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"IMPACT ANALYSIS OF BULLET ON DIFFERENT BALLISTIC RESISTANT MATERIAL USING ANSYS"

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ABSTRACT

When a bullet hits body armor, the ballistic resistant material defeats the bullet by deforming it and dissipating its energy over the successive layers of the armor. Not only does this keep the bullet from penetrating your body, it also helps protect you from blunt trauma (the whack of the bullet against your body) by redirecting the absorbed energy throughout the armor. This paper presents the impact analysis of the projectile (bullet) over the armour shield. Models of the armor shield and projectile are created using UNIGRAPHICS-NX10 and simulated using ANSYS 18.1 software which is based on the finite element method (FEM). The investigation is carried out on the effect of the impact of bullet on the armor. In our project we take Graphene & Kevlar 149 fibre. Finally, comparisons between these materials are carried out at stresses and deformations level. Then we have found out, Graphene is best material than other materials. The obtained result could be utilized to design an optimized anti ballistic vest.

Keyword: *Graphene, Kevlar 149, Ballistic, Armour, Projectile, Stresses, Deformation, UNIGRAPHICS, ANSYS.*

I. INTRODUCTION

The two separate components, a matrix and filler (reinforcement section) makes composite material. Composites take benefit of directional properties of the reinforcement section and adhesive effects of the matrix. The reinforcement section can be any fabric in fiber, platelet, or combination form. The matrix sections have to be able to glide across the reinforcement and later hardened. The properties of composite like high impact strength, excessive strength to weight ratio, chemical inertness, stiffness, and good corrosion resistant and good fatigue [1] make it suitable for opposing the projectile's impact. Bullet-resistant substances (additionally termed as ballistic materials or, equivalently, anti-ballistic materials) are normally rigid, however can be supple. They will be complex, together with Kevlar, UHMWPE, Lexan, or Carbon fiber composite substances, or they'll be simple and simple, which include steel or titanium. Bullet resistant materials are regularly used in regulation enforcement and navy packages, to protect personnel from dying or critical injuries. The reason of the ballistic shielding substances is not to simply prevent the dashing bullets but to guard the individual from fragmenting gadgets as well, i.e. from grenades, mortars, artillery shells, and improvised explosive devices. we need to notice that the harm precipitated to the civilians is mainly due to two factors:

•The long range weapons such as rifles shot high velocity of projectile,

•The short range weapons such as handgun which has low velocity of projectile [4].

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ARMOR CLASSIFICATIONS FOR BALLISTIC-RESISTANT ARMOR

There are six formal armor classification types, as well as a seventh special type, as follows:

Type I (.22 LR; .380 ACP). This armor protects against .22 long rifle lead round nose (LR LRN) bullets, with nominal masses of 2.6 g (40 gr), impacting at a minimum velocity of 320 m/s (1050 ft/s) or less, and against .380 ACP full metal jacketed round nose (FMJ RN), with nominal masses of 6.2 g (95 gr), impacting at a minimum velocity of 312 m/s (1025 ft/s) or less. Type I body armor is light. This is the minimum level of protection every officer should have, and the armor should be routinely worn at all times while on duty. Type I body armor was the armor issued during the NIJ demonstration project in the mid-1970s. Most agencies today, however, because of increasing threats, opt for a higher level of protection.

Type II-A (9mm; .40 S&W). This armor protects against 9mm full metal jacketed round nose (FMJ RN) bullets, with nominal masses of 8.0 g (124 gr), impacting at a minimum velocity of 332 m/s (1090 ft/s) or less, and .40 S&W calibre full metal jacketed (FMJ) bullets, with nominal masses of 11.7 g (180 gr), impacting at a minimum velocity of 312 m/s (1025 ft/s) or less. It also provides protection against Type I threats. Type II-A body armor is well suited for full-time use by police departments, particularly those seeking protection for their officers from lower velocity 9mm and 40 S&W ammunition.

Type II (9mm; .357 Magnum). This armor protects against 9mm full metal jacketed round nose (FMJ RN) bullets, with nominal masses of 8.0 g (124 gr), impacting at a minimum velocity of 358 m/s (1175 ft/s) or less, and .357 Magnum jacketed soft point (JSP) bullets, with nominal masses of 10.2 g (158 gr), impacting at a minimum velocity of 427 m/s (1400 ft/s) or less. It also provides protection against Type I and Type IIA threats. Type II body armor is heavier and more bulky than either Types I or II-A. It is worn full time by officers seeking protection against higher velocity .357 Magnum and 9mm ammunition.

Type III-A (High Velocity 9mm; .44 Magnum). This armor protects against 9mm full metal jacketed round nose (FJM RN) bullets, with nominal masses of 8.0 g (124 gr), impacting at a minimum velocity of 427 m/s (1400 ft/s) or less, and .44 Magnum jacketed hollow point (JHP) bullets, with nominal masses of 15.6 g (240 gr), impacting at a minimum velocity of 427 m/s (1400 ft/s) or less. It also provides protection against most handgun threats, as well as the Type I, II-A, and II threats. Type III-A body armor provides the highest level of protection currently available from concealable body armor and is generally suitable for routine wear in many situations. However, departments located in hot, humid climates may need to evaluate the use of Type III-A armor carefully.

