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Impact Analysis on Armoured Vehicle During Mine Blast

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ABSTRACT

Armoured vehicles are accustomed to carry troopers and other machinery within the war-field. The foremost threat for Armoured vehicle is anti-tank mines. These are principally damaged from the Blast loads critically in sight of the environment. Future wars insist on light weight tanks that can withstand land mines with higher order destruction. These are also exposed to mine explosions despite the actual fact that they are usually not designed to resist such loadings. The intensity of blast loads, combination with the structural geometry and mechanical properties of the materials involved, will cause vehicle damages, crew injuries and even death. Therefore, it is necessary to look at and improve the response of Armoured vehicles to high-intensity loads, particularly in the early design stages of prototype development. In this report on The Blast Analysis of An Armoured Vehicle and its impact of the blast on the vehicle with explosion on under-side of the vehicle is taken into account in the analysis. FEA has been accomplished to perform analysisin which ANSYS is used. By using SOLIDWORKS and ANSYS, analysis has been accomplished for under-side blast of the model. The similar model is tested with addition of composite metal sheet inside the bottom part of vehicle. The deflections and deformations of bottom plate of armoured vehicle obtained by FEA results which are compared with and without composite metal sheet. The results shown are often changed with changes in the weight of the vehicle and sheet thickness for further studies. The simulation is carried out with varying blast charges of TNT (4kg, 6kg and 8kg) in the distance from the TNT to bottom of the vehicle is 500mm. The deformation caused at the bottom of the vehicle is compared with the relative performance of vehicle with and without carbon metal sheet placed at inner side of the vehicle at its bottom end.

KEYWORDS: Armoured Vehicle, Finite Element Analysis, Ansys, Solid Works, TNT

1. INTRODUCTION

Acombat vehicle protected by armour, typically merge operational quality withoffensive and defensive capabilities is said to be an Armoured fighting vehicle. AFVs can be wheeled or tracked. The Examples for AFV's are armoured cars, armoured carriers (APC), armoured self-propelled guns and infantry fighting vehicles. According to Oxford English Dictionary the Armor is defined as: "The steel or other metallic protective sheathing of a warship, military fortification, vehicle or aircraft." In this thesis, the word "Armor" refers to the protective layer mounted on a vehicle to stop damages or injuries to its parts. The importance of Armor has been definite since Man was concerned in conflicts and wars. So as to guard themselves against the weapons or enemies, troopersaccomplished the necessity to guard themselves with consumer goods made up of stronger materials. Likewise, this need for defence has conjointly been applied to vehicles and also the other equipment's which are used in war-field.

The new developments of weapons to defeat armour results in developments of armour applications as well. For ground vehicles there has been an excellent interest in survivability concepts and ideas, vulnerability reduction, maintainability improvement and also their impact on the design and functions of ground vehicles and the ground vehicle persistence is element shielding, which is largely controlled by Armor. The common use of the term "armoured vehicles" in the thesis, is recognized as a collective term that refers to automotive platforms with additional Armor protection.

In general, armoured vehicles are categorized into battle tanks, infantry combat vehicles, armoured force carriers and self-propelled guns. The principal consideration for Armor growth and selection may apply for almost all the platforms, each category of armoured vehicles may have its own essentials due to its individualoperations.

2. FINITE ELEMENT ANALYSIS:

FEA is a way to simulate the loading on a design and evaluate them at different conditions. The design is modelled using individual building blocks called elements. Each element has exact equations that describe how it replies to a certain load. The elements have a finite number of unknowns; hence it is named as finite elements. The finite element model is required to reduce the amount of prototype testing. Different scenarios are tested quickly and effectively. By using this computer simulations cost and time are saved to the market. It also creates more reliable and better-quality designs. ANSYS is an absolute software package used worldwide effectively in almost all the fields of engineering. ANSYS Multi physics is the flagship ANSYS product which includes all capabilities in all engineering disciplines

3.NUMERICAL SIMULATION:

