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Research Paper

SIMULATION STUDIES ON THE EFFECT OF PROJECTILE NOSE SHAPE IMPACTING ON ALUMINUM PLATES

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In mechanics, an impact is a high force or shock applied over a short period when two or more bodies collide. Such a force or acceleration usually has a greater effect than a lower force applied over a proportionally longer period of time. The effect depends critically on the relative velocity of the bodies to one another. Structural failure due to impact is a common but complex phenomenon. In earlier days the impact problems were primarily confined to the military. As the civilian technology has grown in sophistication, more studies are being carried out to understand the behavior of materials subjected to short duration of loading. The field of impact dynamics is of interest to engineers concerned with design of light weight body amour, safety of nuclear-reactor containment vessels subjected to missile or aircraft impact, protection of spacecraft from meteoroid impact, safe demolition of pre stressed concrete structures and transportation safety of the hazardous materials. In the present work, simulation is performed by impacting aluminum plates of three different thicknesses viz. 0.81 mm, 1.51 mm and 2.05 mm by three different nose projectiles, i.e., blunt, conical and hemispherical with varying kinetic energy in Finite Element Code. Problem is modeled using ANSYS/Explicit Axi-symmetric Model.

Keywords: Impact, Projectile velocity, Impact velocity, Residual velocity, Velocity drop

INTRODUCTION

In earlier days, the impact problems were primarily confined to the military. As the civilian technology has grown in sophistication, more studies are being carried out to understand the behavior of materials subjected to short duration of loading. The field of impact dynamics is of interest to engineers concerned with design of light weight body amour, safety of nuclear-reactor containment vessels subjected to missile or aircraft impact, protection of spacecraft from meteoroid impact, safe demolition of pre-stressed concrete structures and transportation safety of the hazardous materials.

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Impact could be defined as collision of two bodies. The intensity of impact couldbe as small as the hit of a droplet of rainwater on earth and as high as the collision of two heavenly bodies such as comets or asteroids.

In mechanics, an impact is a high force or shock applied over a short period when two or more bodies collide. Such a force or acceleration usually has a greater effect than a lower force applied over a proportionally longer period of time. The effect depends critically on the relative velocity

OBJECTIVE OF THE PROJECT

In the present work numerical simulations are performed on thin aluminium plates of three thicknesses 0.81 mm, 1.51 mm and 2.05 m, subjected to impact by conical, hemispherical and blunt projectiles. Projectiles are impacted normally with velocities in the sub-ordinance range.

In modelling the problem in ABAQUS, effect of number of elements on the plate and type of element (triangular, quad) for different projectiles is studied.

Impact and residual velocities are measured and energy absorbed by the projectile is calculated. Thicknesses of the plates and impact velocity of the projectile are varied. Mass and dimensions of the projectile are kept constant. Impact velocity is related to the residual velocity and velocity drop. Also variation of absorbed energy with impact energy is studied.

MODELLING OF THE PROBLEM

Figure 1: Examples of Impact

Table 1: Physical Parameters of Used Projectiles

S. No.	Projectile Shape	Projectile Dimensions					Mass (gram)
		Total Length	Shank Length	Nose Length	Diameter	Semi Cone Angle	
1.	Blunt	30.26	-	-	12.8	-	30.2
2.	Conical	40	26.10	13.9	12.8	22.5	30.2
3.	Hemispherical	32.4	25.9	6.4	12.8	-	30.3

Table 2: Combination of Projectiles and Plates for Different Readings

S. No.	Projectile	Plate Thickness (mm)	Plate Diameter (mm)	Effective Diameter (mm)
1.	Blunt	0.81,1.51,2.05	255	210
2.	Conical	0.81,1.51,2.05	255	210
3.	Hemispherical	0.81,1.51,2.05	255	210

Table 3: Properties of Aluminium Used in Modelling

Modulus of Elasticity (N/mm^2)	68 X 10^3
Poisson's Ratio	0.3
Density (Kg/m^3)	2698
A	102.82
B	49.79
N	0.183
C	0.001
Reference Strain Rate	1
M	0.859
Tmelt	893
Troom	293
D_1	0.071
D_2	1.248
D_3	–1.142
D_4	0.147
D_5	0

Meshing Strategy

The target plate for the case of conical and hemispherical nosed projectiles was modelled with continuum solid axisymmetric triangular 3 noded elements with single integration point. This was done in order to reduce element distortion in case of conical nosed projectile. For the case of impact by blunt and hemispherical nosed projectiles, quadrilateral elements were employed. An impact zone was created, where the projectile comes in contact with the plate, in which the mesh density was higher and was reduced as the distance from the impact area increased. The aspect ratio of the elements in the impact zone was maintained as unity; however it was allowed to increase elsewhere.