Type III (Rifles). This armor protects against 7.62mm full metal jacketed (FMJ) bullets (U.S.military designation M80), with nominal masses of 9.6 g (148 gr), impacting at a minimum velocity of 838 m/s (2750 ft/s) or less. It also provides protection against Type I through III-A threats. Type III body armor is clearly intended only for tactical situations when the threat warrants such protection, such as barricade confrontations involving sporting rifles.

Type IV (Armor Piercing Rifle). This armor protects against .30 caliber armor piercing (AP) bullets (U.S. military designation M2 AP), with nominal masses of 10.8 g (166 gr), impacting at a minimum velocity of 869 m/s (2850 ft/s) or less. It also provides at least single-hit protection against the Type I through III threats. Type IV body armor provides the highest level of protection currently available. Because this armor is intended to resist “armor piercing” bullets, it often uses ceramic materials. Such materials are brittle in nature and may provide only single-shot protection, since the ceramic tends to break up when struck. As with Type III armor, Type IV armor is clearly intended only for tactical situations when the threat warrants such protection.

Special type. A purchaser who has a special requirement for a level of protection other than one of the above standard threat levels should specify the exact test rounds and minimum impact velocities to be used and indicate that this standard shall govern in all other respects.

Figure 1: Hard and flexible Bullet resistant body armor.

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II. PROBLEM DEFINITION

The reason of the ballistic shielding substances is not to simply prevent the dashing bullets but to guard the individual particles from fragmenting gadgets as well, i.e. from grenades, mortars, artillery shells, and improvised explosive devices. These gadgets exploded in the small particles form & move with very high velocity. We consider particle as bullet form. Apart this the bullet stopping capacity is high in the metal plate or ceramic reinforced ballistic vest, but it seems to be very difficult for a soldier to carry additional weight which is near about half of their weight. In order to overcome these difficulties of the ballistic vest, A Graphene reinforced bulletproof vest would be an ideal solution.

ASSUMPTION

The following are made for the bullet proof vest:

- For analysis, only a part of vest is taken (i.e. 100mm x100mm)
- The bullet strikes at the centre of the vest (i.e. at x=50mm, y=50mm).
- Twisting of vest is not considered for analysis.

III. MATERIALS

These are the mechanical properties of reinforcement composite material that are listed in the below table:

Material Field Variable	Graphene[3]	Kevlar 149 Fibre[1]
Density	0.77 mg/m^2	1.47 g/cm^3
Young's modulus	1TPa	2.3GPa
Poisson Ratio	0.39	0.36
Shear modulus	0.358 TPa	0.845 GPa
Tensile Strength	130GPa	3450 MPa

Table- 1 Mechanical properties of reinforced material

IV. METHODOLOGY

ANSYS software is widely used in finite element analysis, but its pre-processing function is so complex that takes too much time and energy for complex model. In our project we have used UNIGRAPHICS NX-10 for modeling and ANSYS for meshing and analysis. The comprehensive application of various finite elements software can exert their corresponding advantages and makes the analysis more efficient [4].

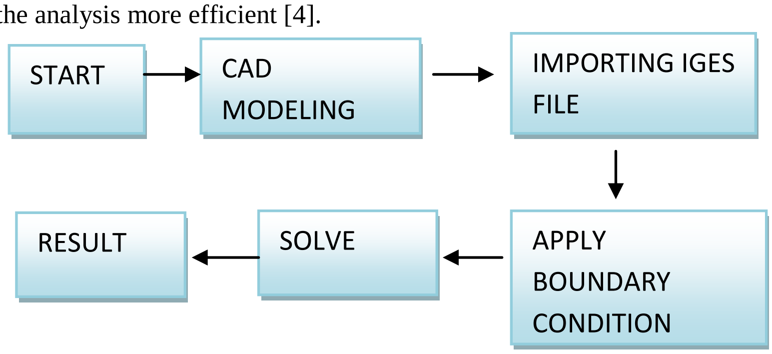

Figure- 2: Steps of working

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As we have taken the shape of bullet or the exploded particle in 12.7×99mm cartridge's projectile form & the copper shell with lead core for the bullet material.

Specification of individual particle (bullet) from fragmenting gadgets:
Diameter of bullet = 12.7mm
Length of bullet = 39.12mm
Velocity of bullet = 928m/sec
Mass of bullet approx. = 36grams.
(As maintaining the shape of the bullet,
the mass differ with the actual bullet mass)

Dimension of fibre materials:
Thickness of fibre material = 8mm
Dimension of bullet proof vest = 100mm x 100mm

Graphene and Kevlar149 fibres are taken for the analysis
Calculations:
Thickness of the armor shield = 8mm
Distance between armour's back side face and bullet's bottom face = 300mm
Velocity of bullet = 928×10^3 mm/sec
End time = (Distance covered by the bullet) / (Velocity of bullet)
= 0.300/928
= 0.000323sec

CAD Model of bullet and vest.

The modeling is done in the Unigraphics NX10 and further exported into iges (initial graphics exchange specification) file which is input for the simulation as geometry.

