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# Bullet Impact Analysis on Armour Plate by Using Finite Element Method

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**ABSTRACT:** Ballistic impact of typical armor metal plate of medium thickness by ogive-nosed projectiles travelling with ordnance velocities has been investigated through numerical simulations. Johnson-Cook material and failure models have been used to simulate the behavior and failure of the material under impact conditions. The stages of penetration and have been predicted. The residual velocities, ballistic limit velocity and perforation times have been determined from the simulation results and found to match with experimental data. The Ballistic Impact is a high and low velocity impact on a target by a projectile having a small mass and size. The aim of this thesis is to study ballistic impact using the Johnson-Cook material Numerical simulation of ballistic impact is gaining momentum due to the complexities and large costs involved with experimental study of ballistic impact. But it is seen that most numerical simulations use empirical failure criterion which are based on the results of experiments. In this study, A Steel and Aluminium plate has been impacted with a projectile based on bullet. Finite Element software package ABAQUS/CAE Explicit has been used to numerically simulate the scenario. Analyses have been performed for two different plate, three different shapes of bullet, different projectile velocities and different projectile angles. Damage Evolution Parameter have been calculated using Finite element method and the results are compared for the different cases to observe trends of variation of the damage initiation time with the temperature of the target and velocity of the projectile

**KEYWORDS:** Penetration, Perforation, Angles, Velocity, Abaqus, Finite Element Method

## I. INTRODUCTION

Ballistic Impact is the high velocity impact on a target by a projectile having a small mass and size. The damage in such an impact happens within fractions of milliseconds. When the projectile hits the target, impact force is applied within a short period of time and this is called shock loading. This shock loading has relatively greater effect on the target than a lower force applied over a proportionally longer period of time. The reactions and the mechanisms that occur during a ballistic impact depends upon thickness, strength, ductility, toughness, acoustic impedance and density of both the target and the projectile and the velocity of the projectile. The maximum velocity at which the projectile fails to penetrate the target is called the ballistic limit of the target and the projectile.

At low impact velocities, dynamic deformation mechanisms within the projectile and the target govern the penetration resistance of the target material. However, as the impact velocity increases into the hypervelocity regime, hydrodynamic effects dominate and the penetration response becomes controlled by only the density of the impacted material and projectile.

The study of ballistic impact is of utmost importance in military and defence. This knowledge is useful in developing body armours and other bulletproof objects used in warfare. However, during the development of



bulletproof materials, large scale experiments need to be conducted which are expensive and time consuming. Hence, one general solution techniques using numerical simulation of ballistic impact are needed to supplement the high-precision testing, so that the experimental costs can be reduced. The phenomenon of ballistic impact has been well researched both experimentally and numerically. With the help of powerful computational software packages, like ABAQUS, LS-DYNA, etc. ballistic impact can be easily simulated to substitute the expensive experimental setup. However, it is seen that in the numerical simulations, a fracture criterion has to be defined to simulate the fracture in the target. Most numerical simulations use the Johnson-Cook failure initiation criterion, which is an empirical criterion and it is based on the results of experiments.

## II. METHODOLOGY

The problem has been numerically modelled and analysed using the finite element software package ABAQUS/CAE Explicit. Explicit analysis is used in case of an impact problem because the dynamic force which is applied is very large compared to the time period and involves large deformations and nonlinear material response. This procedure solves every problem as a wave propagation problem. ABAQUS Explicit provides the capability to analyse problems involving high-speed (short duration) dynamics, large, nonlinear, quasi-static analyses, highly discontinuous, post-buckling and collapse simulations. Therefore, ABAQUS Explicit has been used in this case to study the ballistic impact problem for this research

The ABAQUS program has many FE analysis capabilities ranging from a simple linear static analysis to complex non linear transient dynamic analysis. The procedure for typical ABAQUS EXPLICIT analysis can be divided into ten distinct steps.