Figure 2: Meshed Plate

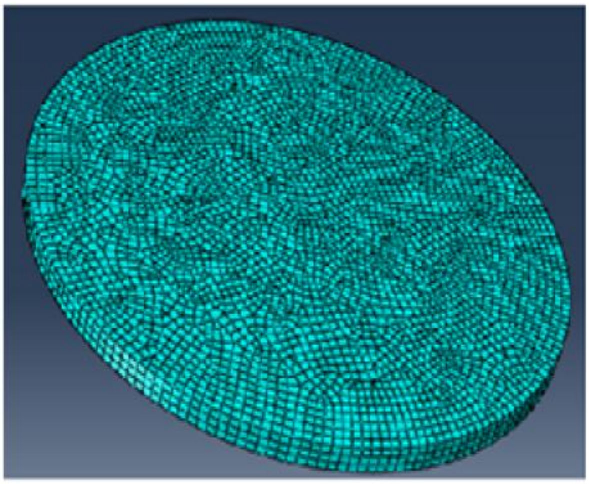


Figure 3: Meshes in the Impact Zone

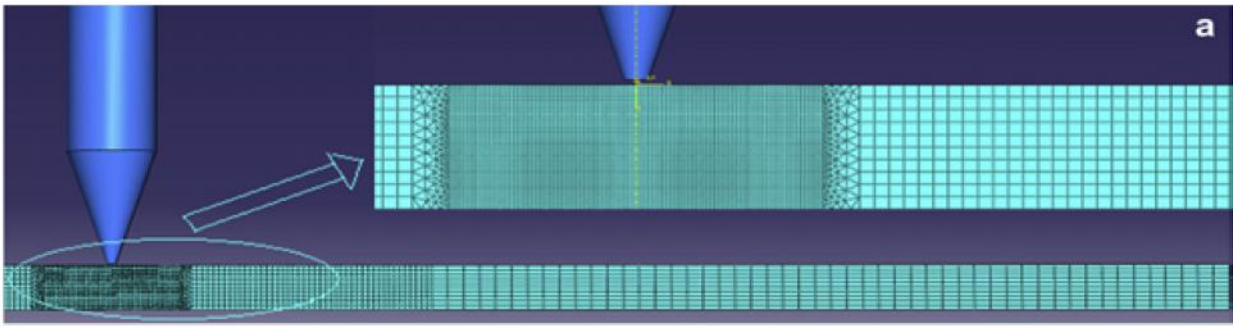


Table 4: Number of Elements Along the Thickness in Meshing

Projectile	Thickness (mm)	No. of Elements Along the Thickness
Conical	0.81	8
	1.51	24
	2.05	36
Blunt	0.81	12
	1.51	10
	2.05	24
Hemispherical	0.81	6
	1.51	16
	2.05	24