In modern engineering manufacturing, computer-aided engineering techniques play an important role in design process of different products in different types. Thus, the time involved for the development of the new model has been reduced significantly due to increase complexity of the developed system in electronicand automotive industry. Moreover, the cost required to develop and evaluate anew model was also reduced. Though, it should be considered that the model tobe designed should have enough complexity to provide good accuracy andvaluable information about the system performance and simultaneously modestto reduce the computing time. However, to achieve these tasks, different techniques need to be investigated to develop the model.This paper investigates the numerical parameters that were to conduct numerical analysis. The Cad model of the armoured vehicle was designed to perform numerical analysis. Different models were analysed and validated to determine the required parameters for the analysis of armoured vehicle. Blast load of 4,6 and 8 kg TNT are used for explosion of armoured vehicle. Different models were analysed and validated to determine required parameters for the analysis.

4. PROCEDURE OF NUMERICAL SIMULATION:

Initially a 3D design is modelled by using solid works. First case of the model includes Armoured vehicle with a TNT cube placed at 500 mm distance from the vehicle bottom end to the centre of the explosion. In the second case of the model there is an addition of a sheet with 10 mm thickness inside at the bottom of the vehicle. Now consider ANSYS workbench for the numerical simulation. The simulation is carried out in explicit dynamics module to evaluate the numerical analysis of armoured vehicle with TNT explosion. Explicit dynamics pre-processing includes all the inputs like engineering data, geometry selection, configuring contact mode, meshing, Analysis settings and boundary conditions respectively. Further the simulation is carried out in Ansys pre-post to analyse the explosion on the vehicle and evaluate the deformations and stresses observed on the vehicle while explosion.

5. GEOMETRY:

The initial step in analysis is the cad modelling of the physical entity. In the present work the solid modelling of the armoured vehicle was carried out in solid works software. The model includes The Armoured vehicle of 3580mm X 1084.5mm X 1200 mm is subjected to blast load of TNT cube which is kept at over 500mm distance from bottom of the vehicle is solved using ANSYS AUTODYN solver. The explosive charge is TNT. In the second case of the model there is an addition of a sheet with 10 mm thickness inside at the bottom ofthe vehicle.

These two cases are simulated at different TNT weights. The TNT charge is varied between 4,6 and 8 kg for evaluation. The model considered is shown in the below figure.

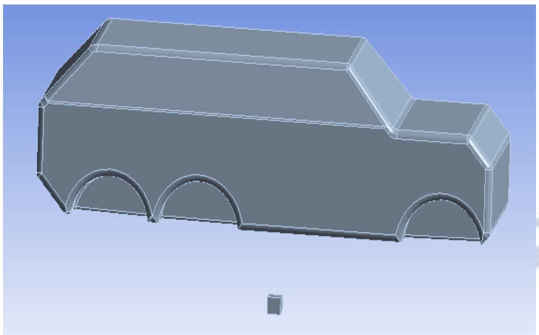

Figure1: Geometry

6. GEOMETRY PARAMETERS:

The Model was designed in solid works software with available design data given below:

Vehicle dimension: 3580mm X 1084.5mm X 1200 mm

4kg TNT cube dimension: 135mm X 135mm X 135mm

6kg TNT cube dimension: 155mm X 155mm X 155mm

8kg TNT cube dimension: 170mm X 170mm X 170mm

Distance from bottom of the vehicle to TNT: 500 mm

Sheet thickness: 10 mm

The Analysis for 4,6 and 8 kg TNT blast are compared with and without sheet placed inside the armoured vehicle at its bottom for vehicle strength.

