International Journal of Impact Engineering 74 (2014) 46–56

Contents lists available at ScienceDirect

International Journal of Impact Engineering

journal homepage: www.elsevier.com/locate/ijimpeng

The ballistic resistance of thin aluminium plates with varying degrees of fixity along the circumference

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ARTICLE INFO

Article history:
Available online 4 February 2014

Keywords:
Varying fixity
Projectile shape
Ballistic limit
Thin plates

ABSTRACT

The ballistic performance of thin aluminium targets and influence thereon of different circumferential fixity conditions were studied both experimentally and by finite element simulations. A pressure gun was employed to carry out the experiments while the numerical simulations were performed on ABAQUS/Explicit finite element code using Johnson–Cook elasto-viscoplastic material model. 1 mm thick 1100-H12 aluminium plates of free span diameter 255 mm were normally impacted by 19 mm diameter ogive and blunt nosed projectiles. The boundary conditions of the plate were varied by varying the region of fixity along its circumference as 100%, 75%, 50% and 25% in experiments and the numerical simulations. Further, simulations were carried out to compare the response of the plates with 50% and 75% continuous fixity with those with two and three symmetrical intermittent regions of 25% fixity respectively.

The variation in the boundary condition has been found to have insignificant influence on the failure mode of the target however; it significantly affected the mechanics of target deformation and its energy absorption capacity. The ballistic limit increased with decrease in the region of fixity. It decreased for intermittent fixity in comparison with equivalent continuous fixity. And, it has been found to be higher for the impact with projectile having blunt nose in comparison with the one having ogive nose.

1. Introduction

Response of thin metallic plates both single and layered to the impact of various projectiles has received considerable attention of the researchers in the past. A large number of experimental and numerical studies are available in literature addressing the mechanics of deformation and ballistic resistance [1–5] of thin metallic plates and the influence of various parameters including projectile shape [6–10] and target configuration [11–17].

Corran et al. [6] studied the effect of projectile mass, nose shape and hardness on the perforation behaviour of 1.3–5.9 mm thick steel and aluminium alloy plates. It was concluded that blunt projectile failed the target through plugging, wedge projectiles through penetration and hole enlargement and sharp nosed projectile through petalling. It was also observed that the perforation velocity increased with a decrease in clamp load as the plate edge condition changed from a built in edge to a loosely held condition allowing considerable rotation and slip. The perforation energy increased with an increase in projectile mass up to 40 g and thereafter remained constant, and it decreased drastically with an increase in nose radius.

Kpenyigba et al. [7] studied the effect of projectile shape on the ballistic resistance and failure mechanism of 1 mm thick mild steel plates. Blunt projectile caused failure through shear plugging, conical projectile through radial necking and petalling, and hemispherical projectile through circumferential necking and plug ejection. The nose angle of conical projectile which varied from 20° to 60°, affected the number of petal formed in the target whereas energy absorbed by the target at high incidence velocities was almost same against all three projectiles.

The effect of projectile shape has been studied by Gupta et al. [8] wherein blunt, ogive and hemispherical nosed projectiles were normally impacted on 0.5–3 mm thick 1100-H12 aluminium plates. The ogive nosed projectile was found superior penetrator for 0.5–1.5 mm thick while blunt projectile for 2.0–3.0 mm thick plates. Hemispherical projectile was found to be least efficient penetrator. The caliber radius head (CRH) of ogive nosed projectiles [9] varied from 1 to 2.5 showed no influence on the ballistic resistance of 1 mm thick 1100-H12 aluminium plates, while it was significantly

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http://dx.doi.org/10.1016/j.ijimpeng.2014.01.007

affected when the nose shape was changed as blunt, ogive or hemispherical.

Iqbal et al. [10] studied the ballistic resistance of 0.82 and 1.82 mm thick aluminium plates when impacted by conico–blunt, blunt–blunt and blunt–conico double nosed projectile. The results obtained were compared with single nosed conical and blunt projectile. The ballistic limit of 0.82 mm thick plate was found highest against blunt–blunt while that of the 1.82 mm thick plate against single nosed blunt projectile.

