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Observations on impacts of deformable conical projectiles at 60 degree target obliquity

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Abstract

Conical aluminium projectiles of apex angle 34 degrees were made to impact thin aluminium targets inclined at an angle of 60 degrees at low subordnance velocities where material strength effects are still valid. Thin targets of thickness 1.5mm and 2mm underwent failure by reverse petalling as the projectiles penetrated the targets. Projectiles underwent ricochet while impacting 2.5mm targets causing severe dents and visible contact marks on the target. While the projectile nose tips were separated in the 1.5mm and 2mm cases, the projectiles impacting 2.5mm targets underwent substantial nose deformation. Numerical simulation performed using ABAQUS/Explicit was able to capture the projectile deformation and target deformation quite well phenomenologically.

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1. Introduction

Oblique impacts have been widely studied for impacts using rigid projectiles with various nose shapes for a range of impact velocities and target thickness through experiments [1-3] and numerical simulation techniques [4]. Target obliquity affects the ballistic properties of the projectiles and deformation behavior of target plates [5]. Except the disparity very close to normal incidences, the increase in obliquity generally offers more resistance to projectiles

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until perforation is completely halted and ricochet occurs. Target obliquity increases the effective thickness of the target and tends to exert an oblique reaction force on the projectile tending to change its trajectory.

Where projects are assumed rigid, the classical failure mode of the inclined target perforated by pointed projectiles is described by the occurrence of major and minor petals extending outward along the direction of motion of the projectile. The design of projectiles to penetrate thick armours and hypervelocity shields leverages on the ability to cause unconventional damage on targets due to projectile deformation [6]. Not much work is available on oblique impacts of deformable conical projectiles during oblique impacts at low velocities.

A series of experiments were conducted using aluminium projectiles and targets to study the effect of obliquity on projectile deformation and ballistic properties, along with target damage and failure behaviour at low subordance velocities of the order of 130 m/s. Several interesting observations were made. The current discussion however is restricted to a special case of aluminium conical projectiles impacting thin aluminium targets at an obliquity of 60 degrees. The details on the analysis approach are briefly discussed and a few interesting observations are presented.

2. Methodology

Projectile impact tests were conducted at low velocities on thin aluminium targets of thickness 1.5mm, 2mm and 2.5mm, inclined at an angle of 60 degrees to the axis of the launcher barrel. Post impact observations (and appropriate measurements) were made on the damage and failure behaviour of the projectile and the target. Numerical simulations were performed to get further insights on the mechanics of large deformation observed in the case of 2.5mm target.

2.1. Experimental details

Projectiles made from Al 6063 (Al0.7Mg0.4Si) rod stock were impacted on targets with a circular span of 206mm cut from Al 1100-H12 (Al0.12Cu1Si) sheets. Cylindrical projectiles with conical nose with an apex angle of 34^0 were used in the study. Projectiles were of 15.6±0.1mm in diameter. Projectiles were launched from a compressed air operated smooth bore gun with a barrel diameter of 15.7±0.05mm. A clearance of approximately 0.05 to 0.11mm existed between the projectile and the barrel in the current study, nevertheless satisfactory normality was ensured before the oblique impact experiments were conducted. The targets were placed at a distance of approximately 250 to 300 mm away from the muzzle end and were held in place at the required inclination with a special fixture attached to the target holder frame. The projectile used, the target obliquity definition and holder fixture are shown in figure 1.

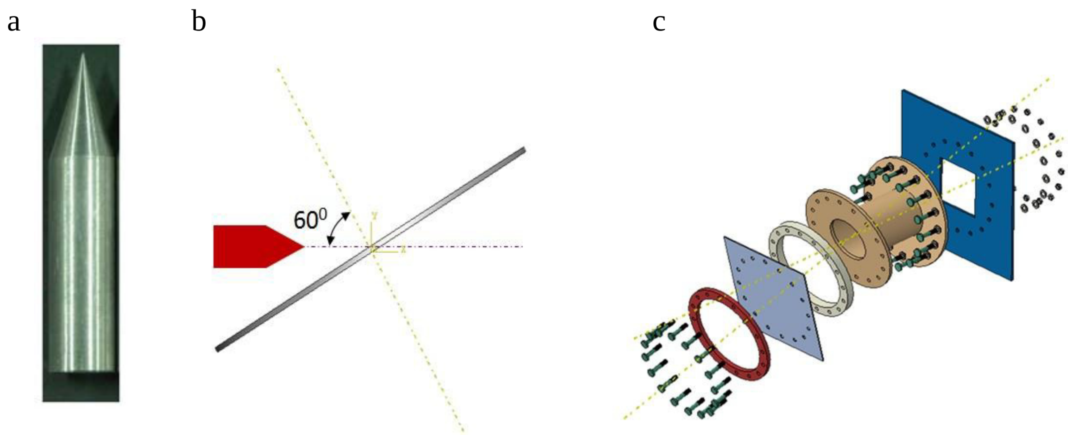

Fig. 1. (a) Projectile used; (b) Target definition and (c) Target holding fixture employed in the study