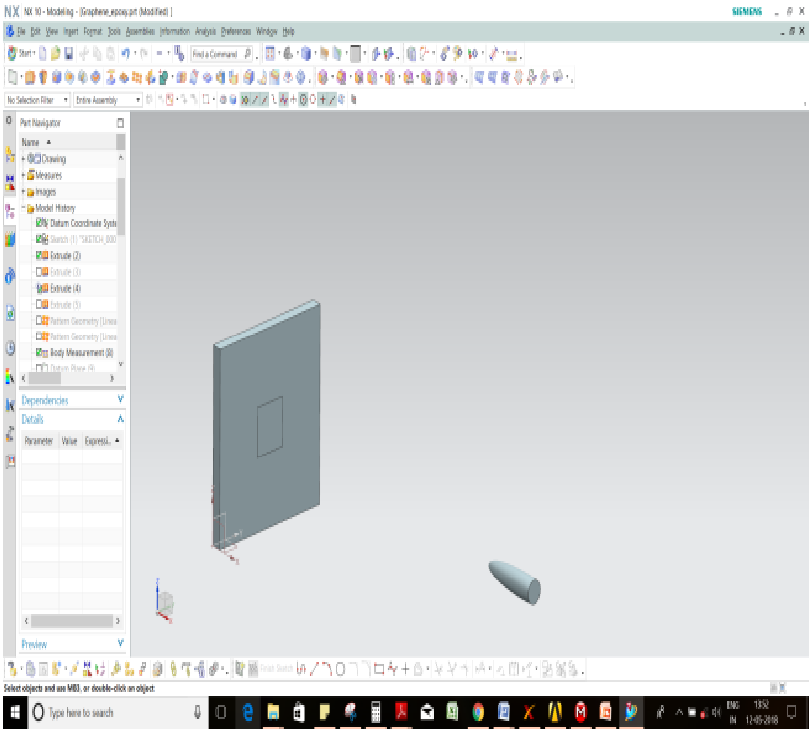

Figure- 3: Cad model in Unigraphics-NX10

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V. RESULT & DISCUSSION

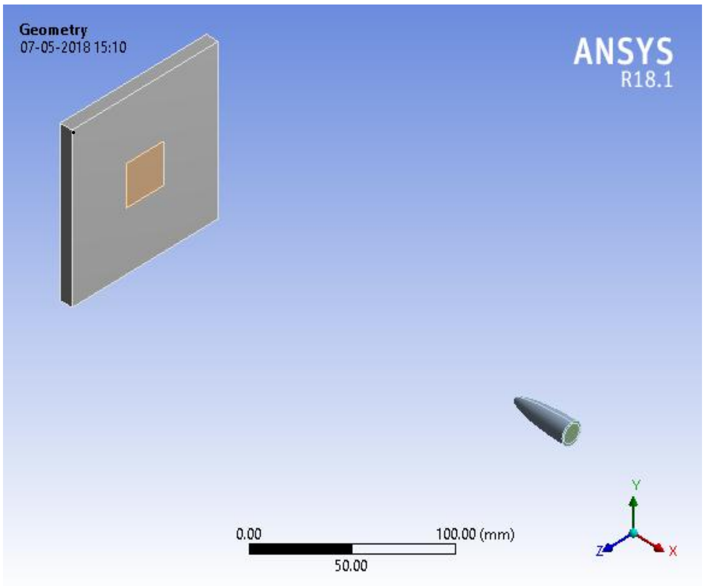

Figure 4: Imported model in ANSYS

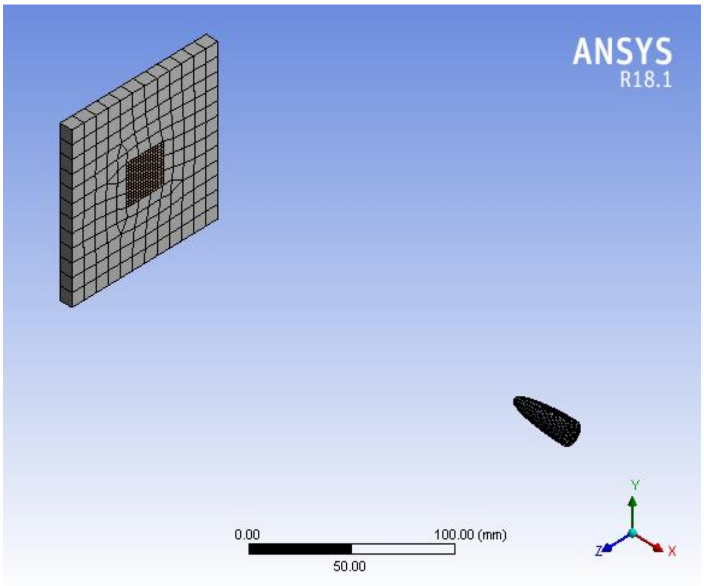

Figure 5: CAD Model import in ANSYS and generating meshing

This is the first step to start the analysis, importing cad model file in .igs format. Meshing is the second step, in which nodes and elements are generated. Here the small part is fine meshed which strikes with bullet so as the result would we more accurate in this region.

