Materials and Design 37 (2012) 491–499

Contents lists available at SciVerse ScienceDirect

Materials and Design

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

Micromechanical behavior study of forged 7050 aluminum alloy by microindentation

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ARTICLE INFO

Article history:
Received 28 December 2011
Accepted 19 January 2012
Available online 28 January 2012

Keywords:
A. Non-ferrous and alloy
F. Plastic behavior
G. Non-destructive testing

ABSTRACT

In order to investigate the micromechanical behavior of forged 7050 aluminum alloy with different heat treatment conditions, microindentation experiments of 7050-T7451 and 7050-T7452 were performed with various maximum indentation loads and various loading speeds. A non-destructive instrumental approach was applied to indicate mechanical properties such as Young's modulus *E*, microhardness *H*, initial yield stress σ_y and strain hardening exponent *n* using the available experimental indentation *P*–*h* curves from the microindentation tests. The experimental results revealed that loading speed exerted little influence on measurement of *E* and *H*. *E* decreased rapidly because of the indentation damage accumulation, and *H* decreased with the increase of indentation load, which showed strong indentation size effects. Dimensionless functions Π_1 and Π_2 were used to describe the plasticity constitutive equations and revealed that the heat treatment conditions influenced the micromechanical properties. *H* and σ_y tested from the microindentation of 7050-T7451 were higher than those of 7050-T7452, and microindentation plasticity constitutive equations were obtained by using Hookean elastic and power-law plastic stress–strain relation equations, which were verified by finite element method (FEM) simulation well.

1. Introduction

For over a century, indentation has been employed to probe into the mechanical behaviors of materials for a wide range of engineering applications. It has been found that size effect contributes to the difference in mechanical behaviors at micromechanical and macromechanical levels. The size effect cannot be explained by the classical plasticity theories because they do not possess any intrinsic material length [1]. In the study of the above concepts, microindentation for hardness is of micro-size scale and has been extensively applied at the investigation of the micromechanical level [2–4] because hardness is sensitive to the structure parameters as well as to characterization parameters (such as initial yield stress, and Young's modulus). Microindentation hardness increases with the decrease of indentation depth which shows a strong size effect [5–7]. Recent works have been investigated in terms of titanium [8,9], aluminum [10], copper [11], composite [12] and other materials [13–16] with the microindentation or nanoindentation technique.

7050 aluminum alloy is a wrought product and has been widely used for thick section products in structural aircrafts due to its high strength, perfect stress corrosion cracking property and high fracture toughness [17]. Compared with 7075, the use of zirconium in lieu of chromium reduces the sensitivity to quenching, which results in high strength in thick sections [18]. Both strength and fracture toughness can be improved through the heat treatment processes, depending on the intermetallic compound like CrFeAl7 and CrMnAl13, which are different from other AlZnMgCu series aluminum alloys. Its obdurability is sensitive to the heat treatment conditions, and its high strength is achieved through quenching and ageing. Over ageing T74 is extensively used for 7050 aluminum alloy. To obtain desirable mechanical properties such as strength and fracture toughness, it is necessary to quench 7050-T74 aluminum alloy. In general, quenching stress should be reduced by stress relief methods. The most commonly used mechanical stress relief methods in the industry include stretching deformation (denoted as T7451) and compressive deformation (denoted as T7452). For this reason, great attention has paid in the scientific literature to the study of the behavior of 7050 alloy with different heat treatment conditions of T7451 and T7452 [19–23]. The purpose of the current study is to investigate micromechanical behavior of 7050 aluminum alloy with these two different heat treatment conditions. Therefore, microindentation experiments will be chiefly conducted on the micromechanical behavior of 7050 aluminum alloy with the heat treatment conditions of T7451 and T7452.

2. Experimental details

Commercial 7050 aluminum alloy was used in the present investigation, and the principal chemical compositions were: 5.90Zn,

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0261-3069/$ - see front matter
doi:10.1016/j.matdes.2012.01.036

2.10Mg, 2.10Cu, 0.11Zr, 0.07Fe, 0.03Si, 0.03Ti, 0.01Cr and the bal. Al. Young's modulus E was 71.7 GPa and Poisson ratio v was 0.33. The samples were respectively treated using the heat treatment conditions of T7451 and T7452. The standard technological processes of T7451 were given as follows: solution treatment (473 °C × 1 h) → water quench → stress relief treatment (2.5% permanent cold stretching deformation) → ageing treatment (121 °C/6 h + 163 °C/12 h), and T7452 were: solution treatment (473 °C × 1 h) → water quench → stress relief treatment (2.5% permanent cold compressing deformation) → ageing treatment (121 °C/6 h + 163 °C/12 h). The chiefly differences between T7451 and T7452 laid in the process of the stress relief treatments, and cold stretching in T7451 carried out a better distribution of residual

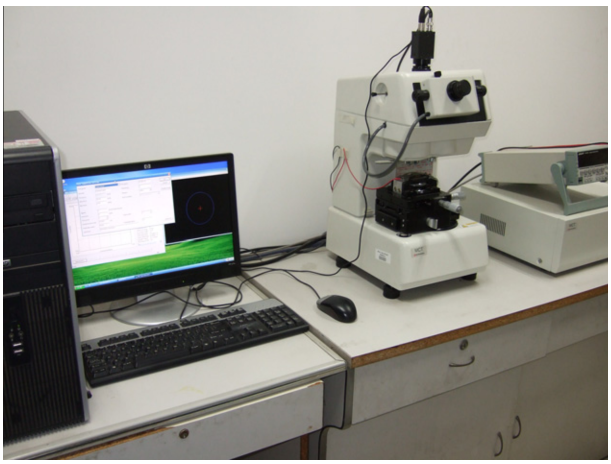

Fig. 1. MCT W501.