1. Build the model
2. Material property
3. Assembly
4. Interaction
5. Step creation
6. Boundary conditions and constrains
7. Field output request
8. Meshing
9. Job creation and submission
10. Review the results

The interaction property is given to select the master and slave surface. This property is much important for the selection of target model and moving impact projectile model. The surface property step has been assigned as surface to surface contact explicit. Solving method was chosen as default kinematic contact method. For the target plate displacement, rotation should be arrested in all directions. For the impact bullet model  $u_1$ ,  $u_2$ ,  $u_{r1}$ ,  $u_{r2}$ ,  $u_{r3}$  should be fixed. The bullet will be allowed to move in  $u_3$  i.e. towards the target plate alone. The property assigned fully defined model with constraints would give by job name. Finally the job will be submitted for analysis.



III. EXPERIMENTAL RESULTS

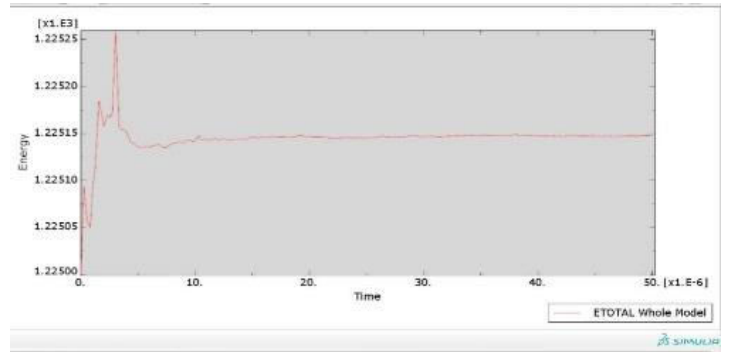
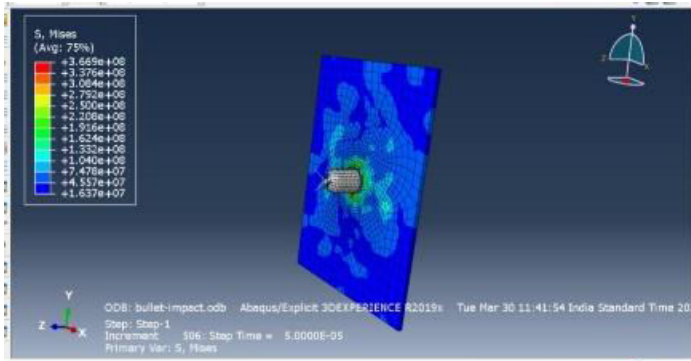


Figure.1- Projectile 350m/s at an angle of 0 degree

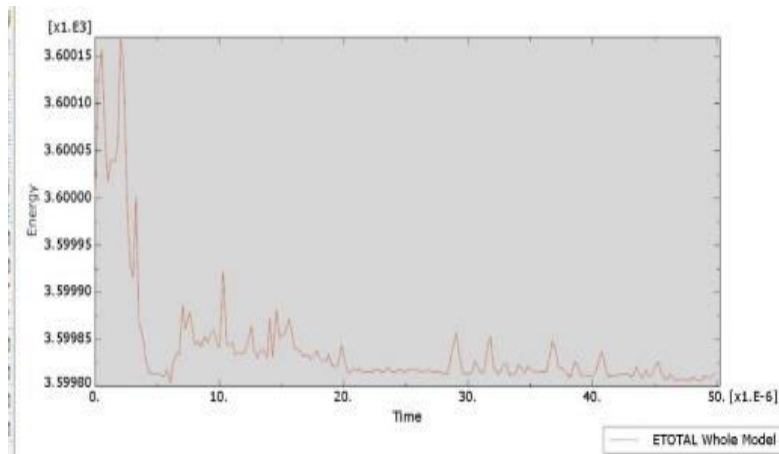
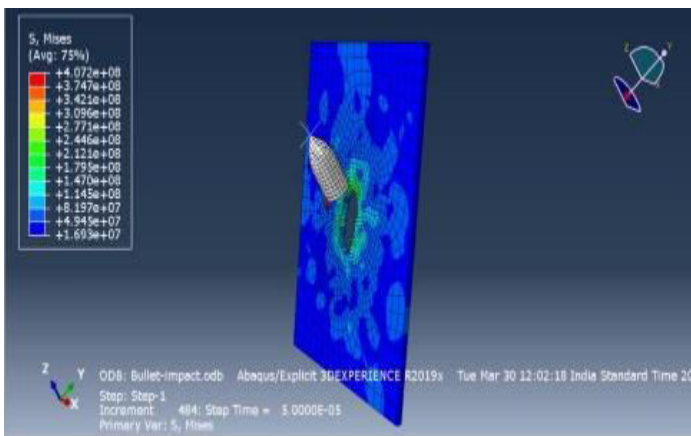