ABACUS INTRODUCTION

Figure 4: Step 1 – Blunt

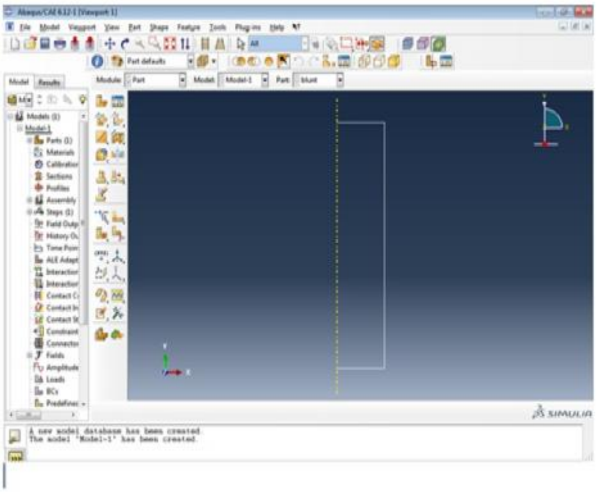


Figure 5: Step 2 – Plate

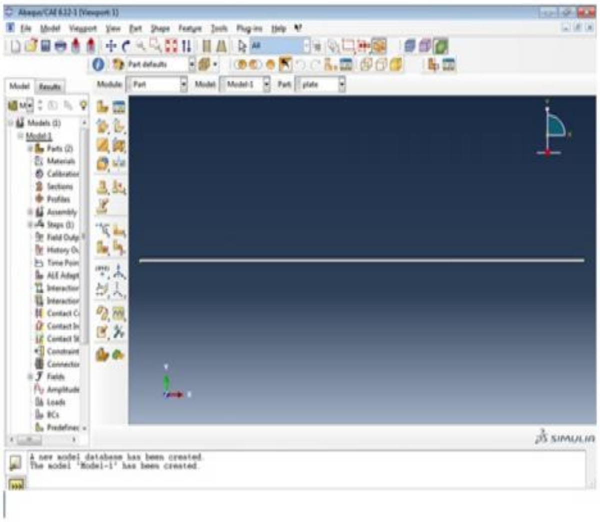


Figure 6: Step 3 – Entering the Material Properties, Inertia, Boundary Condition for the Figures

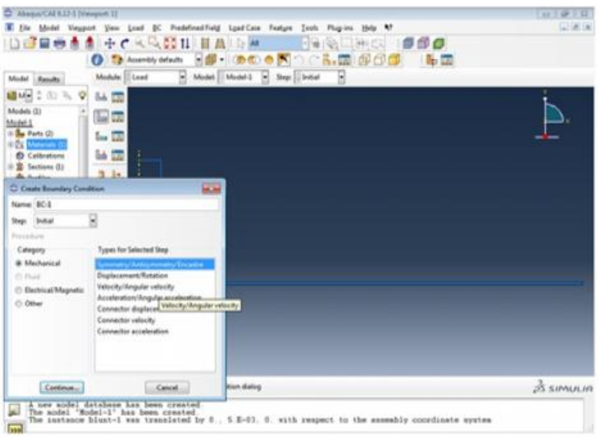
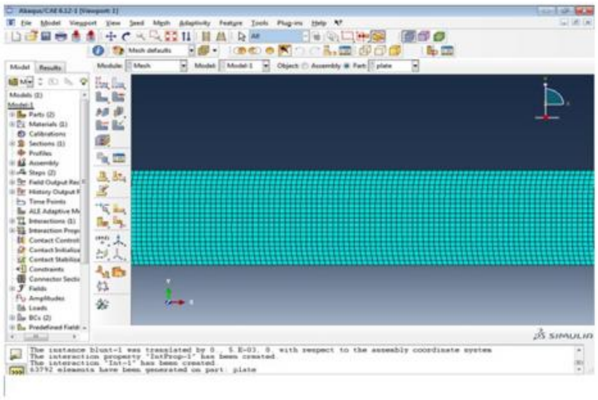