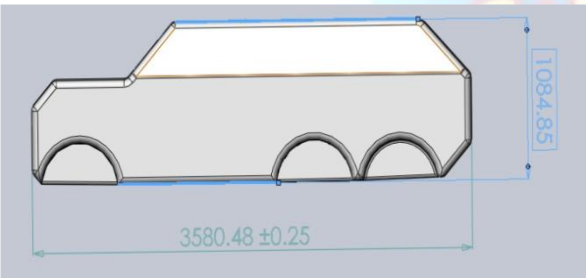

Figure 2: Geometry parameters

CASE 1: FINITE ELEMENT ANALYSIS OF ARMOURED VEHICLE WITH 4,6 AND 8 KG TNT

In this case the finite element Analysis of armoured vehicle is evaluated in three different explosion charge varied at 4kg, 6kg and 8 kg. By evaluating these three cases the deformations and stresses are noticed on the vehicle.CASE 2: Finite Element Analysis of Armoured vehicle with 4,6 and 8 kg TNT with addition of Carbon fiber sheet

In this case the finite element Analysis of armoured vehicle is evaluated in three different explosion charge varied at 4kg, 6kg and 8 kg with an addition of a sheet inside the bottom of the vehicle. The sheet is used in this case to strengthen the vehicle and decrease the explosion effect on the vehicle. In further studies the sheet thickness can be increased and can also be evaluated with different material to increase the strength of the vehicle. By evaluating these three casesthe deformations and stresses are noticed on the vehicle. After evaluating all the results each case of Analysis is compared with and without carbon fiber sheet.

7. MATERIAL PARAMETERS:

As far as the research is concerned, a sample armoured vehicle was taken for the analysis. The Materials used for armoured vehicle is AISI Steel 4340 and TNT for blast load. The sheet inside the armoured vehicle is assigned with carbon fibre. Material Properties used in Ansys workbench are shown below:

- AISI Steel 4340:

Density	7.83e-06 kg/mm³
Thermal	
Specific Heat Constant Pressure	4.77e+05 mJ/kg·°C
Other	
Bulk Modulus	1.59e+05 MPa
Johnson Cook Strength	
Strain Rate Correction	First-Order
Initial Yield Stress	792 MPa
Hardening Constant	510 MPa
Hardening Exponent	0.26
Strain Rate Constant	0.014
Thermal Softening Exponent	1.03
Melting Temperature	1519.9 °C
Reference Strain Rate (/sec)	1
Shear Modulus	81800 MPa

Figure 3: Properties of AISI Steel 4340

- TNT:

Density	1.63e-06 kg/mm³
Other	
Explosive JWL	
Parameter A	3.7377e+05 MPa
Parameter B	3747.1 MPa
Parameter R1	4.15
Parameter R2	0.9
Parameter W	0.35
C-J Detonation Velocity	6.93e+06 mm/s
C-J Energy / unit mass	3.681e+06 J/kg
C-J Pressure	21000 MPa
Burn on compression fraction	0
Pre-burn bulk modulus	0 MPa
Adiabatic Constant	0
Additional specific energy / unit mass	0 J/kg
Begin Time	0 s
End Time	0 s

Figure 4: Properties of TNT

- CARBON FIBER:

Density	1.8e-06 kg/mm³
Structural	
Orthotropic Elasticity	
Young's Modulus X direction	3.95e+05 MPa
Young's Modulus Y direction	6000 MPa
Young's Modulus Z direction	6000 MPa
Poisson's Ratio XY	0.2
Poisson's Ratio YZ	0.4
Poisson's Ratio XZ	0.2
Shear Modulus XY	8000 MPa
Shear Modulus YZ	2142.9 MPa
Shear Modulus XZ	8000 MPa

Figure 5: Properties of Carbon fiber

8. MESHING:

The mesh size of the armoured vehicle and 2 kg TNT is 20mm and 3mm respectively which is shown in the figure.

