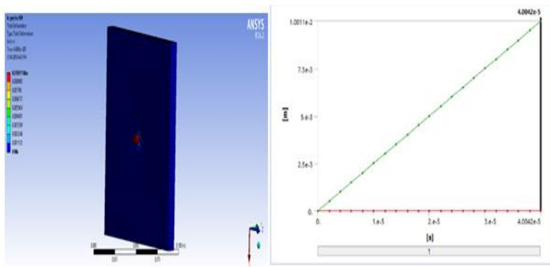

*Fig 3 Total Deformation of spectra900 fiber*

4. Total deformation of structured steel

In dynamics analysis, the model has been extracted in IGES format. Here the material chosen is structured steel fiber which is subjected to boundary conditions such as the plate has been fixed and given a bullet velocity as 200 m/sec indented on a plate. The Fig.4 shows the total deformation along Y-axis. It is found that maximum Deformation in the plate is 10.21mm.

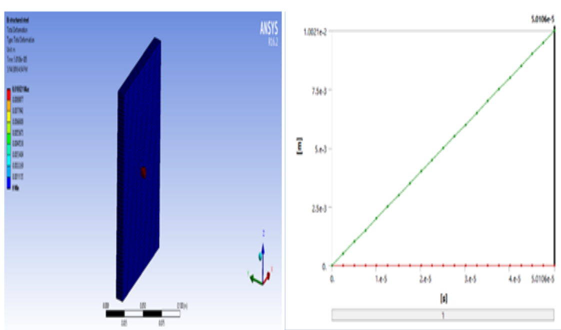

*Fig 4 Total Deformation of structured steel*

5. Directional deformation of boronfiber

In dynamics analysis, the model has been extracted in IGES format. Here the material chosen is Boron fiber which is subjected to boundary conditions such as the plate has been fixed and given a bullet velocity as 200 m/sec indented on a plate. The above Fig.5 shows the directional deformation. Directional deformation along y direction of the plate is 0.5158mm.

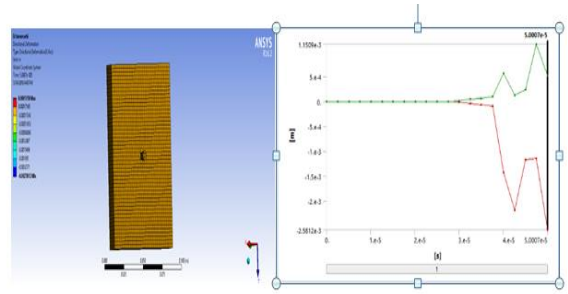

*Fig 5Directional deformation of boronfiber*

6. Directional deformation of Kevlar149

In dynamics analysis, the model has been extracted in IGES format. Here the material chosen is Kevlar149 fiber which is subjected to boundary conditions such as the plate has been fixed and given a bullet velocity as 950 m/sec indented on a plate. The Fig.6 shows the directional deformation. Directional deformation along y direction of the plate is 1.10006mm.

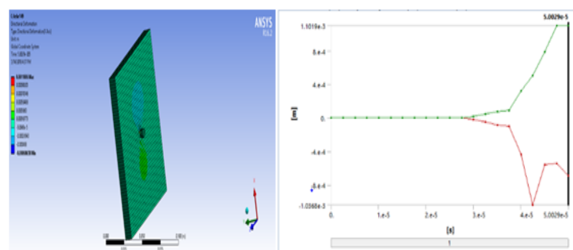

*Fig 6 Directional deformation of Kevlar149*

7. Directional deformation of Spectra900

In dynamics analysis, the model has been extracted in IGES format. Here the material chosen is Spectra900 fiber which is subjected to boundary conditions such as the plate has been fixed and given a bullet velocity as 200 m/sec indented on a plate. The Fig 7 shows the directional deformation. Directional deformation along y direction of the plate is 0.21104mm

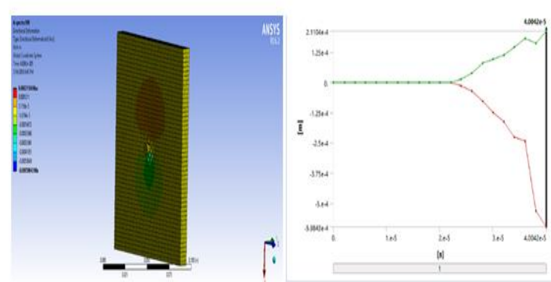

*Fig 7 Directional deformation of Spectra900*

8. Directional deformation of structured steel

In dynamics analysis, the model has been extracted in IGES format. Here the material chosen is Spectra900 fiber which is subjected to boundary conditions such as the plate has been fixed and given a bullet velocity as 200 m/sec indented on a plate. The Fig 8 shows the directional deformation along y direction of the plate is 0.25169 mm.