Figure.2-Projectile 520 m/s at an angle of 50 degree

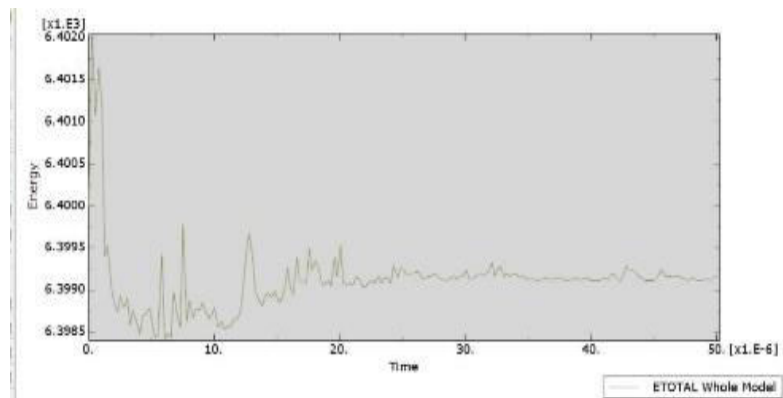
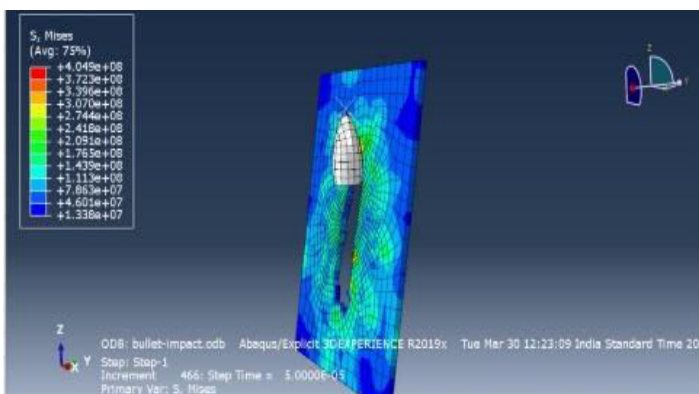


Figure.3- Projectile 800 m/s at an angle of 80 degree

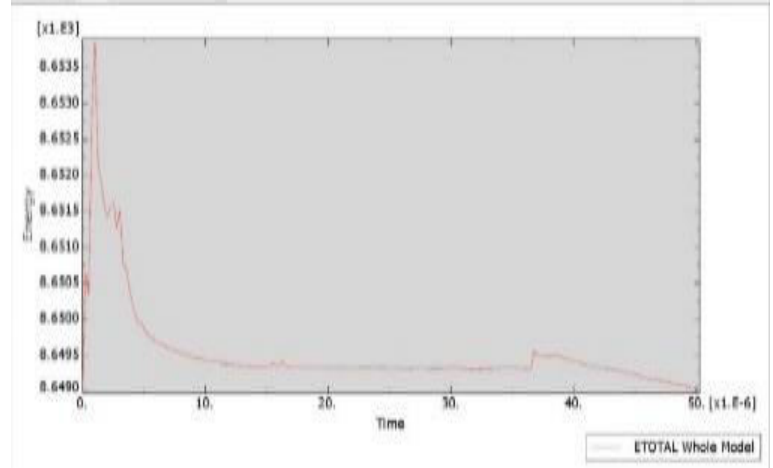
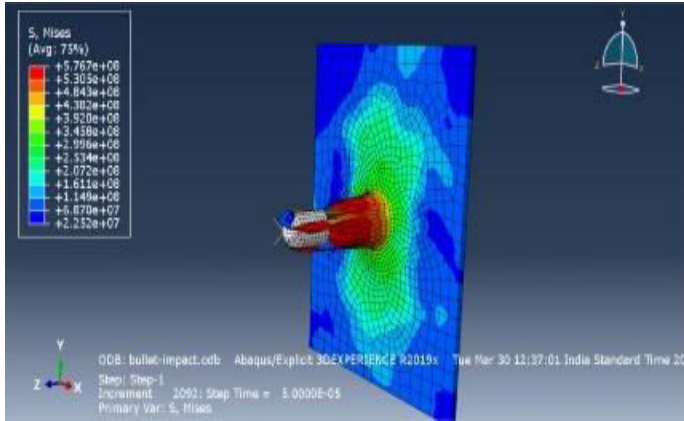


