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DETERMINATION OF BURST PRESSURE OF THIN-WALLED PRESSURE VESSELS

Ľ. Gajdoš, M. Šperl*

Abstract: *A simple fracture-mechanics based method is described for assessing a part-through crack in the wall of a pipe subjected to internal pressure of liquid and/or gas. The method utilizes simple approximate expressions for determining the fracture parameters K, J, and employs these parameters to determine critical dimensions of a crack on the basis of equality between the J-integral and the J-based fracture toughness of the pipe steel. The crack tip constraint is taken into account by the so-called plastic constraint factor C, by which the uniaxial yield stress in the J-integral equation is multiplied. The results of the prediction of fracture conditions are verified by burst tests on test pipes.*

Keywords: ***Fracture mechanics, J integral, pressure vessels, burst tests***

1. Introduction

The threat which crack-like defects in the pipe wall can pose to the gas pipeline can be assessed by the use of fracture mechanics. If the gas pipeline is made of a high toughness material, the plastic strains become extensive before the crack reaches instability. Hence, some elasto-plastic fracture mechanics methods, such as J-integral, crack opening displacement, the two-criterion method or some other procedures, can be employed to assess the fracture condition of the pipeline. In principle, the method of determination of burst pressure of thin-walled pressure vessels utilizes simple approximate expressions from literature for determining the K factor and the J integral for both a through thickness crack and a part-through thickness crack.

2. An engineering method for determination of fracture conditions of a cracked pipe

The basic idea of the method is to calculate the J integral for a crack in the pipe wall and to compare it with the fracture toughness (in terms of the J integral) of the pipe material. If we confine our analysis to a longitudinal part-through crack then we can use any of two relations for an approximate J integral determination, numbered by (1) and (2):

$$J = \frac{K^2}{E'}\left[1 + \frac{2\alpha n}{(n+1)}\left(\frac{\sigma}{C\sigma_0}\right)^{n-1}\right] \tag{1}$$

$$J = \frac{K^2}{E'}\left[A + \frac{0.5\left(\sigma/C\sigma_0\right)^2}{A}\right] \tag{2}$$

The function A in Eq. (2) is given by the relation: $A = 1 + \alpha\left(\frac{\sigma}{C\sigma_0}\right)^{n-1}$ and C is the so called plastic constraint factor on yielding with the average value C = 2. The K factor in Eqs. (1) and (2) is recommended to be determined by the modified Newman formula for longitudinal part-through cracks in thin-walled cylindrical shells.

3. Burst tests

Three pipes with cycled-up cracks were used for burst tests. The cracks were made in such a way that the test pipes were first provided with working slits and the check slits. The latter slits were of the

* Ing. Ľubomír. Gajdoš, CSc., Ing. Martin Šperl, PhD., Institute of Theoretical and Applied Mechanics AS CR, v.v.i., Prosecká 76, 190 00 Prague 9, Czech Republic, e-mail {gajdos|sperl}@itam.cas.cz

same surface length as the working slits but their depth was greater. These check slits functioned as a safety measure to prevent cracks that developed at the working slits from penetrating through the pipe wall. For illustration, DN1000 test pipe body results are presented in Tab. 1 for two cracks: B and B´.

Tab. 1: DN1000 test pipe body results

Characteristics	Crack B	Crack B´
CRACK DIMENSIONS		
half-length, c (mm)	115	127
depth in fracture, a_f (mm)	7.1	6.7
RAMBERG-OSGOOD PARAMETERS		
α / n /σ_0 (MPa)	5.92 / 9.62 /536	5.92 / 9.62 /536
FRACTURE TOUGHNESS		
$J_{cr} = J_m$ (N/mm)	439	439
FRACTURE PRESSURE		
p_f (MPa)	9.55	9.86

The results of fracture prediction by the GS method (Eq. 1) and FC method (Eq. 2) for crack B are illustrated in Fig. 1.

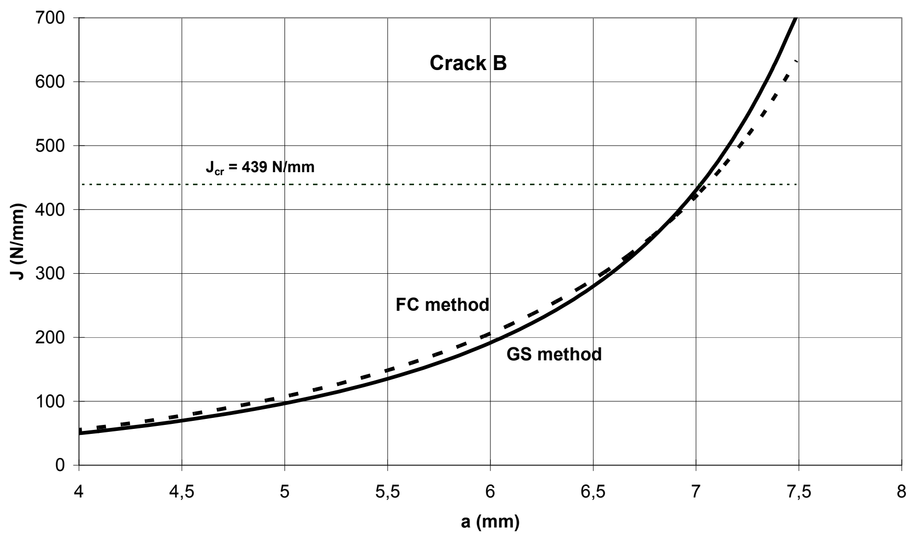

Fig. 1 Prediction of the fracture depth for the crack B ($p = p_f = 9.55$ MPa and $C = 2.07$)

4. Conclusions

An engineering method has been worked out for assessing the geometrical parameters of critical axial crack-like defects in a high-pressure gas pipeline wall for a given internal pressure of a gas. The method makes use of simple approximate expressions for determining fracture parameters K, J, and it accommodates the crack tip constraint effects by means of the so-called plastic constraint factor on yielding. Two independent approximate equations for determining the J-integral provided very close assessments of the critical geometrical dimensions of part-through axial cracks.

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