Digital Image Correlation investigation of Portevin–Le Chatelier effect in an aluminium alloy

Joanna Zdunek, Tomasz Brynk, Jarosław Mizera, Zbigniew Pakieła, Krzysztof J. Kurzydłowski*

Warsaw University of Technology, Materials Science and Technology Faculty, Wołoska 141, 02-507 Warsaw, Poland

ARTICLE DATA

Article history:
Received 25 June 2007
Received in revised form
5 December 2007
Accepted 7 January 2008

Keywords:
Digital Image Correlation
Plastic instability
Portevin–Le Chatelier effect

ABSTRACT

The Portevin–Le Chatelier (PLC) effect in an Al–4.5 Mg–0.7Mn alloy was studied using the Digital Image Correlation technique. The results provide a new insight into the development of deformation bands related with the stress oscillations observed during the tensile testing of the alloy.

1. Introduction

Instabilities during the process of plastic deformation, which are observed at a microscopic level in some metals [1–3], are considered to be related to interactions between dislocations and other defects, including point defects and shearable particles. At the macroscopic scale, these instabilities result in a specific relief on the surface of the deformed samples in the form of localized deformation bands, which are inclined at an angle of about 60° to the tensile axis [4]. Despite the progress made in recent decades in the understanding of the PLC effect, the theory is far from complete. In particular, this applies to the conditions required for the nucleation of deformation bands and their propagation. It has been assumed in the current work that progress can be made by applying modern measurement techniques to investigate the properties of the deformation bands.

Digital Image Correlation (DIC) was used in these studies to measure strain fields on the surface of testpieces subjected to tensile deformation. The DIC method allows for in-situ registration of digital images of the surface of the strained specimens. The images are analyzed as a function of elongation to determine the local strain tensor components by examinations of the relative displacement of pre-determined surface markers.

The DIC method was used to investigate the propagation of plastic deformation bands during tensile straining of a 5XXX aluminium alloy, which exhibits the Portevin–Le Chatelier effect. Previously similar investigations were carried out on an Al–Mg alloy [4]. Quantitative analyses of PLC bands were undertaken using high speed digital cameras or laser extensometers [5–7]. The special feature of the present investigations is the application of Digital Image Correlation to provide a complementary description of the Portevin–Le Chatelier effect.

2. Experimental Details and Results

Cold rolled sheet of aluminium alloy 5182 (Al–4.5 Mg–0.7Mn) was used for the investigations. Samples of 40 mm gauge length,

* *Corresponding author.*
E-mail addresses: jzdunek@inmat.pw.edu.pl (J. Zdunek), tom_br@go2.pl (T. Brynk), jmizera@inmat.pw.edu.pl (J. Mizera), zpakiela@inmat.pw.edu.pl (Z. Pakieła), kjk@inmat.pw.edu.pl (K.J. Kurzydłowski).

1044-5803/$ – see front matter
doi:10.1016/j.matchar.2008.01.004

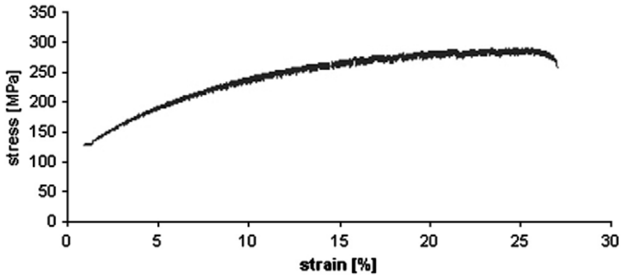

Fig. 1 – An example of stress–strain curve of tensile 5182 aluminium alloy.

7 mm wide and 1.8 mm thick were cut from the bulk material which had an average grain size of about 30 μm. The surfaces of the specimens were covered by sprayed graphite particles to enhance the image's contrast. Tensile tests to fracture were carried out at room temperature on a static testing machine (QTEST MTS) at an initial strain rate of $5.3 \times 10^{-4} s^{-1}$.

