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Numerical Simulation of Impact of Truncated Cone Projectile On Thin Aluminum Plate

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ABSTRACT
In this paper numerical study of normal impact of truncated cone projectile on Aluminum plate of 0.82 mm thicknessis carried out. Projectile is rigidly hardened and the major diameter and mass of projectile is taken as 12.8 mm and 25.8 g respectively. Numerical simulation is carried out on Abaqus explicit, Johnson-cock model is used to define the thermoviscoplastic behavior of the material constituting the plate, The Johnson–Cook fracture criterion has been coupled with homogeneous behavior to predict complete perforation process. Axi-symmetric simulation is performed, material properties of Aluminum is taken from previously published results, whereas projectile is taken as analytic rigid.
Keywords: *Abaqus, Aluminum, Ballistic limit, Normal impact, Truncated cone projectile.*

I. INTRODUCTION

As in previous result, found by the author that nose shape of projectile is very much influenced in failure mode of target and on ballistic limit.Backman and Goldsmith [1]found that blunt missiles cause failure through plugging, wedge missiles by hole enlargement, small radius projectile by tensile stretching and sharp nosed projectile by petalling. Gupta et al. [2,3]found that the failure in thin ductile targets occur through shear plugging by blunt projectiles, petal formation by ogival projectile and tensile stretching by hemispherical projectile. Borvik et al. [4]reported that blunt nosed projectiles cause failure by shear plugging, conical projectiles through petalling in thin plates and ductile hole enlargement in thick plates while hemispherical projectiles by tensile stretching. Corran et al. [5]mentioned that an increase in the projectile nose radius changes the failure mode from ductile hole enlargement to thinning and tensile stretching to shearing of the target. Goldsmith and Finnegan [6]carried out experiments where in cylindro-conical and blunt projectiles were impacted on 1.78 mm to 25.4 mm thick aluminum and up to 19.05 mm thick steel targets. It was observed that the nose shape of projectile has insignificant effect on the ballistic limit. Ipson and Recht [7]reported that blunt projectiles penetrated the target more efficiently than conical projectiles when the thickness was moderate. For thin and thick targets however, an opposite trend was observed.

II. NUMERICAL MODELLING.

In present study finite model of projectile and target plate are made in preprocessing module of the code ABAQUS/CAE. The target plate is model as Axi-symmetric deformable plate (1100-

H14 Aluminum plate of 255 mm diameter is taken).Whereas projectile is taken as analytic rigid of major diameter of 12.8 mm diameter, the minor diameter of truncated cone is taken half of the major diameter(fig 1). Mass of projectile is 25.8 gand assign at center of gravity.

The surface to surface contact between the projectile and target plate was modeled using kinematic contact algorithm with finite sliding formulation. The projectile was considered as the master surface and the impact region of the plate as node based slave surface. Due to the small thickness, the friction effects between the plate and the projectile were assumed negligible. The target plate was fixed at periphery with “encastre” boundarycondition available in the code to restrict all degrees of freedom. The projectile is given a initial velocity with in sub ordinatevelocity range,Initial velocity start with very low velocity to know the ballistic limit of plate for truncated cone projectile and the increases up to 60 m/s to know the residual velocity for different velocities.

The target plates were meshed with CAX4R element(4-node bilinear axisymmetric quadrilateral, reduced integration, hourglass control) the reduced integration element has an advantage thatthe strains and stresses are calculated at locations which provide optimal accuracy. Residual velocity is also varies with the no of element on thickness of plate, to decide the optimal size of mesh the variation of residual velocity with no of element on thickness is shown in table 1. Initial velocity taken as 50 m/s.Zukas andScheffler[8] suggested that a numerical simulation approachesthe real values when the aspect ratio approaches unity so the aspect ratio is taken as unity.The material behavior of the target, 1100-H14 aluminum was incorporated through Johnson-Cook elasto-viscoplastic material model [9]. In assembly module projectile is placed just above the plate to analyze the first indention. Assembly module of plate and projectile is shown in fig 2.Material properties is taken from [9] and mention in table 2.Impact velocity is assign to the projectile in predefined module. The minimum velocity get to perforate the plate is 24 m/s then velocities taken from the multiples of 10 i.e. 30, 40,50,60,70 m/s.

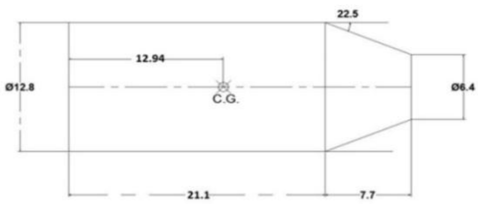

Fig 1:- 2D view of truncated cone projectile

Table 1 Residual velocity variation with no of element on plate thickness.

