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Study and Analysis of a Bullet penetrating Armor material.

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Abstract: Finite element method (FEM) is a numerical method for solving a differential or integral equation. It has been applied to a number of physical problems, where the governing differential equations are available. The Ansys explicit dynamics suite enables you to capture the physics of short- duration events for products that undergo highly nonlinear, transient dynamic forces. This paper studies the impact of bullet with aluminium alloy plate fixed on all sides. Simulations were carried out to study effect of bullet impact angle and thickness of aluminium alloy plates. These simulations were performed through Ansys Workbench and the impact velocity was 1500 m/s in the test. Explicit dynamics simulations are addressed by three products in the Ansys suite, and the right tool for the job depends on user needs and applications: ANSYS AUTODYN was the software used in this analysis. The aim of the present paper is to determine whether velocity or distance is the key factor to determine that the bullet can pierce the Armor. The deformation is done on Plate and Bullet.

For the Analysis two materials are been used:

AL2024-T4 for Plate & Steel 1006 for the Bullet.

Dimensions are in mm.

Keywords: FEM, Explicit Dynamics, AUTODYN

1. **Introduction:** Combat soldiers operate in a diverse range of operational environments and injury threats. The need for study of protection against small arms and light weapons is very important both from a civilian and a military point of view. The Threats to public security and premises security are on the rise because of increasing terrorism and violence. At the time of war civilians along with the military personnel have to go to war. The knowledge of arms, ammunitions should be known to the general public as well. Safety of individual is a matter of Concerns, hence there is need to develop bullet resistant solutions for soldiers, tanks, and other military vehicles. Most of the ballistic studies consider only normal impact where the angle between velocity vector of projectile and normal vector of target plane is zero. There is a huge scope for the upcoming generation in the area of defence and intelligence to make the country's military power as well as it's economy strong & sufficient. The Armor to be used should be durable and easy to produce, use, and repair. The traditional method of armouring is the use of thick steel plates. However, multilayer armour was developed in decades and improved penetration resistance/weight ratio relative to steel. In multi-layered armours, the outer ceramic layer deflects the bullets, the artificial fibres hold the bullet particles, and the metal part stops the bullets.

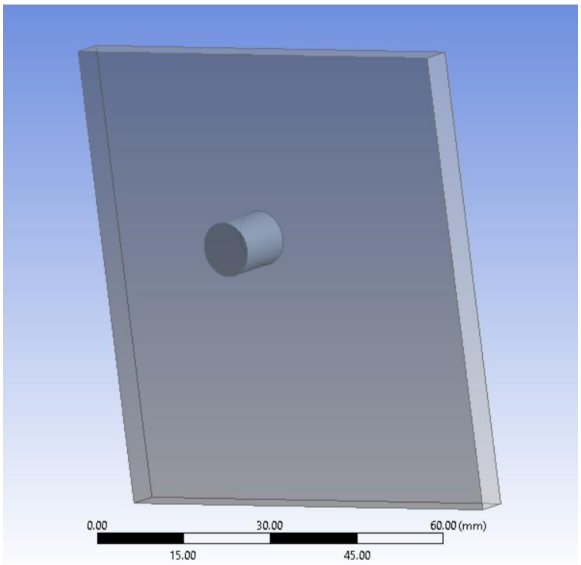


Fig.1 Aluminium plate & Steel Bullet

Material	AL2024-T4	Steel 1006
Source	Explicit material	Explicit material

Fig.2 Materials

2. **Methodology**

A) <u>Details of materials.</u>

- **Plate – (AL2024-T4)**

All units are in Millimeters.

Geometry > Operation (Add frozen Material) > FD1 (5mm)

AL2024-T4

Properties:

Initial Yield Stress	2.6E+08
Max Yield Stress	7.6E+08
Shear Modulus	2.86E+10

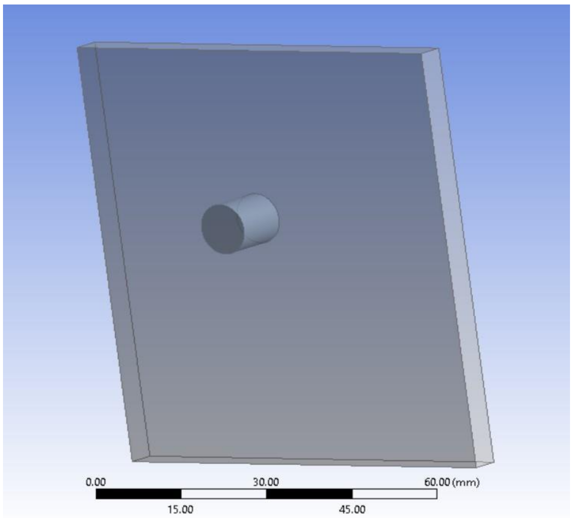


Fig.3 Aluminium Plate

Sketching	Modeling
Details View	
Details of Extrude1	
Extrude	Extrude1
Geometry	Sketch1
Operation	Add Frozen
Direction Vector	None (Normal)
Direction	Normal
Extent Type	Fixed
FD1, Depth (>0)	5 mm
As Thin/Surface?	No
Merge Topology?	Yes
Geometry Selection: 1	
Sketch	Sketch1

