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J integral solution for semi-elliptical surface crack in high density poly-ethylene pipe under bending

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ABSTRACT

The goal of this work is to analyse the severity of semi-elliptical crack defects and to study the degree of damage in the poly-ethylene pipe in bending during the crack propagation. The semi-elliptical cracks are considered in this work located in different position in the wall of the pipe. The three finite element method based on the computation of the *J* integral was used to analyse the fracture behaviour of these structures. The effect of the position, shape and size of the crack on the *J* integral values was highlighted. The effects of strain rate and the temperature on the *J* integral values were also examined. The obtained results show that the strain rates have a strong influence on the *J* integral values especially for circumferential crack at higher bending moment. However, the energy for circumferential crack is more important compared to axial crack. The effect of the depth of the crack becomes important when the ratio (a/t) reaches a critical value of 0.6 ($a/t = 0.6$), especially when the ratio a/c is weak (semi-elliptical crack, $a/c = 0.2$) where the *J* integral values becomes independently of the crack depth, this conclusion is opposite to the above for the poly-ethylene pipe subjected to internal pressure. We recall finally, that the temperature effect on circumferential cracks behaviour is more important compared to the axial cracks at critical crack size ($a/c = 0.2$ and $a/t = 0.6$). It is also shown that in the wall of pipe, the internal cracks are more dangerous than the external cracks.

1. Introduction

Pipes and elbows are important components in any piping systems for transportation of hydrocarbons. These structures are subjected to complex loads taking into account their geometrical configuration and the multiplicity of the loading conditions in service. The origin of failure of these mechanical components is directly related to the presence of defects during fabrication and the problem could be worsened for cyclic loading, where there is a risk of initiation and crack growth. The fracture prediction and the reliability of such piping systems in various practical applications are primordial given their impact on the economic plan and security. Several authors [1–6] have been studied pipe fracture problems by means of experimentation and numerical simulation in order to asses the mechanical integrity, taking into account different crack shapes. In the same context, a thorough examination of this subject can be found in Refs. [7–11], where the influences of semi-elliptical cracks in plates are analysed. The tests was carried out on plates at room temperature and higher temperatures by Boukharouba et al. [7], their results indicate that the two ratios a/t (crack depth/plate thickness) and a/c (crack depth/half-length of crack) will be changed during the propagation and the position of maximum stress is related to these two geometrical parameters defining the crack shape. The crack propagation in longitudinal (large half axis for semi-elliptical crack) and in radial (small half axis for semi-elliptical crack) directions were found to be different. Moreover, it showed that, for this type of cracks the direction of propagation is related to the size, the shape of the cracks and the sensitivity of mechanical behaviour of materials at high temperature. Pressurized plastics pipes have been used successfully for several decades and, especially, pipe systems made of poly-ethylene (PE) are widely used in fuel gas and water supply as well as in sewage systems [12,13]. In 2007, the worldwide demand for pipes made of poly-ethylene with high density (HDPE) was about 3.7 million tons and a growth rate of 6% per year up to 4.9 million tons is expected in 2012 according to Brescia [14]. The polymer pipes offer several advantages in comparison to metallic pipes: they have good resistance to wear and corrosion, low density, low cost, easy of installation, production of complex shape (elbow

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