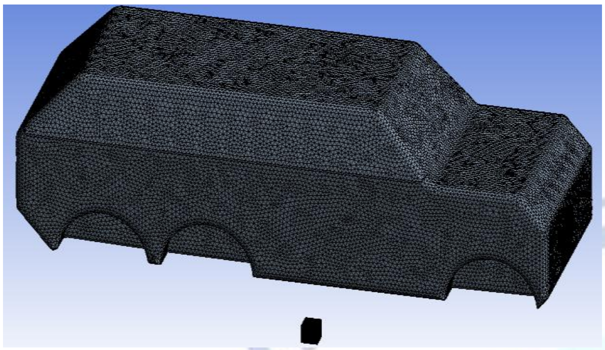

Figure 6: Meshing

The Mesh metrics for the above model are shown below.

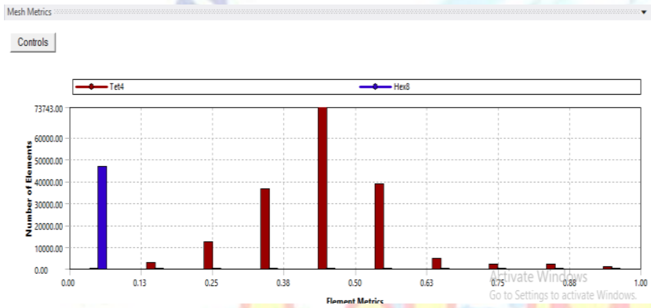

Figure 5.4.2: Mesh Metrics

9. BOUNDARY CONDITIONS & ANALYSIS SETTINGS:

The Numerical Simulation of armoured vehicle is subjected to TNT Blast Load with and without carbon fibre sheet. This methodology is applied for blast charges of 4kg, 6kg and 8 kg TNT. Only by altering the change of weight in the boundary condition, the simulations are done.

- Fixed support is given on the wheel faces.
- Detonation point is given at the centre of TNT cube for explosion.
- End time is given as 0.001s.

The boundary conditions applied are shown below:

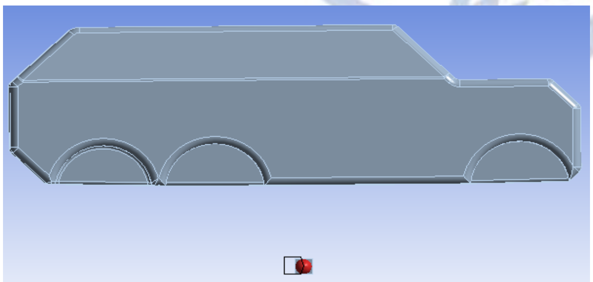

Figure 7: Detonation Point

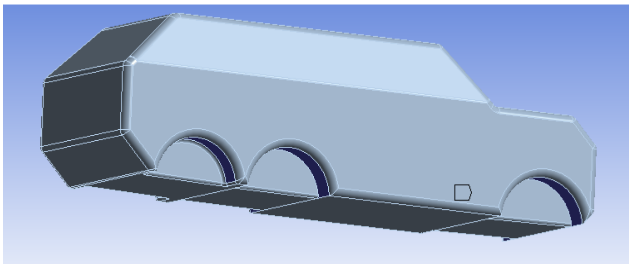

Figure 8: Fixed Support

10. RESULTS AND VALIDATION:

A. 4KG TNT BLAST WITHOUT CARBON FIBRE PLATE:

- Deformation: Maximum deformation of 111.25mm occurred on the vehicle

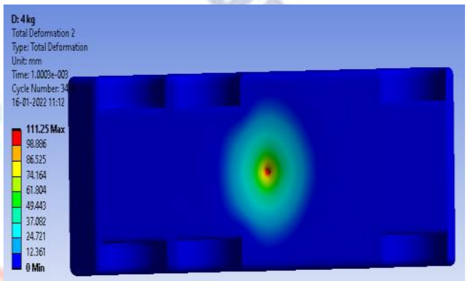

Figure 9: Maximum deformation on 4 kg TNT

- Equivalent Stress: Maximum Stress of 818 Mpa occurred on the vehicle.