Figure 5: Step 4 – Meshing in Abacus Software



RESULTS

Figure 6: Vonmises Stress Contour for Blunt Materials

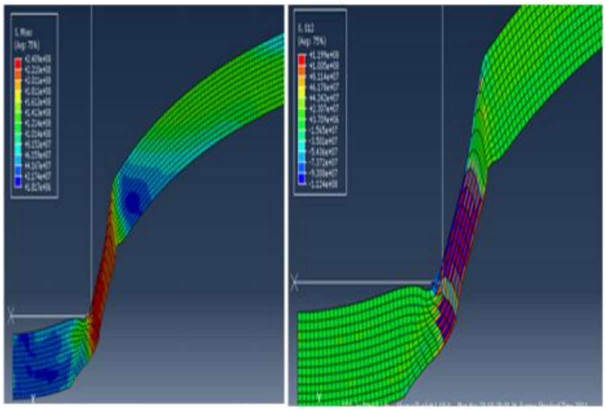


Figure 7: Vonmises Stress Contour for Blunt and Conical Materials

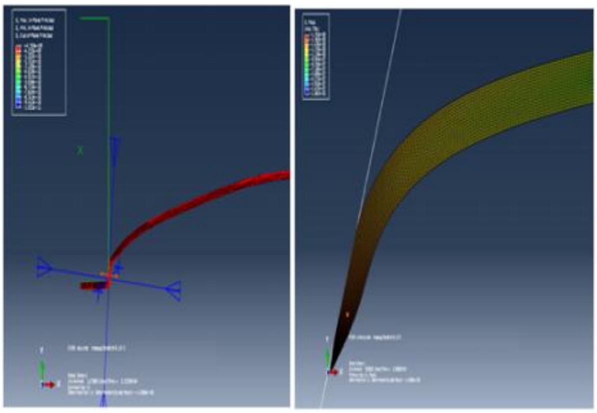


Figure 8: Deformation Shape for Conical Materials

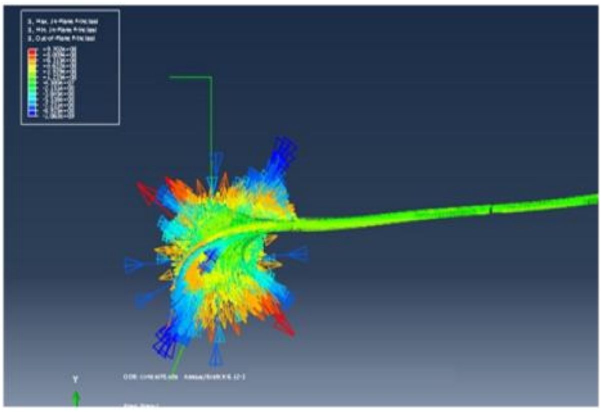


Figure 9: Vonmises Stress Contour Hemi Spherical Materials

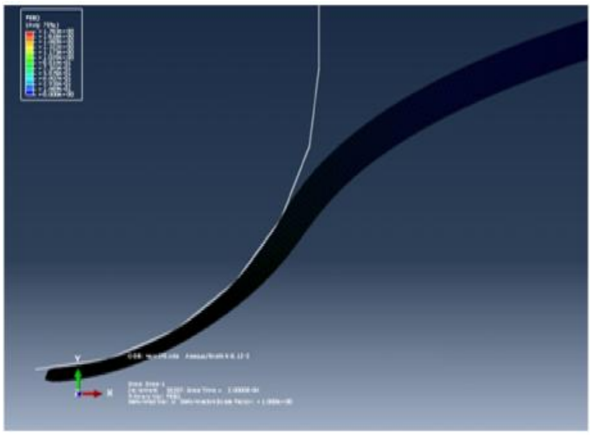


Table 5: Residual Velocity

Blunt		Conical		Hemi Spherical	
Impact Velocity	Residual Velocity	Impact Velocity	Residual Velocity	Impact Velocity	Residual Velocity
60	42	50	35	40	25
68	50	68	55	57	33
75	64	83	78	67	40
83	75	90	83	90	70
105	100	95	95	100	95

Figure 10: Comparison of Residual Velocities for Different Projectiles in Plate of 0.81 mm Thickness

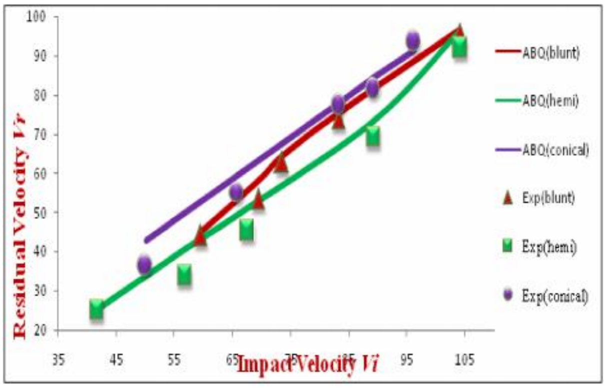


Table 5: Velocioty Drop

Blunt		Conical		Hemi Spherical	
Impact Velocity	Residual Velocity	Impact Velocity	Residual Velocity	Impact Velocity	Residual Velocity
65	55	60	42	70	20
75	65	75	55	75	38
85	68	85	70	85	55
95	75	95	75	90	60
105	89	105	86	105	66

