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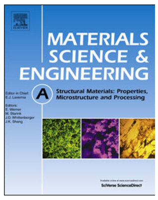

Quantitative characterization of cleavage and hydrogen-assisted quasi-cleavage fracture surfaces with the use of confocal laser scanning microscopy

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ABSTRACT

"True" cleavage (TC) and quasi-cleavage (QC) fracture surfaces of low-carbon steel specimens tested in liquid nitrogen and after hydrogen charging respectively were investigated by quantitative confocal laser scanning microscopy (CLSM) and conventional scanning electron microscopy (SEM) with electron-backscattered diffraction (EBSD). Topological and crystallographic features of the TC fracture surface are found in good agreement with the generally accepted cleavage mechanism: TC facets diameters correspond to those of grains; the crack path strictly follows the crystallographic orientation of grains and the most of the cleavage cracks are parallel to {100} planes. On the 2D SEM images, the QC facets appeared resembling the TC ones in terms of river line patterns, shapes and sizes. However, the substantial differences between the topography of these two kinds of fracture surfaces were revealed by 3D CLSM: the average misorientation angle between QC facets and the roughness of the QC fracture surface were much lower than those measured for TC. It is demonstrated that all these features are attributed to the specific fracture mechanism operating during hydrogen-assisted cracking.

1. Introduction

"True" cleavage (TC) and quasi-cleavage (QC) represent the most common fracture modes of metals and alloys along with brittle intergranular cracking and ductile microvoid coalescence [1]. The TC is referred to as the brittle transgranular fracture mode, which is usually caused by dynamic loading or loading at low temperatures. Cleavage cracks propagate transgranularly with little or no plastic deformation in the well-defined low-index crystallographic planes. The faceted crack-path morphology with river line patterns is characteristic of cleavage [1–4]. In iron and ferritic steels, the cleavage occurs primarily along the {100} cubic planes [2,4,5], though cleavage along the {011} and other low-index planes have also been noticed [4,6]. In contrast to the TC, the term "quasi-cleavage" or "cleavage-like fracture" is less defined and is related rather to a fracture surface appearance than to a certain fracture mechanism. Therefore, many different transgranular fracture surfaces are broadly associated with QC though the underlying mechanisms of their formation can be fundamentally different. Various types of QC fracture surfaces are found in steels with ferritic [7], bainitic [8], martensitic [9] microstructures. Transgranular fracture surfaces of hydrogen embrittled steels are also often referred to as QC [10–14]. As of today the experimental database covering the nature and features of QC fracture surfaces is far from being complete. Particularly, the QC mechanism related to the so-called "fisheyes" , which are the specific round-shape defects found commonly on fracture surfaces of mild ferritic steels saturated with hydrogen, has been just scarcely studied [15–18]. Moreover, as it will be shown below, the QC facets on the fisheye surface visually resemble the TC facets in terms of size, shape and appearance of river line patterns. Nevertheless, the difference in the nature of these two fracture modes is evident. Quantitative characterization of fracture surface topography is vital for unambiguous identification of fracture mechanisms. However, the quantitative parameters such as misorientation angles between the facets, area and roughness of fisheyes QC fracture surface describing fracture surface morphology [19] are still vaguely known. *Thus, using the quantitative surface characterization techniques, the objective of this study is to establish a robust criterion capable of distinguishing the quasi-cleavage fracture surfaces of the hydrogen-induced fisheye defects from the 'true' cleavage fracture surfaces formed as a result of low-temperature embrittlement in a low carbon steel.*

With the advent of analytic microscopy and high resolution

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