Available online at www.sciencedirect.com
ScienceDirect
Engineering Failure Analysis 15 (2008) 1088–1096
ENGINEERING FAILURE ANALYSIS
www.elsevier.com/locate/engfailanal

Studies on the role of microstructure on performance of a high strength armour steel

P.K. Jena *, K. Siva Kumar, V. Rama Krishna, A.K. Singh, T. Balakrishna Bhat

Defence Metallurgical Research Laboratory, Kanchanbagh, Hyderabad 500 058, India

Received 18 July 2007; accepted 24 November 2007
Available online 4 December 2007

Abstract

This investigation describes and analyses the experimental results pertinent to the ballistic performance of two apparently identical low alloy high strength steel plates against deformable lead projectiles at a velocity about 840 m/s. All the tests are carried out at normal impact angle, i.e. zero obliquity. One plate stopped all projectiles fired at it. However, the other plate failed to stop the projectiles at some locations. Both the plates were subjected to detailed analysis using standard metallurgical techniques to identify the cause of failure in one plate. The experimental results presented include the variation in the microstructure, hardness and retained austenite of the two target plates. The study concludes that the failure is caused by the decrease in resistance of the plate possibly due to higher retained austenite and coarser martensitic structure.

Keywords: Ballistic impact; Armour; Target; Damage pattern; Retained austenite

1. Introduction

Armour is used for providing protection in different applications. Low alloy high strength steels have long attracted attention, due to their high strength and energy absorbing properties, offering many armour applications for personnel, military and non-military vehicles. Before being put to use, these armour steel plates are assessed mechanically and ballistically to confirm their ability to withstand the resistance of armour-piercing ammunition [1–4]. Mechanical evaluation includes determination of strength and toughness of the steel plates. For ballistic evaluation the plates are fired by the projectiles, they are required to withstand. However, a microstructural observation that is an essential aspect in connection with the performance of armour generally does not form part of the specification.

In the present study, two apparently identically processed armour steel plates of identical composition were brought from the production batch for ballistic clearance. The ballistic performance of the two plates designated 1-A and 5-E was studied in relation to their ability to stop the penetration of the specified projectiles

* Corresponding author. Tel.: +91 9949221167.
E-mail address: pradipta_rrlb@rediffmail.com (P.K. Jena).

1350-6307/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engfailanal.2007.11.011

fired at them at high velocities. The 1-A plate passed the test while the 5-E plate failed in the ballistic testing. The cause of failure was analyzed through comparative optical microscopy, XRD analysis, mechanical properties and hardness measurements of the two plates.

2. Experimental details

The nominal chemical composition of the steel plates is given in Table 1. Rolled and heat treated steel plates of 300 mm × 300 mm × 6.5 mm have been impacted with deformable cylindro–conical lead projectiles of 90 Vickers hardness. The testing arrangement is shown in Fig. 1. The nominal diameter of the projectiles is 7.62 mm whereas the actual diameter is 6.4 mm (Fig. 2). The mass of the projectile is 9.6 g. The projectiles

Table 1
Chemical composition of steel

C	Si	Mn	Cr	Ni	Mo	S	P	Fe
0.37	0.4	1.2	1.5	3.7	0.7	0.01	0.015	Balance

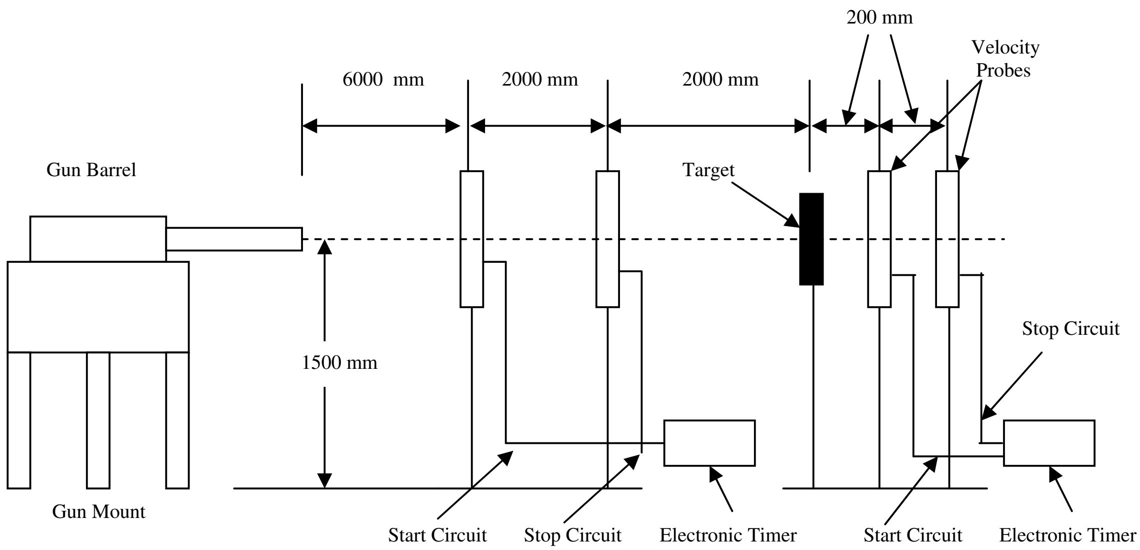

Fig. 1. Schematic diagram of experimental set up.

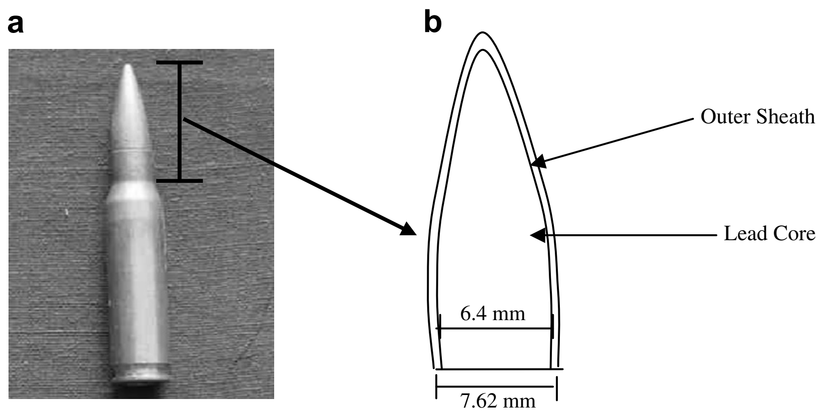

Fig. 2. (a) The projectile. (b) Schematic view of the projectile.