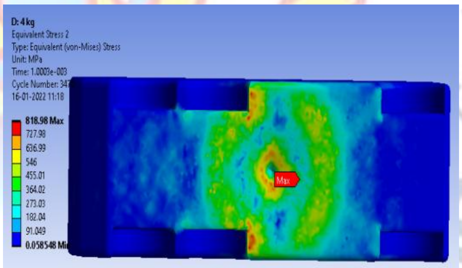

Figure 10: Maximum Stress of 4 kg TNT without carbon fiber sheet

B. 4KG TNT BLAST WITH CARBON FIBRE PLATE:

- Deformation: Maximum deformation of 65.898mm occurred on the vehicle

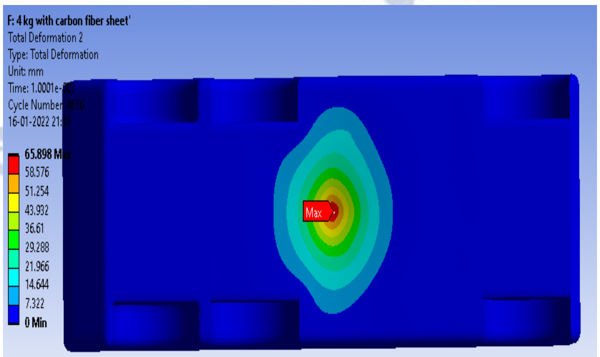

Figure 11: Maximum Deformation for 4 kg TNT on vehicle

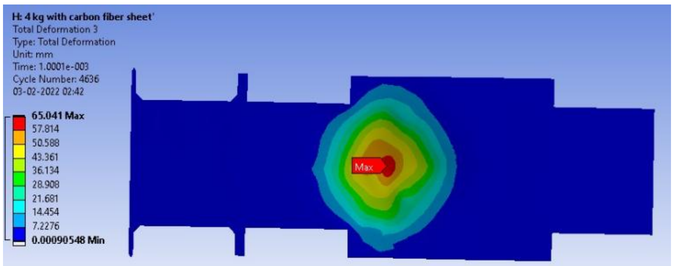

Figure 12: Maximum Deformation for 4 kg TNT on sheet

• Equivalent Stress: Maximum Stress of 799.78 Mpa occurred on vehicle and 605.03 Mpa occurred on carbon fiber sheet.

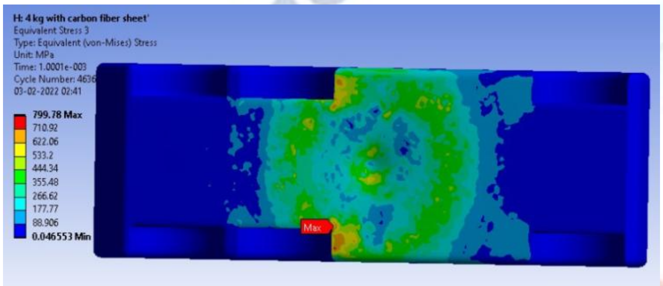

Figure 13: Maximum Stress for 4 kg TNT on vehicle

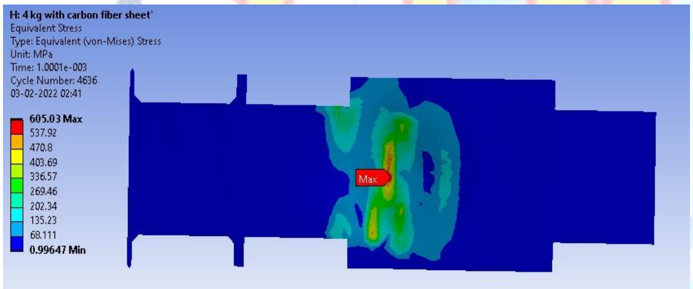

Figure 14: Maximum Stress for 4 kg TNT on carbon fiber sheet

• Result Comparison Between 4 kg TNT with and without carbon fiber sheet are mentioned in the below table:

	Deformation on vehicle(mm)	Equivalent Stress on vehicle (Mpa)
4kg TNT without sheet	111.25	818
4kg TNT with sheet	65.89	799.78

Table 1: 4 kg TNT with and without carbon fiber sheet

6kg TNT blast without Carbon fiber sheet:

Deformation: Maximum Deformation of 139.34 mm occurred on the vehicle.

