Materials and Design 32 (2011) 97–107

Contents lists available at ScienceDirect

Materials and Design

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

Fracture mechanisms of aluminium alloy AA7075-T651 under various loading conditions

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ARTICLE INFO

Article history:
Received 9 March 2010
Accepted 17 June 2010
Available online 22 June 2010

Keywords:
Non-ferrous metals and alloys
Fracture
Scanning electron microscopy

ABSTRACT

The fracture behaviour of the aluminium alloy AA7075-T651 is investigated for quasi-static and dynamic loading conditions and different stress states. The fracture surfaces obtained in tensile tests on smooth and notched axisymmetric specimens and compression tests on cylindrical specimens are compared to the fracture surfaces that occur when a projectile, having either a blunt or an ogival nose shape, strikes a 20 mm thick plate of the aluminium alloy. The stress state in the impact tests is much more complex and the strain rate significantly higher than in the tensile and compression tests. Optical and scanning electron microscopes are used in the investigation. The fracture surface obtained in tests with smooth axisymmetric specimens indicates that the crack growth is partly intergranular along the grain boundaries or precipitation free zones and partly transgranular by void formation around fine and coarse intermetallic particles. When the stress triaxiality is increased through the introduction of a notch in the tensile specimen, delamination along the grain boundaries in the rolling plane is observed perpendicular to the primary crack. In through-thickness compression tests, the crack propagates within an intense shear band that has orientation about 45° with respect to the load axis. The primary failure modes of the target plate during impact were adiabatic shear banding when struck by a blunt projectile and ductile hole-enlargement when struck by an ogival projectile. Delamination and fragmentation of the plates occurred for both loading cases, but was stronger for the ogival projectile. The delamination in the rolling plane was attributed to intergranular fracture caused by tensile stresses occurring during the penetration event.

1. Introduction

In the design of protective structures against ballistic impact, material strength seems to be the single most important parameter [1]. Thus, thin plates of high-strength material are frequently being used both in civil and military ballistic protection systems. Such plates may either be monolithic or layered with or without spacing [2]. In this context, the high-strength aluminium alloy AA7075 is attractive due to its excellent strength-to-weight ratio, as e.g. discussed by Gooch et al. [3]. However, Børvik et al. [4] showed that the alloy is quasi-brittle with considerable fragmentation upon impact. It is therefore of major importance to be able to understand, evaluate and predict this behaviour for design purposes, because fragmentation can considerably lower the perforation resistance of the target and fragments generated from the protective structure may be a serious hazard for both personnel and equipment.

The fracture behaviour of high-strength age hardening alloys has been extensively studied during the last several decades [5,6]. The complex and inhomogeneous microstructure is formed during processing and is unique for the various production processes. How the resulting microstructure affects the fracture toughness and crack propagation in these alloys is of special interest [7]. The fracture behaviour will be different for materials processed by rolling, extrusion or forging. In addition, the heat treatment these alloys are exposed to will change the microstructure, such as the grain morphology, the particle size and distribution, and the crystallographic texture, and thus significantly affect the fracture behaviour [8].

Age hardening aluminium alloys form precipitates, precipitation free zones, grain boundary precipitates and grains with different shapes during processing [9]. The grains can either be equiaxed, obtain a pancake shape or be elongated in the

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doi:10.1016/j.matdes.2010.06.029