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Identification of modes of fracture in a 2618-T6 aluminum alloy using stereophotogrammetry

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A R T I C L E   D A T A

Article history:
Received 1 March 2011
Received in revised form
13 September 2011
Accepted 15 September 2011

Keywords:
Fracture
Stereophotogrammetry
Quantitative
Fractographic

A B S T R A C T

The identification and the development of a quantification technique of the modes of fracture in fatigue fracture surfaces of a 2618-T6 aluminum alloy were developed during this research. Fatigue tests at room and high temperature (230 °C) were carried out to be able to compare the microscopic fractographic features developed by this material under these testing conditions. The overall observations by scanning electron microscopy (SEM) of the fracture surfaces showed a mixture of transgranular and ductile intergranular fracture. The ductile intergranular fracture contribution appears to be more significant at room temperature than at 230 °C. A quantitative methodology was developed to identify and to measure the contribution of these microscopic fractographic features. The technique consisted of a combination of stereophotogrammetry and image analysis. Stereo-pairs were randomly taken along the crack paths and were then analyzed using the profile module of *MeX* software. The analysis involved the 3-D surface reconstruction, the trace of primary profile lines in both vertical and horizontal directions within the stereo-pair area, the measurements of the contribution of the modes of fracture in each profile, and finally, the calculation of the average contribution in each stereo-pair. The technique results confirmed a higher contribution of ductile intergranular fracture at room temperature than at 230 °C. Moreover, there was no indication of a direct relationship between this contribution and the strain amplitudes range applied during the fatigue testing.

1. Introduction

The study of a fracture surface and its relationship to crack propagation, in other words "fractography", is related to unraveling or interpreting the information of the appearance of the fracture surface pattern, as a result of multiple factors such as chemical composition of the material, microstructure and deformation behavior, methods of testing, conditions of the test (environment, strain rate, etc.) and the sequence of micro-deformation processes which resulted in the nucleation and propagation of the crack [1-3].

Stereology methods were developed to collect micro-geometrical information from three-dimensional (3D) objects. The main goal of these techniques is to determine the 3D structure of an object by analyzing two micrographs obtained by viewing the object from different directions [4, 5]. There are

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doi:10.1016/j.matchar.2011.09.005

Notation

$\Delta\varepsilon/2$	Strain amplitude
N_f	Cycles to failure
w	Working distance
M	Magnification
$\Delta\theta$	Total tilted angle
L	Filter value
f	Fraction of the mode of fracture
f_v	Fraction of the mode of fracture in the vertical direction
f_h	Fraction of the mode of fracture in the horizontal direction
L_p	Total path length
TL	Projected linear portion
F_i	Percentage of ductile intergranular fracture
F_t	Percentage of transgranular fracture

two ways to obtain these micrographs, either tilting a) the object with respect to the fixed optic axis, or b) the optics axis relative to the fixed object, as shown in Fig. 1.

The use of a scanning electron microscope (SEM) is considered the most reliable instrument for stereology work due to its advantages in comparison with traditional techniques (e.g. light microscope) such as flexible range of magnifications (10 to 30,000×), higher resolution and depth focus [4-8]. These advantages along with the uniqueness of the stereology techniques to acquire quantitative information make them a powerful tool to understand fracture surfaces. Moreover, the use of these techniques to obtain microscale measurements of deformation, damage and fracture mechanisms could support the development of life prediction models and provide guidance for the production of high-strength materials with damage tolerance [9].

In previous research works, stereo-pairs (stereophotograms) were examined using stereocomparators, mirror stereometer, or photogrammetric analogue plotters. The parallaxes were measured and analyzed using the method developed by Piazzesi [4], and then the 3D coordinates of the points measured were computed for the reconstruction of the feature of interest. The analysis time was reduced with the introduction of automatic image analysis methods. Various procedures were developed to obtain the digital elevation model (DEM) in order to reconstruct the topography of the material surface [7, 10-13].

Some investigations focused on verifying and correlating the use of digital image analysis with the parallax method developed by Piazzesi [11, 12], while other studies explored the potential applications of the technique such as, the calculation of the amount of void energy from the deformation analysis during the final fracture stage of high strength steels

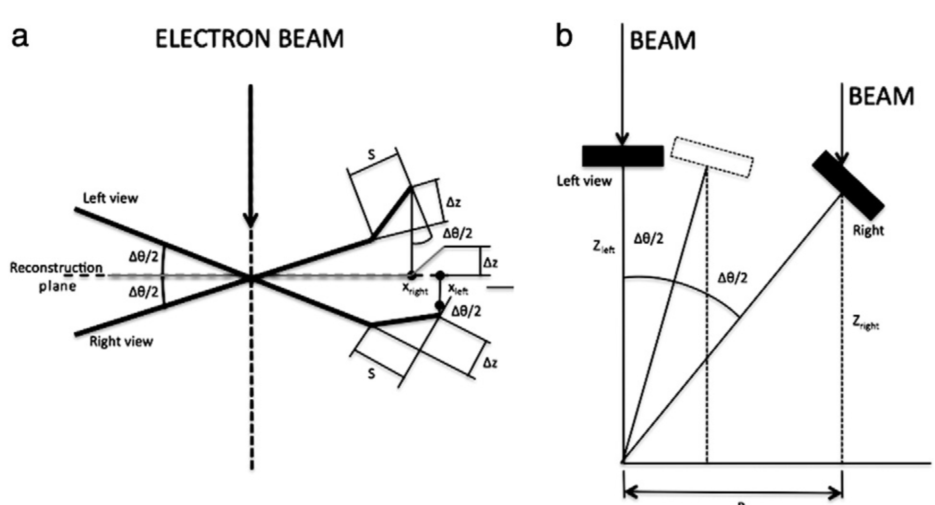

Fig. 1 – a) Configuration if the specimen can be tilted opposite angles; and b) if the specimen can only be tilted in both positive angles [13].