Figure.4-Projectile 930 m/s at an angle of 0 degree

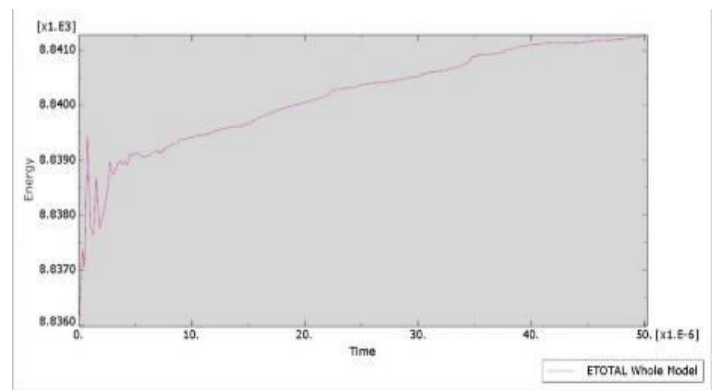
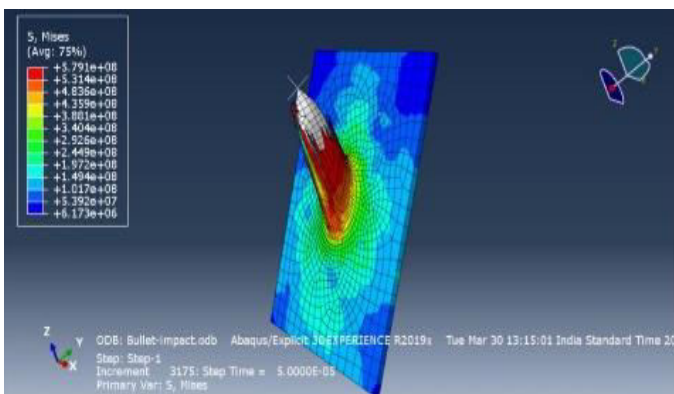


Figure.5-Projectile 940 m/s at an angle of 50

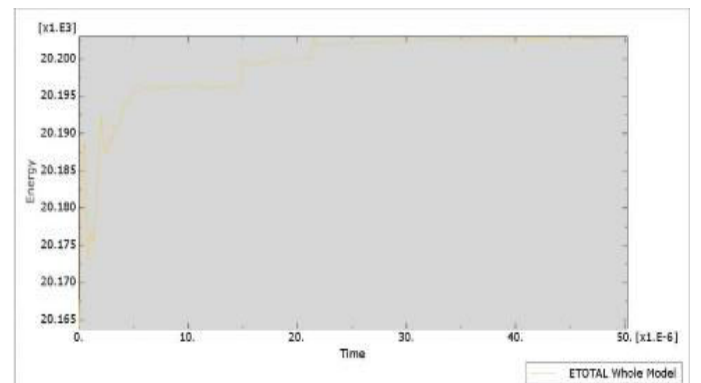
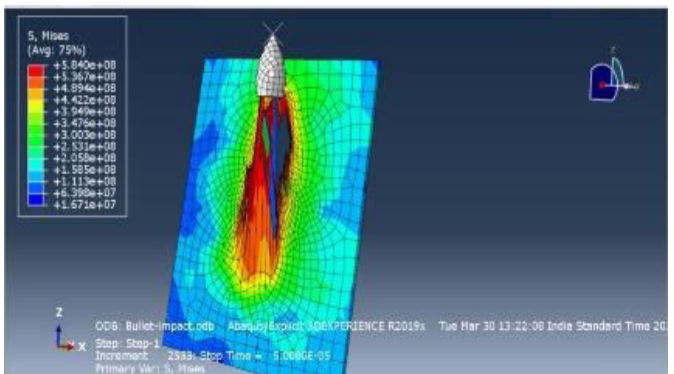


