Materials and Design 32 (2011) 1356–1366

Contents lists available at ScienceDirect

Materials and Design

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

Experimental investigations on the ballistic impact performances of cold rolled sheet metals

A. Durmuş [a,*], M. Güden [b], B. Gülçimen [a], S. Ülkü [a], E. Musa [c]

[a] Department of Mechanical Engineering, Uludağ University, Görükle, 16059 Bursa, Turkey
[b] Department of Mechanical Engineering, İzmir Institute of Technology, Gülbahçe Köyü, Urla, 35430 İzmir, Turkey
[c] Department of Electronic Engineering, Uludağ University, Görükle, 16059 Bursa, Turkey

ARTICLE INFO

Article history:
Received 3 May 2010
Accepted 9 September 2010
Available online 21 September 2010

Keywords:
Impact and ballistic
Film and sheet
Failure analysis

ABSTRACT

This study focuses on the ballistic performances of 1 and 2 mm-thick and 2 × 1 mm-thick cold rolled sheet metal plates against 9 mm standard NATO projectile. The velocity of the projectile before and after perforation, the diameter of the front face deformation, the depth of the crater and the diameter of the hole were measured. The fracture surfaces of the plates near the ballistic limit were also microscopically analyzed. The highest ballistic limit was found in 2 mm-thick plate (332 m s^{-1}) and the lowest in 1 mm-thick plate (97 m s^{-1}). While, the ballistic limit of 2 × 1 mm-thick plate decreased to 306 m s^{-1}. Typical failure mechanism of the projectile was the flattening and mushrooming at relatively low velocities and the separation from the jacket at relatively high velocities. In accord with the ballistic limits, 2 mm-thick target plate exhibited the highest hardness value. Microscopic investigations showed the significant reductions in the grain size of the targets after the test.

1. Introduction

Cold rolled sheet metals are commercially available cost effective materials with quite wide range of applications. At the same time, they have the potentials to be used in the structure of the armor vehicles for the protection against small caliber soft jacketed projectiles. In this specific application, the intended ballistic protection naturally vanishes when the ballistic impact damage/the target failure emerges. Therefore, the target damage initiation and the subsequent emerge of the target fracture are two important phenomena which should be taken into account when assessing the performances of the ductile targets against ballistic treats. In a previous study, Børvik et al. [1] investigated the fracture and penetration of a projectile in a Weldox 460 E steel plate. Chen et al. [2] developed an analytical model for the localized shear zone formation in a Weldox 460 E steel plate. The perforation of ductile metal targets by a conical indenter was investigated by Nazeer et al. [3]. The number and size of petals formed were reported to depend on the sheet metal thickness, sheet metal mechanical properties, indenter angle, anisotropy and the indentation speed. Liu and Stronge [4] showed when a mild steel plate was struck by a flat-ended missile at a velocity near the ballistic limit at a normal angle of obliquity, the failure changed from dishing to plugging as the ratio of the plate thickness to missile radius increased. It was also shown in the same study that the part of the initial missile kinetic energy absorbed by the global deformation (dishing) was larger for the soft missiles since the missile mushrooming increased the plug diameter and the mushroomed nose had a larger curvature at the periphery of the contact region, reducing the shear strain in the hinge band. The formation of multiple necks and cracks around perforations in ductile metals was further studied by Atkins et al. [5]. The numbers of plane-strain radial necks formed by conical and round-ended projectiles into flat targets were determined. Segletes [6] investigated the penetration of ductile targets impacted by a hemispherical-nosed tungsten projectile at the erosion-threshold velocity. In another experimental study, the ballistic resistance and damage formation of the heat treated steel targets with different thicknesses, hole diameters and target mounting was investigated [7]. Rusinek et al. [8] studied experimentally and numerically the failure of mild steel sheets subjected to normal impact by hemispherical projectiles. Klepaczko et al. [9] have recently simulated the projectile impact of DH-36 and Weldox 460-E structural steels using three different material models. The Rusinek–Klepaczko model was shown to be in good agreement with experimental results. Dean et al. [10] modeled the absorbed impact energies of the steel plates using Johnson–Cook plasticity algorithm.

Despite many experimental and numerical investigations on the perforation and penetration of the ductile metal targets by rigid projectiles, few experimental studies have concentrated on

* Corresponding author. Tel.: +90 224 2941989; fax: +90 224 2941903.
E-mail address: adurmus@uludag.edu.tr (A. Durmuş).

0261-3069/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2010.09.016