The vest is bounded by faces on all four sides. These sides are motion arrested as only 25x25 mm part of overall vest is considered. So these sides are to be motion arrested (i.e. $U_x = U_y = U_z = 0$ and $U_{xy} = U_{yz} = U_{zx} = 0$).

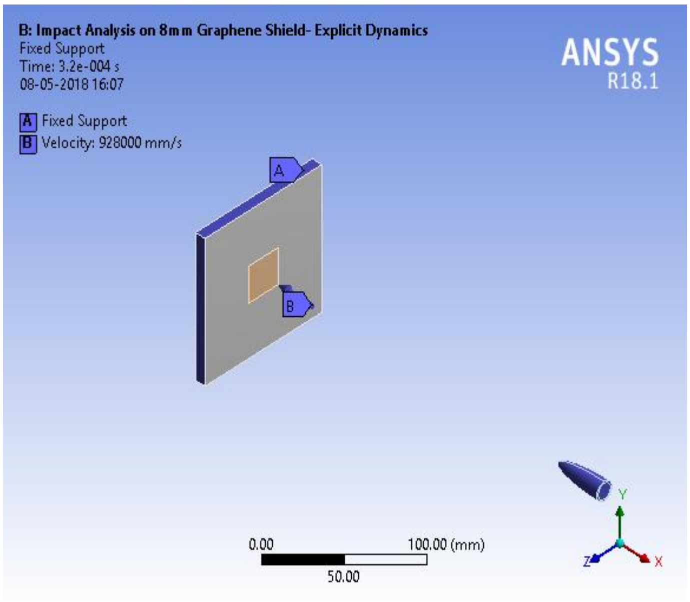

Figure 6: Applied boundary conditions

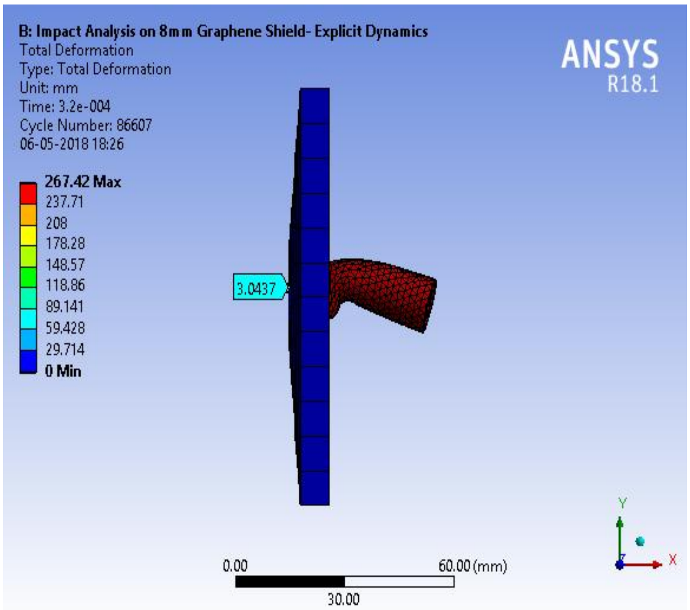

Figure 7: Side view of Total Deformation of raphene shield

In side view the probe is showing the maximum deformation of shield after the impact of bullet which is 3.0437mm. In figure 8 back side view of the total deformation in which again probe is showing the maximum deformation of shield after the impact of bullet which is 3.043mm. Hence the bullet is not crossing the shield.

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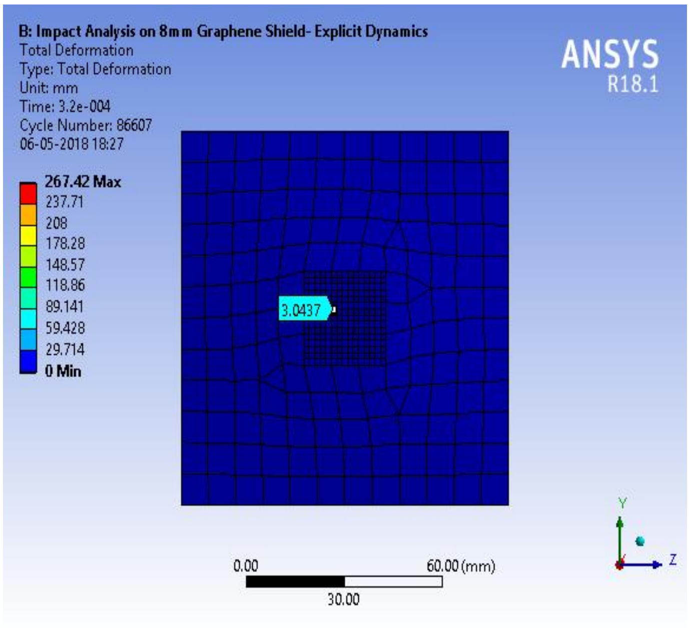