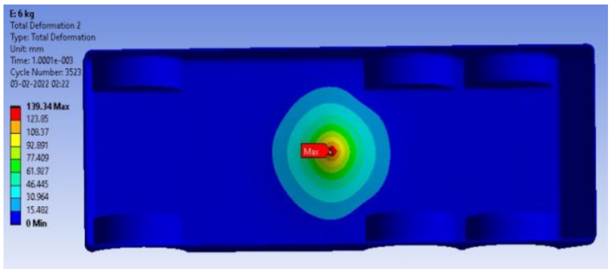

Figure 15: Maximum Deformation on 6 kg TNT without carbon fiber sheet

Equivalent Stress: Maximum Stress of 926.84 Mpa occurred on the vehicle

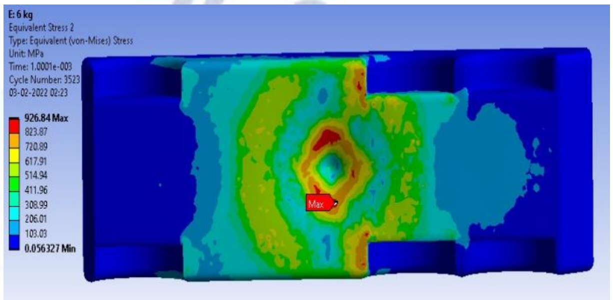

Figure 16: Equivalent Stress on 6kg TNT without carbon fiber sheet inside the vehicle

C.6KG TNT BLAST WITH CARBON FIBRE PLATE:

• Deformation: Maximum deformation of 91.424 mm occurred on inner side of the vehicle and 89.625 mm occurred on the sheet.

•

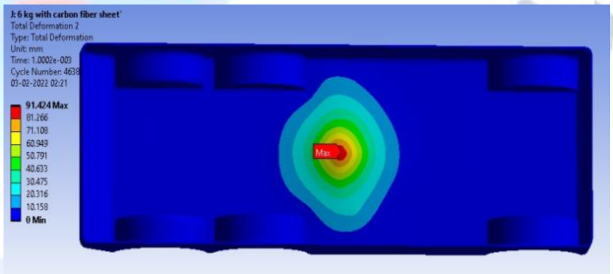

Figure 17: Maximum deformation on 6 kg TNT with Carbon fiber sheet

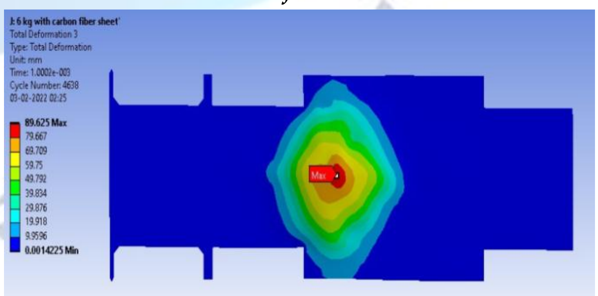

Figure 18: Maximum deformation on Carbon fiber sheet for 6kg TNT

• Equivalent Stress: Maximum Stress of 828.45 Mpa occurred on the vehicle and 849.25 Mpa occurred on the sheet.