No of element at target thickness	Residual velocity in m/s
2	28.04
4	32.14
6	32.41

Table 2 Material parameters for 1100-H14 aluminum. [9]

Modulus of Elasticity, E (N/mm^2)	68948
Poison's Ratio	0.33
Density, (kg/m^3)	2712.6
Yield Stress, A (N/mm^2)	102.82
B (N/mm^2)	49.79
N	0.197
Reference Strain Rate, $\acute{\varepsilon}0$ (s^{-1})	1.0
C	0.001
M	0.859
T_{melt} (K)	893
T_o(K)	293
Specific Heat, C_p (J/kg K)	920
Inelastic heat fraction,	0.9
Thermal conductivity, k (W/m °C)	222
D_1	0.071
D_2	1.248
D_3	-1.142
D_4	0.147
D_5	0.0

Fig 2:- Assembly view of plate and projectile from Abaqus

III. RESULT AND DISCUSSION

Numerical study is performed of Normal impact of truncated cone projectile on Aluminum plate, Initial velocity is kept minimum to perforate the plate, At 24 m/s the plate is un perforated while at 25 m/s the perforate, then next initial velocities are 25, 30,40,50,60 & 70 m/s. Figure 3 shows the different steps of bullet in Abaqus with initial velocity 40 m/s and correspondingly time v/s decrease in velocity of projectile graph is shown in fig 4. Table 3 shows the intial velocity, residual velocity, impact energy, residual energy and absorbed energy. Impact energy is calculated as

$I_E=05*m*V_i^2$ (1)

Where m is the mass of projectile (i.e. 25.8g which is constant in calculating all energy). V_i is the initial velocity. Correspondingly residual energy (R_E) is calculated by replacing impact energy with residual energy. Where absorbed energy A_E is calculated as

$A_E=I_E-A_E$ (2)

Figure 4 show the variation of impact velocity v/s residual velocity.

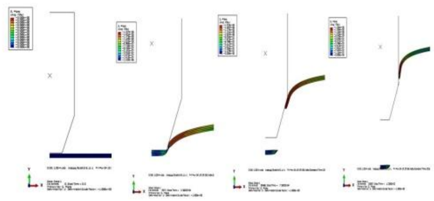

Fig 3: Different steps of impact of projectile on target plate

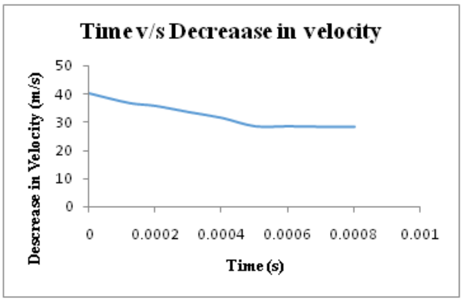

Fig 4: Time v/s decrease in velocity

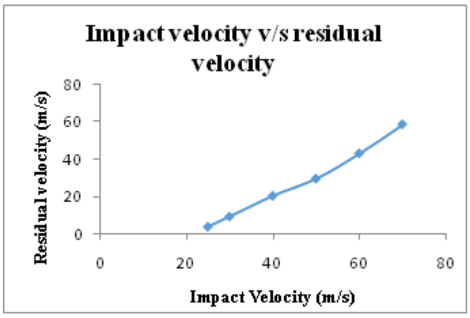

Fig 5: Impact velocity v/s residual velocity

Table 3

S.No	Impact Velocity (m/s)	Residual velocity (m/s)	Impact energy I_E	Residual energy R_E	Absorbed energy A_E
1	25	4.31	80.63	2.40	78.23
2	30	9.72	116.10	12.19	103.91
3	40	20.82	206.40	105.66	100.74
4	50	31.83	322.50	130.70	191.80
5	60	43.52	464.40	244.32	220.08
6	70	59.06	632.10	449.96	182.14

IV CONCLUSIONS

In present study numerical simulation is performed on Abaqus. Target plate is taken as Aluminum and modeled using Johnson cook equation , Different parameters of Johnson cook equation is taken from previously published journals [9]. Projectile is taken as rigidly hardened and modeled as analytic rigid, mass is assign at centre of gravity.

The following conclusion are made in our study. Ballistic limit of 1100-H14Aluminum plate impacted by truncated cone projectile is found to be 24.5 m/s. In present study it is also found that plate is unperforated at 24 m/s and at 25 m/s plate is perforate and residual velocity is 4.31m/s. From fig 5 it is concluded that residual velocity is increases with impact velocity. In each impact a plug is shear of from target plate. The impact energy, residual energy and energy absorbed by the plate is mention in table 3.

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