Fig.4 Aluminium plate Geometry Details

- Bullet – (STEEL 1006)

All units are in Millimeters.

Geometry > Operation (Add frozen Material) > FD1 (10mm

Steel 1006

Properties:

Density	7896
Shear Modulus	8.18E+10

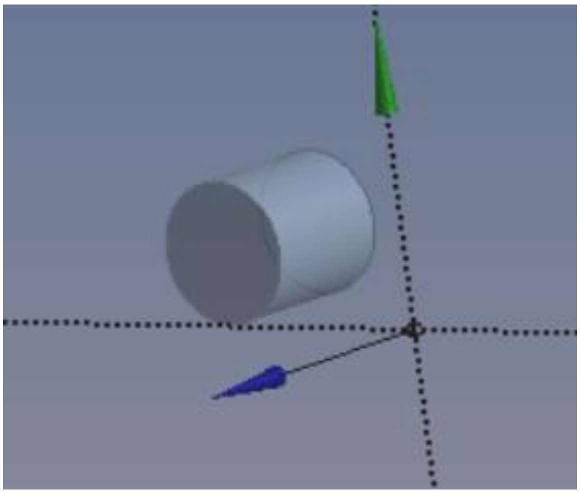


Fig.5: Steel Bullet

Details View	
Details of Extrude2	
Extrude	Extrude2
Geometry	Sketch2
Operation	Add Frozen
Direction Vector	None (Normal)
Direction	Normal
Extent Type	Fixed
FD1, Depth (>0)	10 mm
As Thin/Surface?	No
Merge Topology?	Yes
Geometry Selection: 1	
Sketch	Sketch2

Fig .6 Steel Bullet Geometry Details

B. Meshing of Plate and Bullet

The basic need for ANSYS analysis is to divide the whole section into many tetrahedral elements. This will enable us to analyse the stress of the components at distinct locations. A typical drawing of the meshing of the Plate and Bullet is shown in Figure 7.

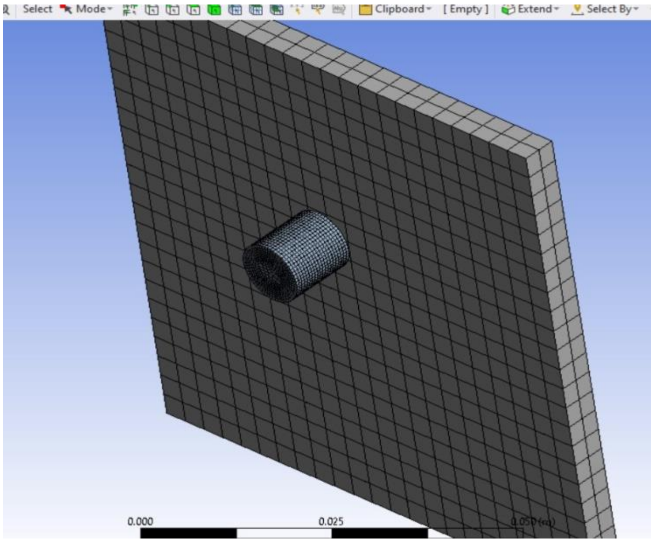
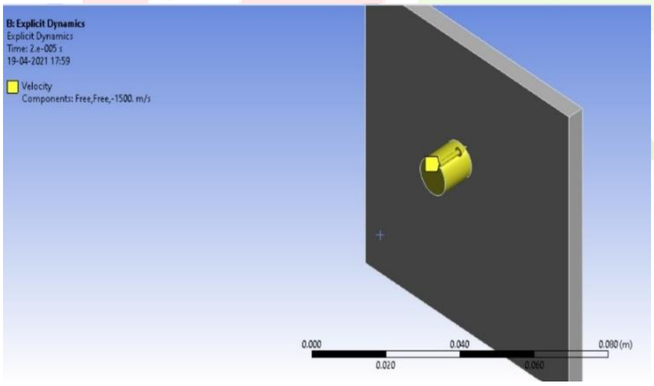