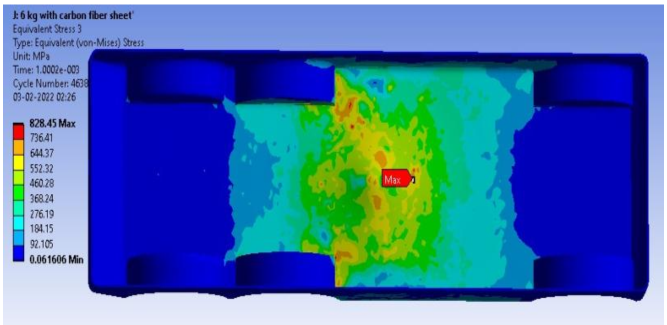

Figure 19: Maximum Stress on 6kg TNT with Carbon fiber sheet

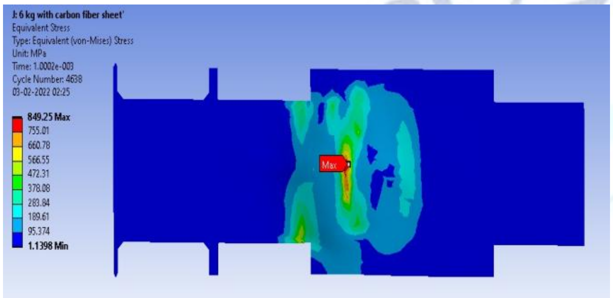

Figure 20: Maximum Stress on Carbon fiber sheet for 6kg TNT

Result Comparison Between 6 kg TNT with and without carbon fiber sheet are mentioned in the below table:

Table 2: 6 kg TNT with and without carbon fiber sheet

	Deformation on vehicle(mm)	Equivalent Stress on vehicle (Mpa)
6kg TNT without sheet	139.3	926.8
6kg TNT with sheet	91.4	828.45

D. 8KG TNT BLAST WITHOUT CARBON FIBRE PLATE:

- Deformation: Maximum Deformation of 479.14mm occurred.

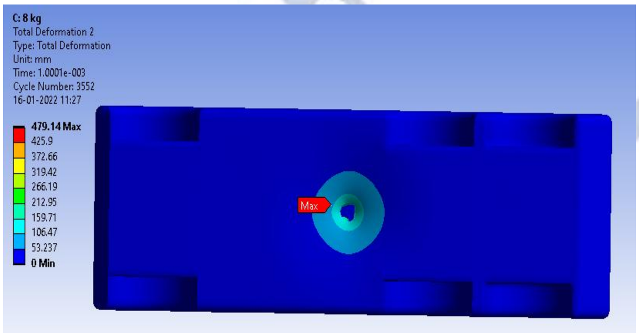

Figure 21: Maximum deformation on vehicle for 8kg TNT without carbon fiber sheet

Equivalent Stress: Maximum Stress of 958.73mpa occurred on vehicle.

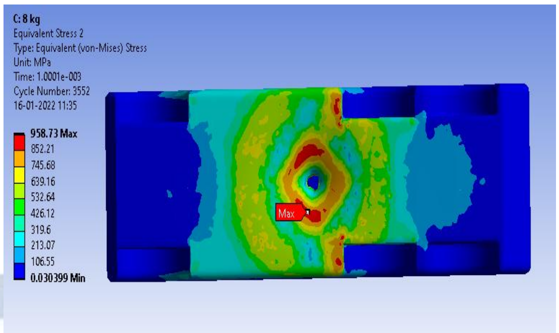

Figure 22: Maximum Stress on vehicle for 8kg TNT without carbon fiber sheet

E. 8KG TNT BLAST WITH CARBON FIBRE PLATE:

- Deformation: Maximum Deformation of 110.15mm occurred on vehicle and 106.95 mm on carbon fiber sheet.