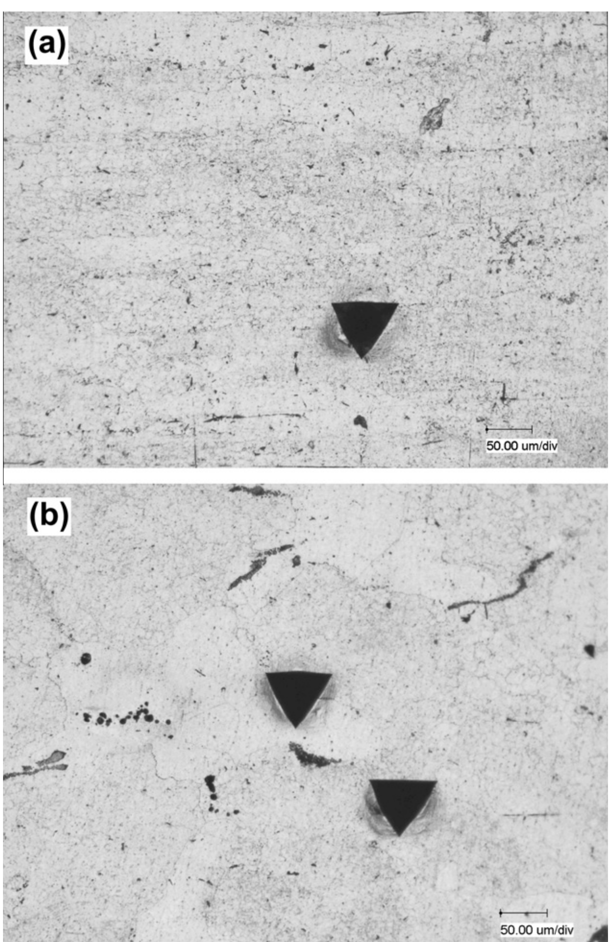

Fig. 2. Micrographs of 7050 aluminum alloy in the microindentation experiment for (a) 7050-T7451 and (b) 7050-T7452.

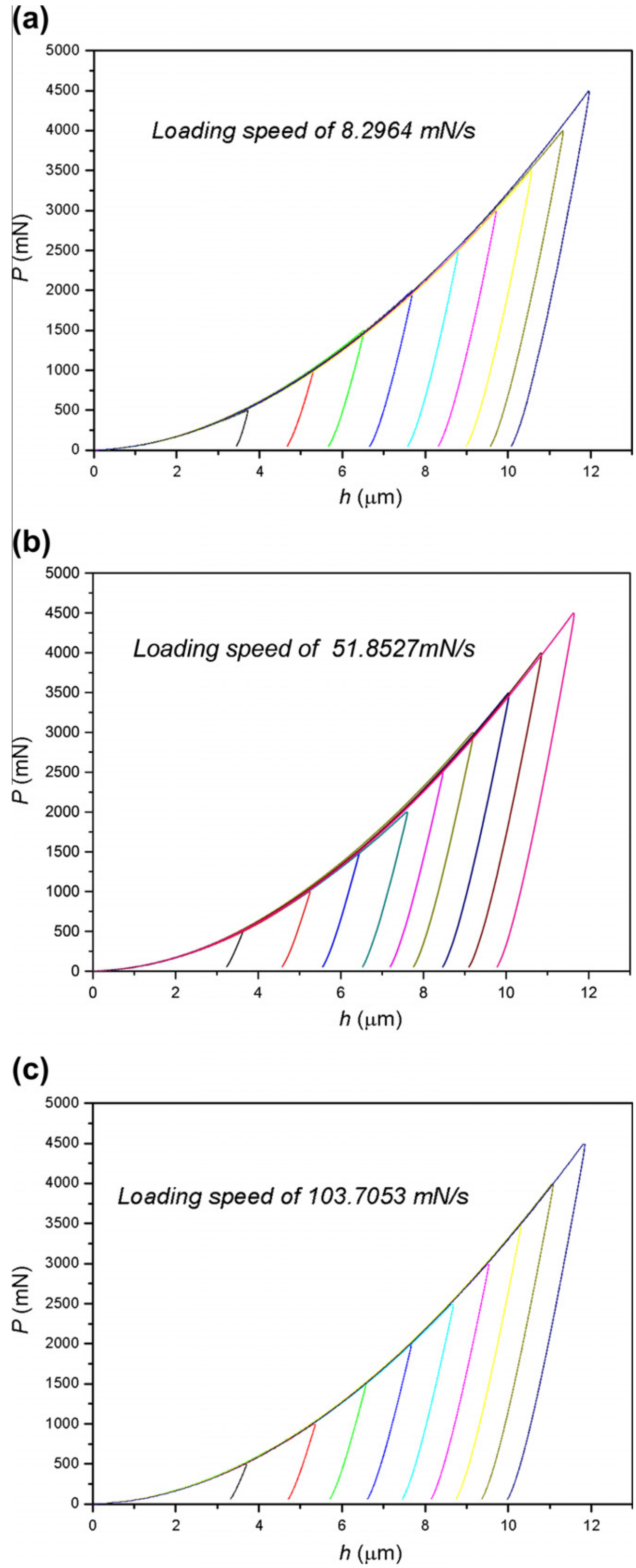

Fig. 3. Experimental P–h curves of 7050-T7451 aluminum alloy at loading speed of (a) 8.2964 mN/s, (b) 51.8527 mN/s and (c) 103.7053 mN/s, respectively.