Figure 8: Back side view of Total deformation of Graphene shield

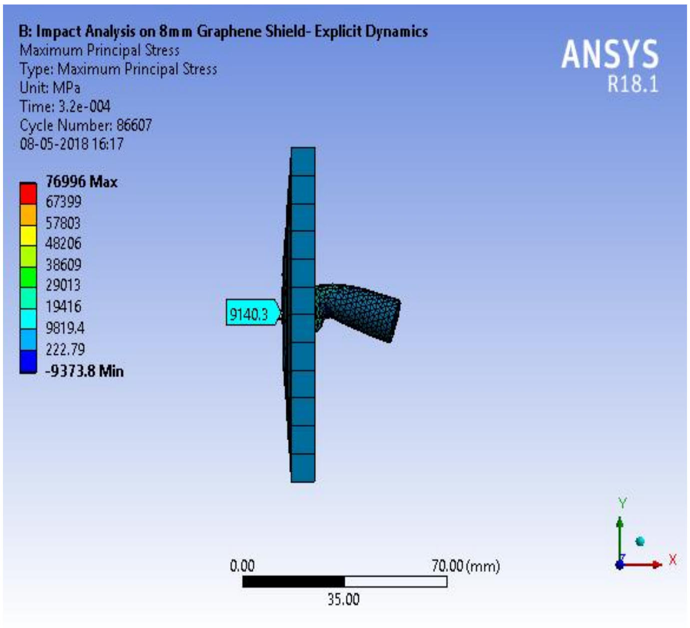

Figure 9: Maximum Principal Stress in Graphene.

In figure 9 The probe is showing the maximum principal stress at the maximum deformed section of the shield after the impact of 928m/s bullet which is 9140.3Mpa and the max. value in fig. 9 which is showing the max. stress value for the element of initial layer of the graphene which are broken at the time of impact & then rest of the layers bends the bullet.

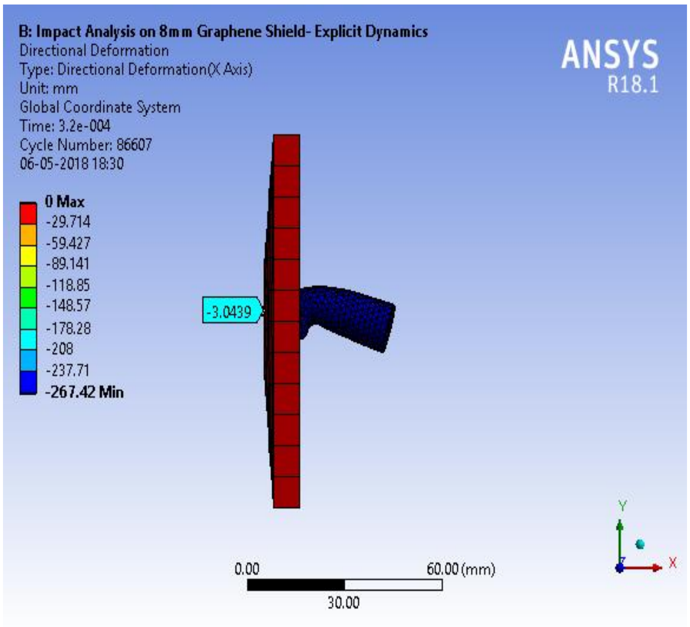

Figure 10: Directional Deformation in Graphene shield

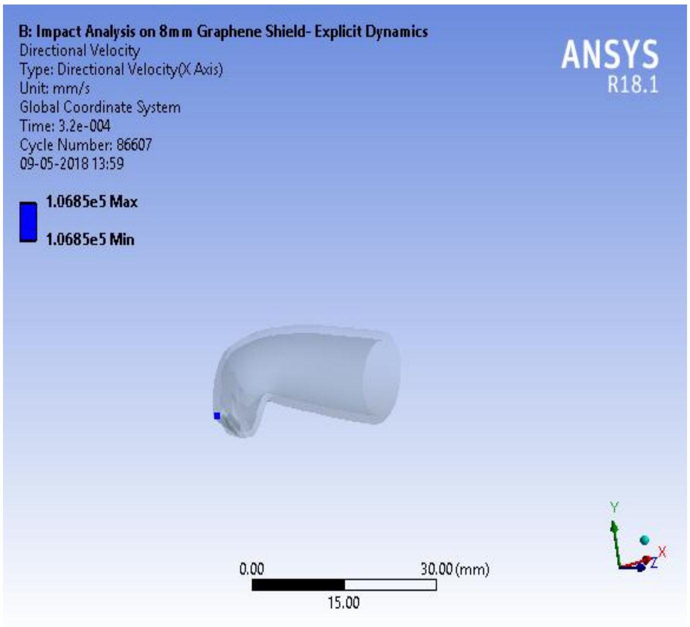

Figure 11: Directional velocity of bullet for graphene

In figure 10 side view, the probe is showing the deformation of the outermost element of shield after the impact of bullet which is 3.043mm. And figure 11 The directional velocity of the bullet is showing in the result is positive, it

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means the bullet is rebound back after the impact with a velocity of 1.685E5 mm/s. The velocity is given in negative x direction to the bullet.