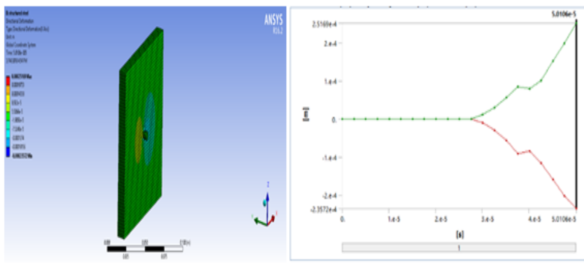

*Fig 8 Directional deformation of structured steel*

## VII. CONCLUSION

| S No. | Fiber material | Total deformation (mm) | Directional deformation (mm) | Maximum principle stress (GPA) | Minimum principle stress (GPA ) | Maximum shear stress (GPA) |
|---|---|---|---|---|---|---|
| 1 | Boronfiber | 10.320 | 0.5158 | 8.428 | -33.043 | 6.896 |
| 2 | Kevlar 149 | 10.066 | 0.1100 | 4.896 | -12.110 | 5.881 |
| 3 | Spectra900 | 10.010 | 0.2110 | 2.027 | -4.357 | 2.485 |
| 4 | Structured steel | 10.021 | 0.2516 | 3.808 | -10.027 | 5.726 |

Table1: Comparison data of kolibir 2.7mm

Finite element analysis is carried out on four materials that is Boroncarbi fiber, Kevlar 149, Spectra 900 and structured steel to determine the deformations and stresses when it is striked with high bullet with different velocities. From the it is evident that Spectra 900 fibers are the best when compared to Boron and Kevlar 149 with minimum deformation when subjected to bullet impact. Spectra 900 based composites are having the desired mechanical properties like higher strength, resistance to chemical reactions, negligible moisture sensitivity.

The modular jackets are meant to provide "graded level of protection" depending on the mission to be undertaken. The jacket would weigh less than 4 kg with a trauma pad with all around soft armor plate including front, side, back, collar and neck for low risk/threat missions. For many years, modern bullet resistant vests were made from woven Kevlar, but newer materials have since been developed that are lighter, thinner and more resistant, although much more expensive. The cost of bullet proof vests ranges anywhere from $100 to more than $1000 for top quality, resistant ones. The term "bulletproof" is a misnomer since the vests depending on their rating may provide little or no protection against rifle , ammunition , unusually high velocity pistol ammunition , pistol ammo fired from a rifle barrel , armor piercing ammunition and sharp edged or pointed instruments (such as knives). Additionally, projectiles that are successfully stopped by armor will always produce some level of injury, resulting in severe bruising, broken wounds, serious internal injuries or even death.

## REFERENCES

[1] Yohannes Regassa, Gessesew Likeleh, Prof. Ratnam Uppala., "Modeling and simulation of bullet resistant composite body armor", International Journal of Research Studies in Science, Engineering and Technology [IJRSSET] Volume 1, Issue 3, June 2014, PP 39-44

[2] Puran Singh, Vikas Malik and Priyawart Lather, "Analysis of composite materials used in bulletproof vests using Fem Techniques", International Journal of Scientific & Engineering Research, Volume 4, Issue 5, May-2013

[3] Y.L.Chen, C.K.Chu, W.Y.Chuang, S.H.Lee and K.C.Lee "A Study of Ceramic Composite Materials for Bullet-proof Optimization by Using Taguchi Method" 16TH INTERNATIONAL CONFERENCE ON COMPOSITE MATERIALS

[4] N.k. Naik and P. Shrirao, "Composite structures under ballistic impact", Composite structures 66 (2004) 579-590 Sciencedirect.com.

[5] W Kevlar® Properties | Kevlar® Technical Guide DuPont USA

[6] http/: www.gunvault.com