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Fractal analysis of stretch zone behavior for AA 7475 aluminum alloy

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Abstract – The quantitative fractography is an important tool on the investigation of structural faults and to enhance manufacturing process. A quantitative study is applied to measure fractal dimension and stretch zone width to characterize the fracture surface of aluminum alloy AA 7475. The results showed a good correlation between fractal dimension and stretch zone width for regions under plane strain state.

A stretch zone is formed under a critical state provided by stable crack propagation in the fracture process. This region characterizes the real crack initiation phenomenon, located between the stable crack propagation zone and the rupture zone. Some authors recognize the stretch zone width (Fig.1) as a local description of the fracture toughness in metallic alloys [1]. Campos et al [2] suggested that stretch zone width is related to fractal dimension under elastic-plastic states. Fractal Dimension is a mathematical sensitive parameter that provides a description for complex shapes [3].

This work consists on the analysis of stretch zone topography data along specimen width, obtained by digital image processing for 3-D reconstruction of fracture surfaces by extended depth of field. The used material was aluminum alloy AA 7475 for aircraft industry. The specimen was fractured in a CTOD testing. Image stacks obtained by light microscopy were processed, resulting in several elevation maps used to analyze fractal dimension and stretch zone width.

Analyzing the results of all stretch zones, any significant correlation was obtained between fractal dimension and stretch zone width. It demonstrates that stretch zone has heterogeneous topographic behavior along thickness, being dependent on local stress fields. By this, it was applied the methodology used by Campos et al [2] to analyze fracture surfaces of 15-5 PH steel, where the correlation between fractal dimension and stretch zone width data was obtained for regions located on center and edges of specimen. Surface reconstructions were done along specimen width following the stretch zone at five regions symmetrically placed: one at center, two between center and edges and two at edges.

There is a large dispersion on stretch zone width values, which grow up towards edges. The increase in dispersion can be related to plane strain state of materials, which is reduced towards specimen edges, because near this region the predominant mechanisms of fracture are tearing and shearing for ductile rupture, which results in complex topographies. Taking the graphs of fractal dimension versus stretch zone width it was observed that the correlation coefficients grow up at the center of specimen width, showing a clear relation with plane strain state (Fig.2).

The results showed consistent with work developed by Campos et al [2], where the fracture surfaces are consistently described by fractal dimension only under plane strain state conditions. In the case of non predominance of plane strain, a large scattering of measured values with low correlation between fractal dimension and stretch zone width is verified. In this way, the fractal dimension can express local toughness behavior, but this relation is limited by the fractured body geometry and elastic-plastic loading conditions.

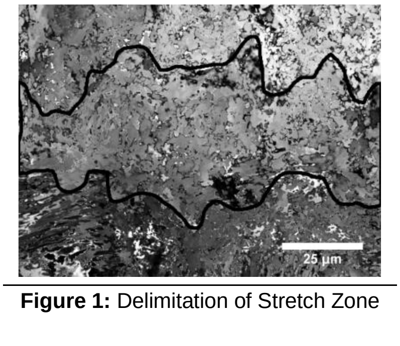

Figure 1: Delimitation of Stretch Zone

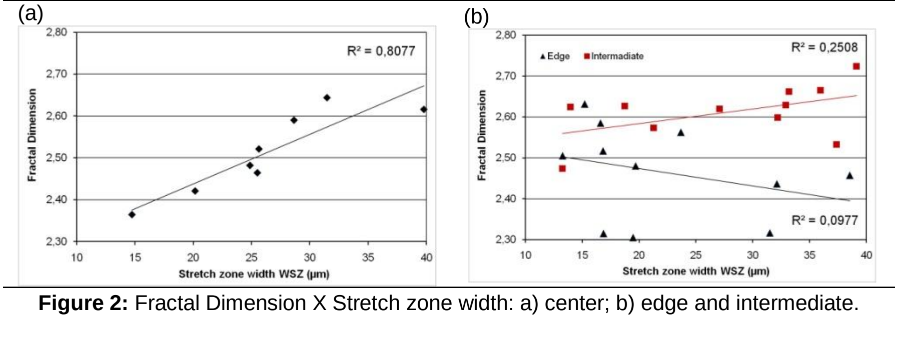

Figure 2: Fractal Dimension X Stretch zone width: a) center; b) edge and intermediate.

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