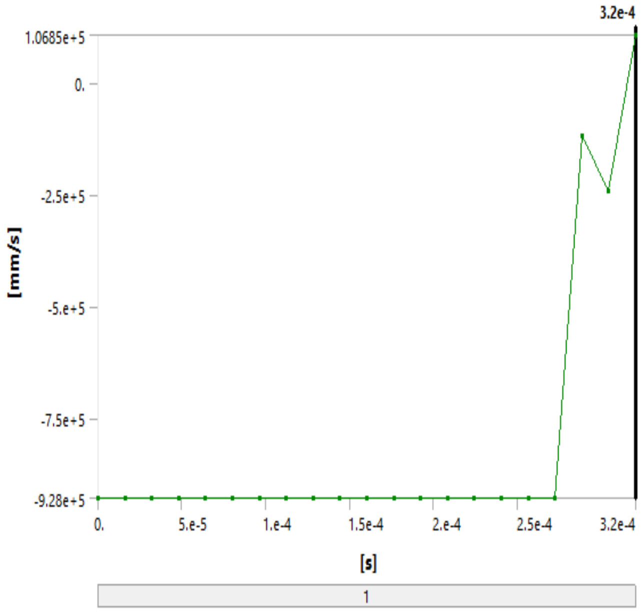

Figure 12: Directional velocity graph of bullet for graphene shield.

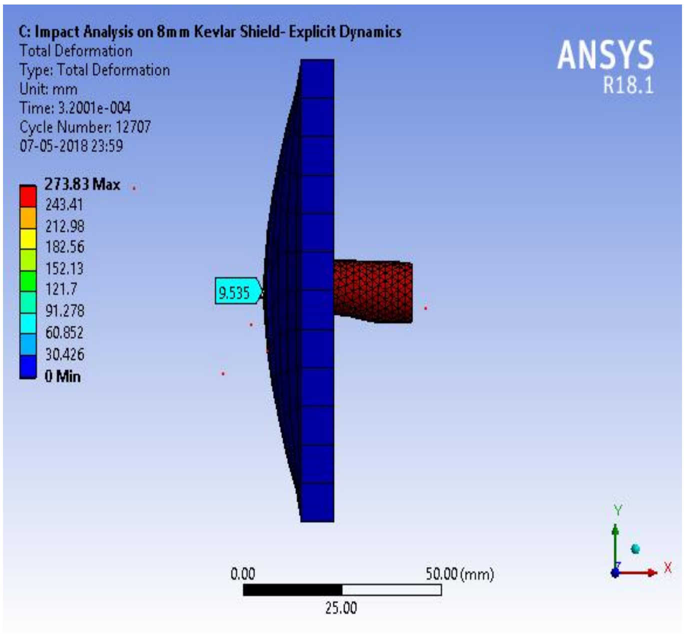

Figure 13: Side view of Total Deformation of Kevlar 149 Fibre

In the graph (Figure 12) is showing the velocity of bullet vs time in which bullet's velocity changes rapidly as it impact with the shield and ends with the positive. It means the kinetic energy of bullet is absorbed by the shield. And figure 13 The probe is showing the deformation of the outermost element of the shield after the impact of bullet which is 9.535mm. As the maximum value in the result is showing the deformation of failure of bullet and shield elements and the shield is constrained so it never deformed at the fix end, which shows minimum or zero deformation in the result.