The studies [11–15] on multi-layered plates have shown that the ballistic resistance of monolithic target is greater than that of the several adjoining plates of same thickness due to the larger plastic deformation of the former. The layered spaced targets were found to be less efficient when compared to the layered in-contact targets of equivalent thickness. The effect is more prominent in the case of the blunt projectile. Dey et al. [16] on the other hand concluded that the ballistic limit of 6 mm thick double layered in contact Weldox 700 E steel plate was 50% higher, and that of the spaced plate 40% higher, than a monolithic plates of 12 mm thickness against blunt nosed projectile. Against ogive nosed projectile however, the ballistic limit of both in contact and spaced layered target decreased by 10% compared to the monolithic plate. Teng et al. [17] studied the ballistic performance of double layered steel plates against blunt and conical projectiles. The configuration with upper layer of high ductility and low strength and lower layer of low ductility and high strength material showed best ballistic performance while the opposite combination showed worst performance against both projectiles at 400 m/s incidence velocity.

Iqbal et al. [13] studied the influence of target span diameter and configuration through numerical simulations performed on ABAQUS/Explicit finite element code. 1 mm thick 1100-H12 aluminium plates of varying span diameter (50, 100, 204, 255, 500 mm) and configuration; monolithic (1 mm), double layered in contact (0.5 mm × 2) and spaced target was impacted by ogive and bunt projectiles. The ballistic limit increased with an increase in the span diameter for both projectiles, due to increase in the energy absorbed in bending.

The effect of the target boundary conditions on the mechanics of deformation and failure of thin metallic plates seems not to have been reported in literature. However, a few such available studies on the influence of boundary conditions are on composite plates.

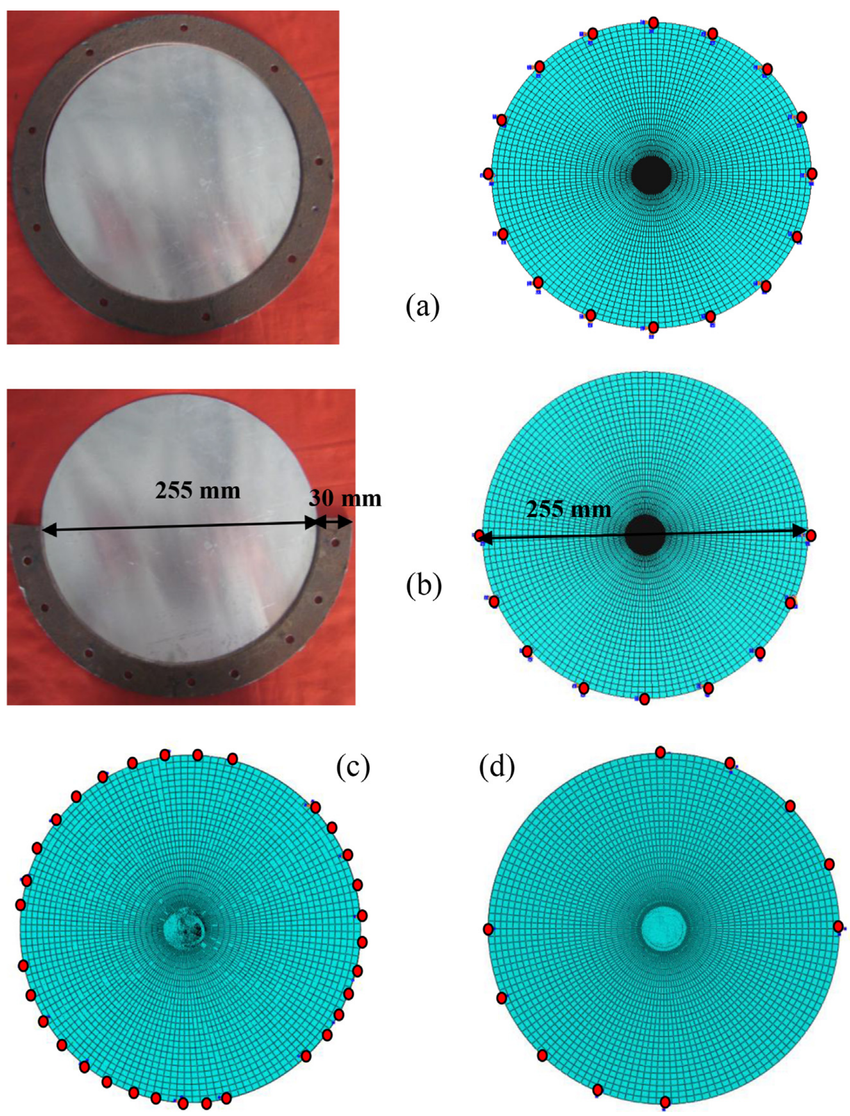

Fig. 1. Typical experimental and numerical models of the target for varying region of fixity at periphery (a) 100% clamped (b) 50%-continuous clamped (c) 75%-intermittent clamped (d) 50%-intermittent clamped.