Figure 11: Comparision of Velocity Drop for Different Projectiles in Plate of 0.81 mm Thickness

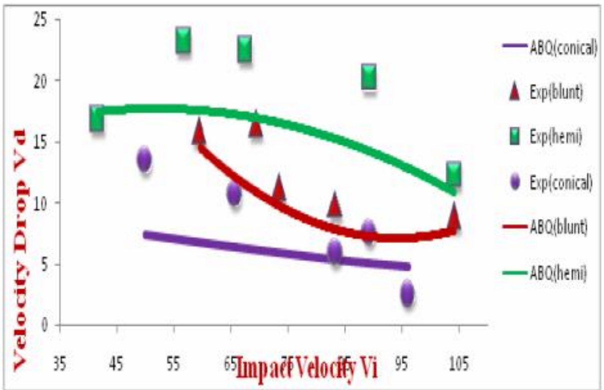
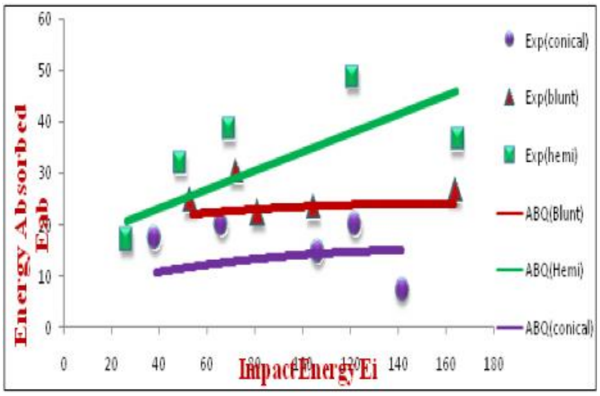


Table 6: Energy Absorved

Blunt		Conical		Hemi Spherical	
Impact Velocity	Residual Velocity	Impact Velocity	Residual Velocity	Impact Velocity	Residual Velocity
65	10	75	45	70	62
80	15	80	25	80	54
85	10	85	35	85	58
90	15	95	30	90	54
95	15	105	32	105	35

Figure 12: Comparision of Energy Absorbed for Different Projectiles in Plate of 0.81 mm Thickness



CONCLUSION

The present study deals with numerical simulation of normal impact of projectile on thin single layered aluminium plates using commercial finite element code ABAQUS. Aluminium Plates are subjected to impact by three different projectiles having conical, hemispherical and blunt noses. Impact and residual velocities are obtained from the finite element code and impact and absorbed energies are then calculated. The deformation mechanisms resulting from different nose shapes are also studied.

In case of conical and hemispherical projectile the mode of deformation is petalling. They cause failure in the target by ductile hole enlargement. The nose of the projectile first made a minute hole in the target along the axis of the trajectory of the projectile and deformed the target at the centre in shape of crater around the nose of the projectile. In blunt projectile impact a circular plug of diameter equal to that of projectile is removed from the plate. The thickness of plug is found to be same as that of the plate. As soon as the projectile comes in contact with the plate a global deformation in form of dishing takes place. The target plate keeps on deforming until the compressive force applied by the blunt projectile equals the plastic shear stress of the plate material and shearing of a plug takes place.

It is observed from graph of residual velocities that they follow a quadratic curve; conical projectile penetrated the target more easily than the hemispherical and blunt projectiles, as is evident from the fact that for the same impact velocity the residual velocity obtained for conical projectile case is more. The residual velocities were found to decrease with increase in plate thickness for all blunt, conical and hemispherical projectiles.

For the same thickness the energy absorbed by target plate in case of hemispherical projectile is highest. In case of conical projectile energy absorbed is lowest and for blunt it lies after hemispherical. For same amount of impact energy (164 J) the energy absorbed by 1.51 mm plate for hemispherical projectile case is around 66.06 J and for conical projectile it is 27.63 J. For the same impact energy, energy absorbed by blunt projectile is 35.9 J. The absorbed energies were found to increase with plate thickness; this increment was higher in case of hemispherical projectiles.

The velocity drop of projectiles was found to increase with plate thickness, as the velocity is increased the drop in velocity decreases for same thickness and follows a quadratic trend line.

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