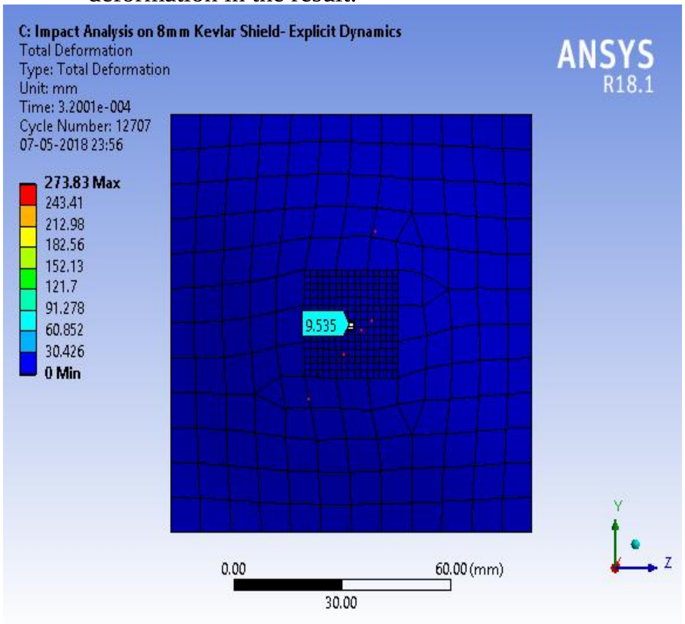

Figure 14: Back Side view of Total Deformation of Kevlar 149 Fibre

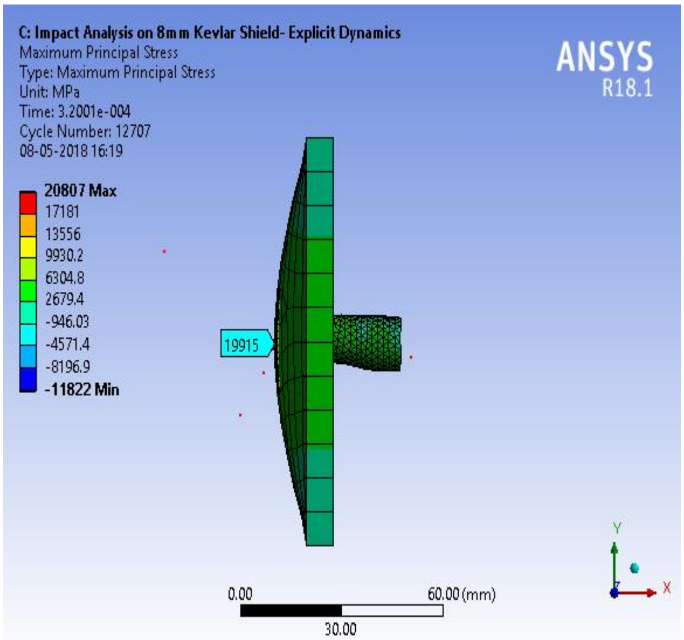

Figure 15: Maximum Principal Stress in Kevlar 149 Fibre.

In figure 14 the back side view of the total deformation in which again probe is showing the maximum deformation of shield after the impact of bullet which is 9.535mm. Hence the bullet penetrate upto some extent but not crossing

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the shield. And in figure 15 The probe is showing the maximum principal stress at the maximum deformed section of the shield after the impact of bullet which is 19915Mpa and the max. value in fig. 15 which is showing the max. stress value for bullet.

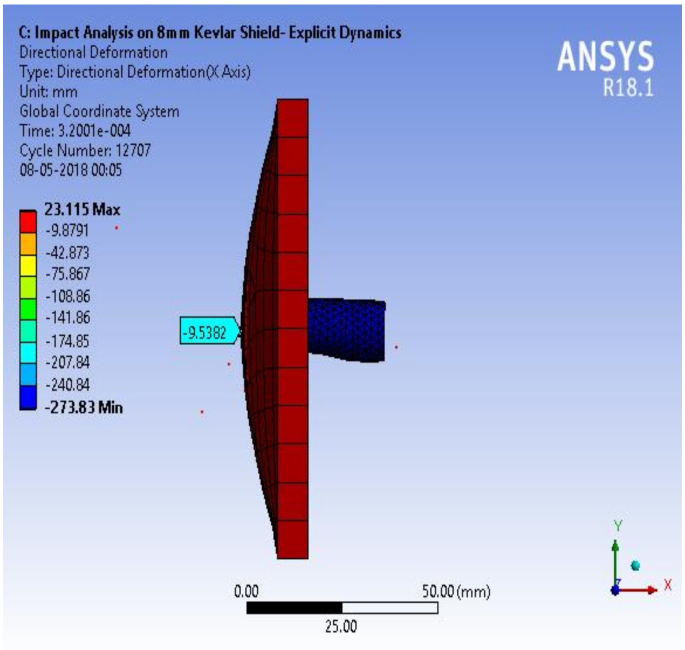

Figure 16: Side view of Directional Deformation of Kevlar 149 Fibre

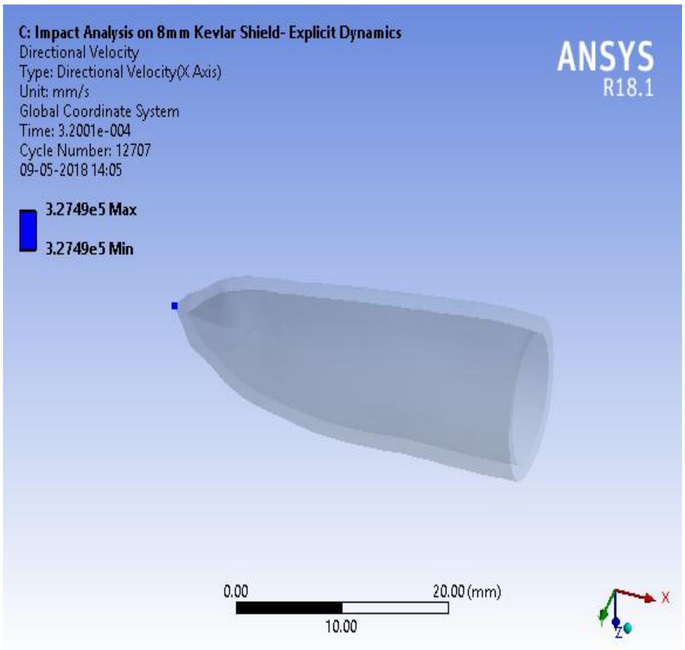

Figure 17: Directional velocity of bullet for Kevlar 149 fiber.

In figure 16 side view, the probe is showing the deformation of the outermost element of shield after the impact of bullet at 928m/s which is 9.5382mm in negative x - direction but the actual value of deformation is 9.8791mm as shown in the result. And figure 17 The directional velocity of the bullet is showing in the result is in positive x direction; it means the bullet is rebound back after the impact with a velocity of 3.2749E5 mm/s. The velocity is given in negative x direction to the bullet.

