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Influence of target span and boundary conditions on ballistic limit of thin aluminum plate

G. Tiwari*[a], M.A.Iqbal[b], P.K.Gupta[b]

[a]*Department of Mechanical Engineering, Visvesvaraya National Institute of technology, Nagpur-440010, INDIA*
[b]*Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee-247667, INDIA*

Abstract

A collective study was performed to probe the influence of projectile nose shape, target span and target boundary condition on ballistic limit of thin aluminium plates. 1mm thick 1100-H12 aluminium target plates were normally impacted by ogive and blunt nosed projectiles of 19 mm diameter and 50.8 mm length. The target span was varied as 95, 190, 285, 380, 475, 570, 665 and 760 mm whereas the target boundary condition was studied by varying the fixity at the target circumference region as 100%, 75%, 50% and 25%. ABAQUS/Explicit finite element code using Johnson-Cook elasto-viscoplastic material model were employed to carry out the numerical simulation. To validity of numerical results are revealed by experiments performed on pressure gun in the sub-ordnance velocity regime.

The numerical as well as experimental study revealed that the ballistic limit of thin target plate was significantly affected by target span as well as target circumference fixity. The ballistic limit increases with increase in target span diameter while opposite trend was observed with increase in the region of fixity.

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Keywords: Target Span; Boundary Condition; Projectile Shape; Thin Plates

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1. Introduction

Impact response of thin metallic shields plays a significant role while designing the protective structure, aeroplanes, armature vehicles etc. The perforation and penetration of thin metallic shields are widely studied in literature from a long time. The different parameters like projectile nose shape, target material, target strength, layered and spaced target and projectile obliquity affected the ballistic resistance of the target significantly. An

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* Dr. Gaurav Tiwari. Tel.: +91-712-2801277
*E-mail address:*gauravtiwari@mec.vnit.ac.in

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important basis for such knowledge is provided by experiments and numerical simulations that properly describe the interaction of projectile and target.

For thin aluminium plates blunt nosed projectile was found to be superior followed by ogive and hemispherical projectile respectively [1-2]. The incidence angle has also been found to affect the ballistic performance of metallic plates. Thin plates (1mm thick) showed a consistent increase in the ballistic resist with an increase in obliquity [3]. For thin targets, the monolithic target was found to be most efficient followed by layered in contact and spaced target plates of equivalent thickness [4-5]. The studies regarding the influence of target span are very limited and needs to be further investigation. Moreover the influence of target boundary condition on ballistic resistance has not been studied. In the present study experimental and numerical results have been presented and discussed to describe the influence of target span and its boundary conditions on the ballistic resistance of 1 mm thick 1100-H12 aluminium plates hit by 19 mm ogive and blunt nosed projectile. The free span of the target was varied as 95, 190, 285, 380, 475, 570, 665 and 760 mm where as the target circumference fixity of 255 mm free span diameter was varied as 100%, 75%, 50% and 25%. The projectile incidence velocity was varied and ballistic limit was obtained.

2. Experimental and Numerical Investigation

A gas gun consisting of a compressor, pressure chamber, actuator valve, a smooth barrel and projectile catcher was employed to carry out the experiments. The projectile velocities were measured with the help of a high speed camera phantom V411. Projectiles were made of EN-24 steel, oil quenched to Rockwell hardness Rc of 47–52. The mass of the blunt as well as ogive projectile was kept 52.5 gm. After perforation, the projectile, and the plug in case of blunt nosed projectile impact were recovered from a catcher positioned behind the target plate. The catcher was filled with cotton rag to avoid damaging the projectile.

For numerical simulation, three-dimensional finite element model of the projectile and target was made using ABAQUS/CAE [6]. Fig. 1 shows a typical finite element model of the projectile and target. Projectile was modeled as rigid body and the target as deformable. The contact between the projectile and target was modelled using kinematic contact algorithm of ABAQUS [6]. Outer surface of the projectile was modelled as master and the contact region of the target as node based slave surface. The clamped zone of target plate was restrained with respect to all degrees of freedom. Eight node brick elements (C3D8R) were considered in all the simulations. A mesh convergence study [3] was carried out wherein the size of element in 1 mm thick monolithic target was varied by varying the number of elements over thickness from 3 to 7 subjected to ogival projectile impact. The residual velocity of projectile was increased from 3 to 5 elements over the thickness and then became constant. Therefore it was decided to use 6 elements over the thickness.

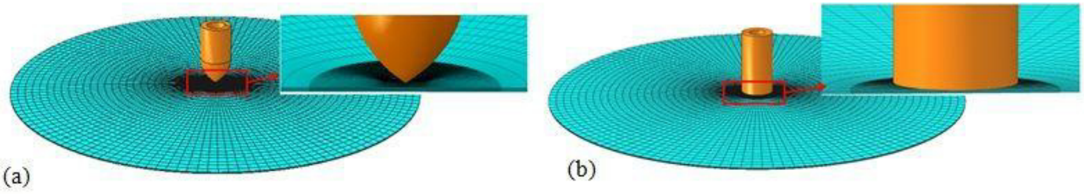

Figure 1 Finite Element Modelling of Plate for (a) ogival projectile (b) blunt projectile

3. Constitutive Model

The material behaviour of 1100-H12 aluminium target was incorporated in the numerical simulations using Johnson-Cook elasto-viscoplastic material model [7-8]. The equivalent von-Mises stress $\bar{\sigma}$ of the Johnson-Cook model is expressed as;

$$\bar{\sigma}\left(\bar{\varepsilon}^{pl},\dot{\bar{\varepsilon}}^{pl},\hat{T}\right)=\left[A+B(\bar{\varepsilon}^{pl})^{n}\right]\left[1+C\ln\left(\frac{\dot{\bar{\varepsilon}}^{pl}}{\dot{\varepsilon}_{0}}\right)\right]\left[1-\hat{T}^{m}\right] \quad (1)$$