Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 173 (2017) 206 – 213

Procedia Engineering

www.elsevier.com/locate/procedia

11th International Symposium on Plasticity and Impact Mechanics, Implast 2016

Quasi-Brittle Fracture of Aluminium Alloy 2014 under Ballistic Impact

Prince Sharma[a,b,*] Pradeep Chandel[a], Puneet Mahajan[b], Manjit Singh[a]

[a] *Terminal Ballistics Research Laboratory, Chandigarh, 160030, India*
[b] *Department of Applied Mechanics, Indian Institute of Technology, Delhi, 110016, India*

Abstract

Experimental and numerical studies were conducted to analyze the ballistic penetration of high strength aluminium alloy 2014-T652. Hardened steel balls were launched using a propellant gun at velocities ranging from 800 to 1300 m/s to cover regions below and above the ballistic limit. Failure in target plates occurred due to a combination of failure mechanisms such as hydrodynamic flow, spalling, ductile hole growth and scabbing. Tensile tests were conducted at different stress triaxialities, strain rates and temperatures to calibrate the material parameters of Johnson-Cook plasticity and fracture model. Finite element analyses of all the impact experiments were carried out using a two dimensional axisymmetric model. Johnson-Cook fracture model was not able to simulate the quasi-brittle fracture of material and numerical ballistic limit velocity was overestimated. Numerical simulations were repeated using hydrostatic tensile stress failure model along with non-linear equation of state, which resulted in excellent correlation with experimental results.

Keywords: Ballistic Impact, High strength aluminium, Failure modes, Constitutive modeling, Numerical simulations.

1. Introduction

The technological advancements in the field of armaments have led to the tremendous increase in demand for light weight armour systems. High strength aluminium alloys have emerged as a strong candidate material for defence and aerospace applications due to their low density, high strength and high corrosion resistance. Their effective utilization in such critical applications require a thorough understanding of penetration phenomena, which is quite complex due to involvement of large plastic deformations, high strain rates, thermal softening due to

---

* Corresponding author. Tel.: +91-1733-307028; fax: +91-1733-253035.
*E-mail address:*prince.drdo@gmail.com, prince@tbrl.drdo.in

doi:10.1016/j.proeng.2016.12.059

adiabatic heating of materials, material degradation and fracture [1]. Moreover, material failure may take place due to a number of different perforation mechanisms like ductile hole growth, spalling, scabbing, plugging, petalling etc [2]. Since analytical solutions are restricted to highly simplified ideal conditions, numerical methods have established themselves as an efficient alternative [3]. Although several studies have been conducted using finite element analyses to model the impact response of different aluminium alloys [4-8], the availability of validated material parameters for dynamic constitutive & failure models has been a cause of serious concern [9].

The present study is aimed at investigating the ballistic impact response behaviour of aluminium alloy AA2014-T652, which is one of the strongest available aluminium alloys used for aerospace, defence and automobile applications. A comprehensive material characterization program was executed to determine the material constants of dynamic constitutive and fracture model. An integrated approach encompassing ballistic impact tests, analytical analysis, dynamic material characterization and numerical simulations was used to understand the quasi-brittle fracture of the material under ballistic impact.

2. Ballistic Impact Tests

2.1. Experimental set-up

A smooth bore propellant gun of 30mm calibre, as shown in Fig. 1(a), was used to propel hardened steel balls of 10mm diameter (hardness 830 HV10) on 15mm thick AA2014-T652 plates. Since the projectile diameter was less than the bore diameter of the gun, a two piece polycarbonate sabot was used to launch the projectile. The complete assembly of cartridge, sabot and projectile is shown in Fig. 1(b). Projectile was mounted inside the two-piece sabot as shown in Fig. 1(c). The sabot pieces were trapped by sabot catcher plate which was placed ahead of the actual target. The impact velocity and residual velocity of the projectile were measured with the help of a high speed camera at 12000 frames per second. The velocity of projectiles was varied by increasing the amount of propellant in the cartridge. The projectiles were impacted at velocities ranging from 800 m/s to 1250 m/s, which covered the velocity regions below and above ballistic limit.

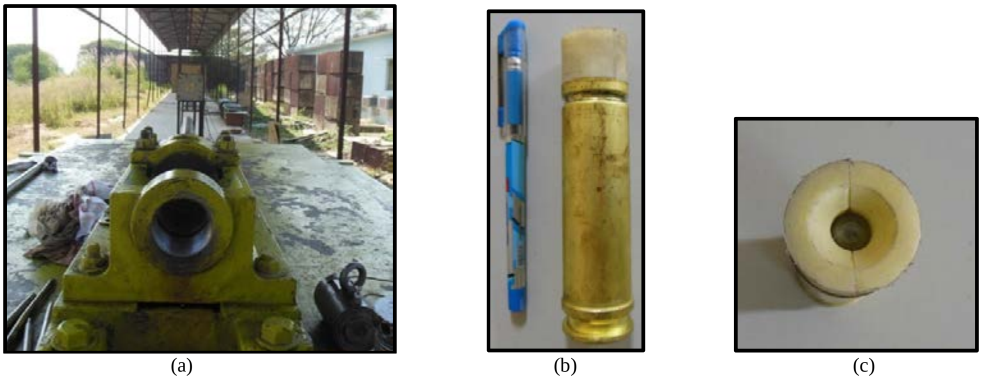
(a) (b) (c)

Fig. 1: (a) Ballistic test set-up (b) Cartridge, sabot and projectile assembly (c) projectile inside the sabot.

2.2. Ballistic Test Results

Recovered projectiles did not show any significant plastic deformation and hence they were considered rigid for the present study. The crater dimensions in the target are summarized in Table 1. Fig. 2 and 3 show the impact face, exit face and cross-section of the target impacted at different velocities below and above the ballistic limit respectively. A “splash” of material was observed at the impact face of the target for all experiments below and above ballistic limit. This splashing was caused by the propagation of compressive shock waves in the projectile and target material on impact.