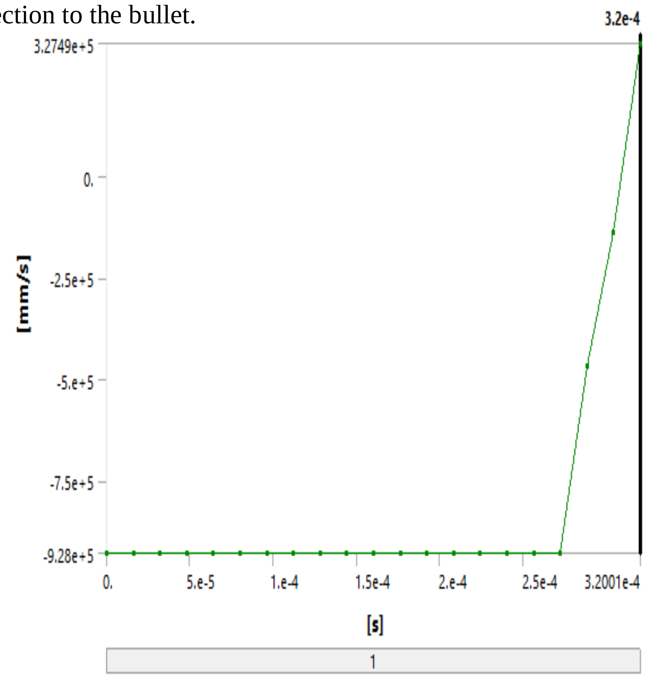

Figure 18: Directional velocity graph of bullet for Kevlar 149 Fibre.

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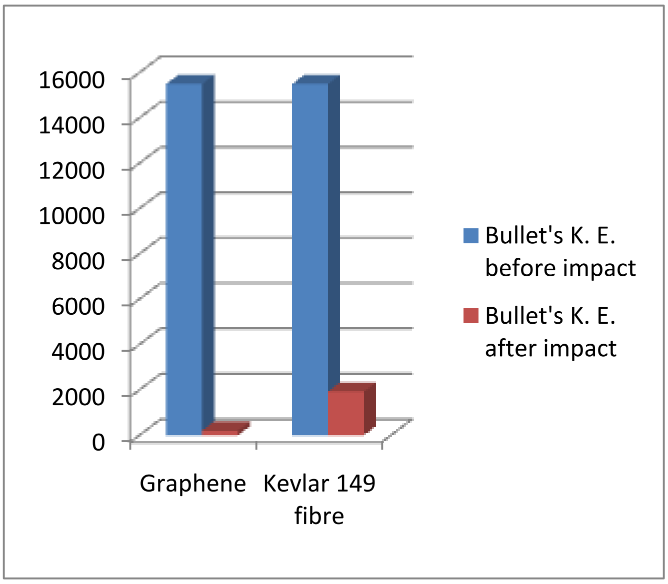
The graph is showing the velocity of bullet vs time in which bullet's velocity changes rapidly as it impact with the shield and ends with the positive. It means the kinetic energy of bullet is absorbed by the shield. the kinetic energy of the bullet is absorbed by the Kevlar 149 fiber



The above graph is showing the absorption of impact energy of bullet is more in case of graphene as compared to the Kevlar 149 fiber.

Comparison of Stresses and Deformations

Materials		Max. Principal Stress (MPa)	Deformation (mm)
Graphene	Max	9140.3	3.04
	Min	0	0
Kevlar149 Fibre	Max	19915	9.87
	Min	0	0

Table- 2 Comparison of Stresses and Deformation

VI. CONCLUSION & FUTURE SCOPE

6.1 CONCLUSION

The impact analysis is carried out with the help of ANSYS 18.1 Explicit Dynamic Solver on the two composite reinforcement materials that is Graphene & Kevlar 149 fibre to determine the stresses, deformation when the bullet hits the 8mm thick reinforcement for composite armor at a velocity of 928m/s. From the results and tabulations it is evident that Graphene is the best reinforcement for the ballistic resistant material as compared to the Kevlar 149 fibre with minimum deformation of 3.04mm and max. principal stress 9140.3Mpa (Tensile strength 130Gpa) when subjected to bullet impact. But in Kevlar 149 fibre's case, the max. principal stress (19915Mpa) cross the tensile strength (3450Mpa) limits, so it fails to resist impact of the bullet at 928m/s. Hence, Graphene based composites are having the desired mechanical properties to use as reinforcement material for ballistic purpose.
This research found that graphene had the highest ballistic resistance per thickness which makes it an extraordinary armour material having excellent impact energy delocalization underneath a high-speed penetration event. Based Upon these findings, it is conclude that the addition of graphene sheets to any matrix will strengthen its ballistic characteristics.

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6.2 FUTURE SCOPE

In future, this work can be extended by using different Fibres or composite materials to enhancing the ballistic properties against projectile and also we can take different projectiles (bullets), on similar or dissimilar material which can absorb the kinetic energy of the projectile along with dissipating it, also preventing penetration & save the life of armour wearer.

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