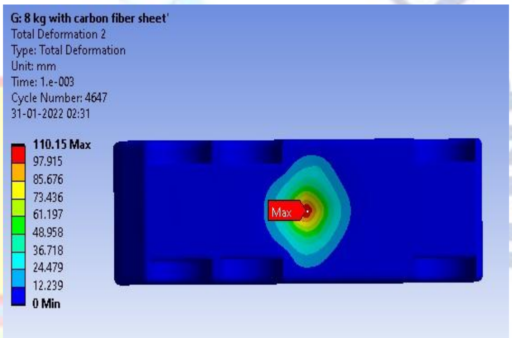

Figure 23: Maximum Deformation of 8 kg TNT with carbon fiber sheet on vehicle

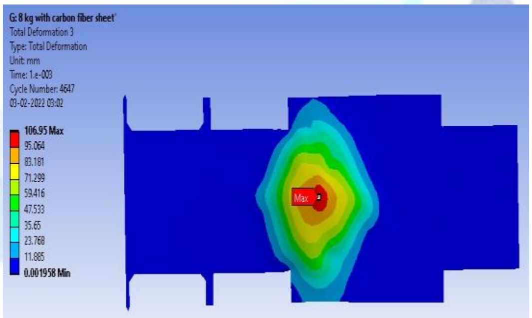

Figure 24: Maximum Deformation of 8 kg TNT on carbon fiber sheet

- Equivalent Stress: Maximum Stress of 908.97 Mpa occurred on vehicle and 946.08 Mpa on Carbon fiber sheet.

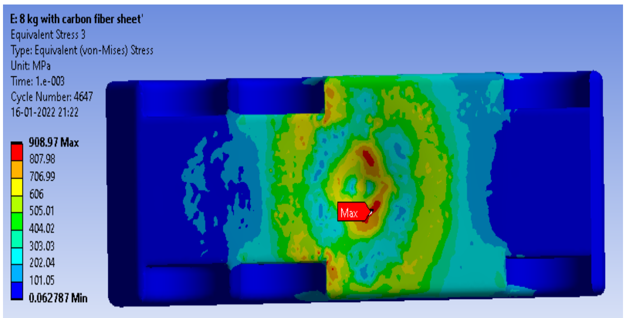

Figure 25: Maximum stress of 8 kg TNT with carbon fiber sheet on vehicle

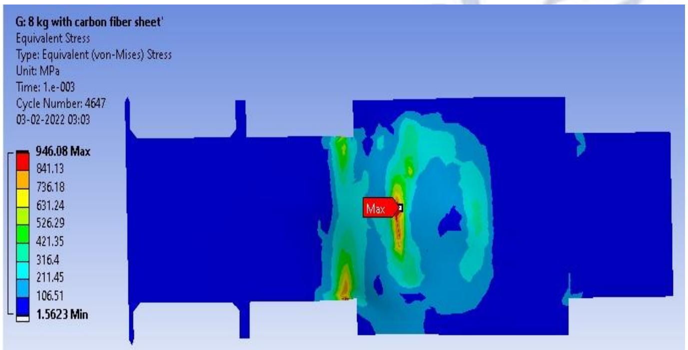

Figure 26: Maximum Stress of 8 kg TNT on carbon fiber sheet

- Result Comparison Between 8 kg TNT with and without carbon fiber sheet are mentioned in the below table:

	Deformation on vehicle(mm)	Equivalent Stress on vehicle (Mpa)
8kg TNT without sheet	479.14	958.73
8kg TNT with sheet	110.15	908.97

Table 3: 8 kg TNT with and without carbon fiber sheet

11. OBSERVATION:

From the simulation results, the deformations and stresses are observed at different cases which are shown in above Table1, Table 2 and Table 3. In these tables mentioned above the results are compared in each case of FEA Analysis of armoured vehicle with and without carbon fiber sheet.

12. CONCLUSION:

In this paper, the comparisons of explosion with TNT modelsof armoured vehiclewith and without sheets are presented. The results showed that the vehicle with addition of sheet on the bottom end of the vehicle has significant improvement in the stresses and deformations while explosion of TNT.In all the above analysed cases the explosion is directly affected on the bottom end of the vehicle. From initial observation, thecases without carbon fibre sheet are exposed to high stresses and deformations on the vehicle. Comparatively when we consider a carbon fiber sheet placed inside the vehicle, it reduced the effect of explosion on the vehicle. So, further studies can be done by changing the sheet thickness and adding structures for improvement of the vehicle for better results and also for the occupant safety. This might also decrease the weight of the model. Carbon fibre Sheet thickness can also be increased but it is much expensive compared to other materials.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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