During the tensile test all data were recorded digitally at a rate of 50 Hz. In order to characterize the nucleation and the movement of individual PLC bands the entire gauge section of the sample was imaged using a digital camera operating at 25 fps (fps – frame per second). The recorded digital images were then analyzed by VIC 2D software which computes the

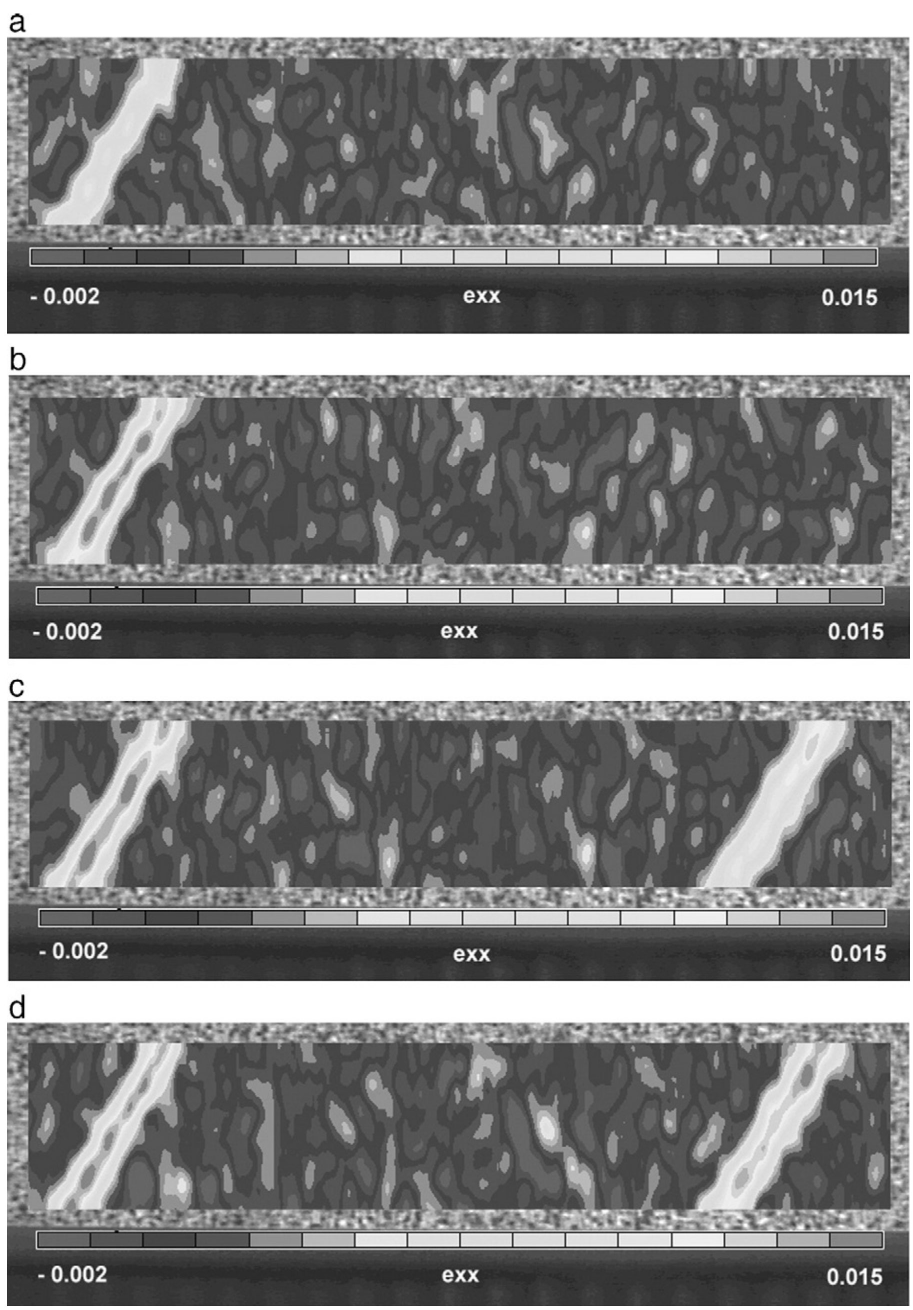

Fig. 2 – PLC band captured at the c.a. 8% of elongation: (a) an image at a time t_0, (b) t_0 +0.040 s, (c) t_0 +0.48 s, (d) t_0 +0.48+0.04 [s] (the arrow indicates elongation axis).