Fig.7 Meshing of Plate and Bullet

C. Boundary Condition

Figure 8 represents the boundary conditions applied to the bullet. The velocity applied by bullet is 1500m/s



Details of "Velocity"

Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Type	Velocity
Define By	Components
Coordinate System	Global Coordinate ...
X Component	Free
Y Component	Free
Z Component	-1500. m/s (step ap...
Suppressed	No

Fig.8 Steel Bullet Boundary condition

D. Build up an End time and Erosion control

Erosion Controls:

On geometric strain	Yes
Geometric Strain	1.5
Material Failure	No
Min element time	No

E. Solution

```
:ycle:     5593, Time:  1.995E-05s, Time Inc.: 3.627E-09s, Progress:  99.76%, Est. Clock Time Remaining: 0s
:ycle:     5594, Time:  1.996E-05s, Time Inc.: 3.627E-09s, Progress:  99.78%, Est. Clock Time Remaining: 0s
:ycle:     5595, Time:  1.996E-05s, Time Inc.: 3.627E-09s, Progress:  99.80%, Est. Clock Time Remaining: 0s
:ycle:     5596, Time:  1.996E-05s, Time Inc.: 3.627E-09s, Progress:  99.81%, Est. Clock Time Remaining: 0s
:ycle:     5597, Time:  1.997E-05s, Time Inc.: 3.628E-09s, Progress:  99.83%, Est. Clock Time Remaining: 0s
:ycle:     5598, Time:  1.997E-05s, Time Inc.: 3.628E-09s, Progress:  99.85%, Est. Clock Time Remaining: 0s
:ycle:     5599, Time:  1.997E-05s, Time Inc.: 3.628E-09s, Progress:  99.87%, Est. Clock Time Remaining: 0s
:ycle:     5600, Time:  1.998E-05s, Time Inc.: 3.628E-09s, Progress:  99.89%, Est. Clock Time Remaining: 0s
:ycle:     5601, Time:  1.998E-05s, Time Inc.: 3.628E-09s, Progress:  99.91%, Est. Clock Time Remaining: 0s
:ycle:     5602, Time:  1.998E-05s, Time Inc.: 3.628E-09s, Progress:  99.92%, Est. Clock Time Remaining: 0s
:ycle:     5603, Time:  1.999E-05s, Time Inc.: 3.628E-09s, Progress:  99.94%, Est. Clock Time Remaining: 0s
:ycle:     5604, Time:  1.999E-05s, Time Inc.: 3.628E-09s, Progress:  99.96%, Est. Clock Time Remaining: 0s