Figure.6-Projectile 1420 m/s at an angle of 80 degree



Table:1-Aluminium Plate with Different Shapes of the Bullet

Sr.no	Angle (degree)	Penetration (m/s)	Perforation (m/s)
<b>ROUND NOSE BULLET</b>			
1	0	< 350	> 350
2	10	< 355	>355
3	20	< 370	> 370
4	30	< 385	>385
5	40	< 400	>400
6	50	< 415	> 415
7	60	< 430	> 430
8	70	< 445	> 445
9	80	< 455	> 455
<b>CONICAL NOSE BULLET</b>			
1	0	<470	>470
2	10	<472	>472
3	20	<477	>477
4	30	<500	>500
5	40	<510	>510
6	50	<520	>520
7	60	<550	>550
8	70	<630	>630
9	80	<850	>850
<b>BOAT TAIL SPITZER SOFT POINT</b>			
1	0	<570	>570
2	10	<575	>575
3	20	<580	>580
4	30	<585	>585
5	40	<590	>590
6	50	<595	>595
7	60	<625	>625
8	70	<650	>650
9	80	<800	>800



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Table-2: Steel Plate with Different Shapes of the Bullet

Sr.no	Angle (degree)	Penetration (m/s)	Perforation (m/s)
<b>ROUND NOSE BULLET</b>			
1	0	< 930	> 930
2	10	<940	>940
3	20	<950	>950
4	30	<960	>960
5	40	<970	>970
6	50	<980	>980
7	60	<990	>990
8	70	<1030	>1030
9	80	<1200	>1200
<b>CONICAL NOSE BULLET</b>			
1	0	<880	>880
2	10	<900	>900
3	20	<910	>910
4	30	<920	>920
5	40	<930	>930
6	50	<940	>940
7	60	<950	>950
8	70	<1000	>1000
9	80	<1200	>1200
<b>BOAT TAIL SPITZER SOFT POINT</b>			
1	0	<850	>850
2	10	<860	>860
3	20	<870	>870
4	30	<880	>880
5	40	<890	>890
6	50	<900	>900
7	60	<920	>920
8	70	<960	>960
9	80	<1420	>1420



#### IV. CONCLUSION

Ballistic Impact has been studied for an Aluminium & steel plate using the FINITE ELEMENT METHOD. The study has been carried out for plate for projectile angle (degree) 0,10,20,30,40,50,60,70,80 and different projectile velocities at which perforation and penetration occur Modelling and analysis has been done using ABAQUS/CAE Explicit FE Package. The values of total energy and time obtained from these numerical simulations are then used to calculate the total energy difference and eventually, the total energy Evolution Parameter. Total energy Evolution Curves are then obtained by plotting the total Energy Evolution Parameter against time, which are used to compare the trends for different plate and different projectile, angle and velocities. It was observed that in case of varying plate angle more damage takes when angle of projectile is higher. In case of varying projectile velocity, it was observed that the higher the projectile velocity, the sooner the perforation occur Also, it is seen that the time at which damages occurs decreases exponentially with increase in projectile velocity. These results are in agreement with the trends observed by several researchers from their experimental studies on ballistic impact for cases of varying projectile angles and velocities and different shapes. The objective of this work is to study ballistic impact using FINITE ELEMENT METHOD. Based on the conclusions of this study and their conformity with the conclusions of experimental results of ballistic impact performed by several researchers, it can be said that the FINITE ELEMENT METHOD can be used to study ballistic impact.

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