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Fracture Toughness Characterizations of Single Edge Notch (SENB) Testing Using DIC System

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Abstract : The fracture toughness resistance curve (e.g., J-R curve and crack tip opening displacement (CTOD) or δ-R curve) is important in facilitating strain-based design and integrity assessment of oil and gas pipelines. This paper aims to present laboratory experimental data to characterize the fracture behavior of pipeline steel. The influential parameters associated with the fracture of API 5L X52 pipeline steel, including different initial crack sizes, were experimentally investigated for a single notch edge bend (SENB). A total of 9 small-scale specimens with different crack length to specimen depth ratios were conducted and tested using single edge notch bending (SENB). ASTM E1820 and BS7448 provide testing procedures to construct the fracture resistance curve (Load-CTOD, CTOD-R, or J-R) from test results. However, these procedures are limited by standard specimens' dimensions, displacement gauges, and calibration curves. To overcome these limitations, this paper presents the use of small-scale specimens and a 3D-digital image correlation (DIC) system to extract the parameters required for fracture toughness estimation. Fracture resistance curve parameters in terms of crack mouth open displacement (CMOD), crack tip opening displacement (CTOD), and crack growth length (Δa) were carried out from test results by utilizing the DIC system, and an improved regression fitting resistance function (CTOD Vs. crack growth), or (J-integral Vs. crack growth) that is dependent on a variety of initial crack sizes was constructed and presented. The obtained results were compared to the available results of the classical physical measurement techniques, and acceptable matchings were observed. Moreover, a case study was implemented to estimate the maximum strain value that initiates the stable crack growth. This might be of interest to developing more accurate strain-based damage models. The results of laboratory testing in this study offer a valuable database to develop and validate damage models that are able to predict crack propagation of pipeline steel, accounting for the influential parameters associated with fracture toughness.

Keywords : fracture toughness, crack propagation in pipeline steels, CTOD-R, strain-based damage model
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