:ycle:     5605, Time:  2.000E-05s, Time Inc.: 3.628E-09s, Progress:  99.98%, Est. Clock Time Remaining: 0s
:ycle:     5606, Time:  2.000E-05s, Time Inc.: 3.628E-09s, Progress: 100.00%, Est. Clock Time Remaining: 0s
:ycle:     5607, Time:  2.000E-05s, Time Inc.: 3.628E-09s, Progress: 100.00%, Est. Clock Time Remaining: -

;IMULATION ELAPSED TIME SUMMARY

:XECUTION FROM CYCLE         0 TO      5607
:LAPSED RUN TIME IN SOLVER =       1.50668E+00 Minutes
:OTAL ELAPSED RUN TIME     =       1.63752E+00 Minutes
'OB RAN OVER      2 WORKERS
'OB RAN USING Intel MPI
'OB RAN USING DECOMPOSITION AUTO

'roblem terminated .... wrapup time reached

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Fig 9: Wrap up time reached

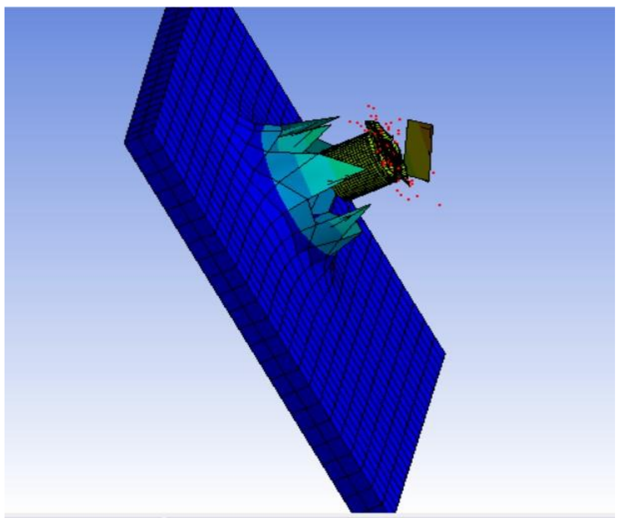

Fig 10: Total Deformation

High-velocity bullet impacts on the plate. Materials assigned, velocity applied to the bullet and solved for 20 microseconds.

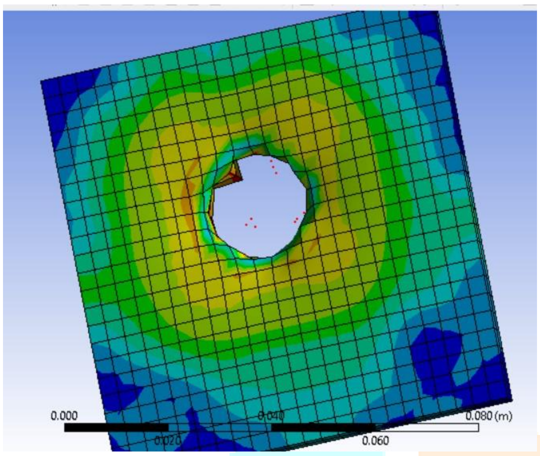

Fig 11: The Equivalent Stress

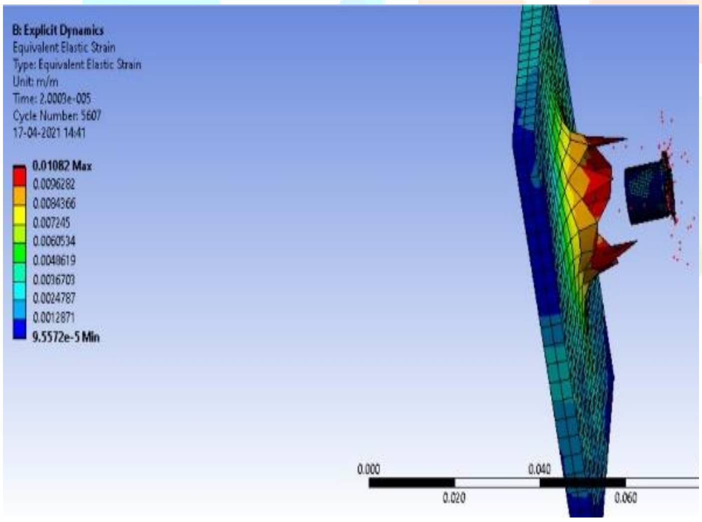

Fig 12 : The Equivalent Strain

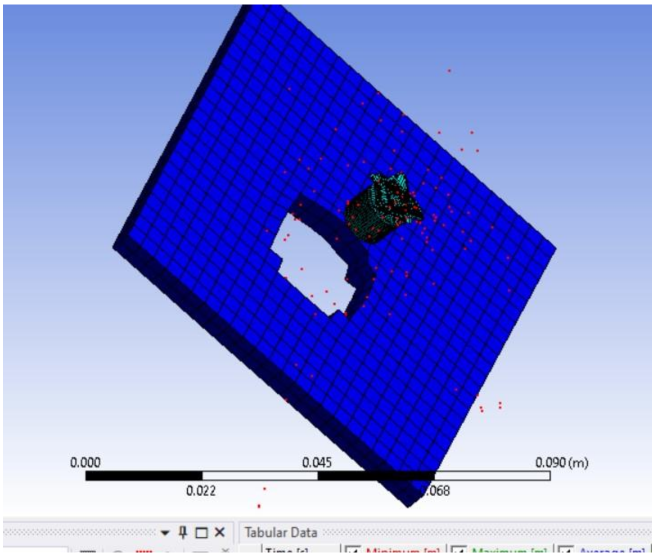

Fig 13: Failure Criteria

3. Result

	Deformation	Stress	strain
Max	0 m	0 pa	0
Min	3.96e-05 m	8.0e-008 pa	1.303

Conclusion:

- Looking at all the analysis here we can conclude that the material of Steel is hard than Aluminum. While the Velocity comes in effect.
- The More the distance between a bullet is fired and the plate the faster the bullet travels irrespective of velocity. The Less the distance the Bullet cannot completely pierce the plate.
- A .50cal bullet can pierce a steel plate too but if the plate is 3times hardened it cannot pierce through then only A shotgun bullet & Automatic Guns Bullets can travel through.

References:

- Simulation and Experimental Tests of Ballistic Impact on Composite Laminate Armor – Ali Murat Soudan

- Finite Element Simulation of Bullet Resistant Composite Body Armor- Riaz Muhammad