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Examples of actual defects in high pressure pipelines and probabilistic assessment of residual life for different types of pipeline steels

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Abstract

During recent internal inspection of an operated high pressure pipeline of the diameter DN700, distinct, quite large indications of cracks were found in one of the pipe sections. A part of the section was taken from the ground for a comprehensive experimental programme containing analyses of the defect type, dimensions and character and also fatigue test at variable internal pressure with the maximum value corresponding to real operation. The analysed defects mostly occurred during pipe manufacture followed by stress corrosion cracking mechanism in some cases. An existence of fatigue crack growth (FCG) during fatigue pressure test in some cases was demonstrated. Within another experimental programme, an extensive measurement of FCG rates in different high pressure pipeline steels was performed. The evaluated data enabled to carry out serious statistical evaluation. Probabilistic assessment of residual life of pipes made of different steels, containing semi elliptical external surface axial crack was carried out using ALIAS HIDA software developed within the European Framework Programme project.

Keywords: High pressure pipelines ; defects ; fatigue crack growth ; probabilistic assessment

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1. Introduction

Natural-gas pipeline accidents mostly result in major damage to buildings and other constructions located not only nearby but also quite far away and often put a lot of people in danger of injury or death. Such crashes are almost always connected with enormous material and financial damages. Therefore, safety and reliability management of high pressure gas pipelines is one of the most important issues for the operators and big effort is being put to various investigation projects with the aim to minimise probability of unexpected pipeline explosions or at least to minimise damages and possible people injuries. One of the research fields is risk assessment of high pressure pipeline explosion and planning of safe distances between the pipeline and buildings on the basis of probability methods like Monte Carlo simulations etc. – Russo and Parisi (2016). The most effective method, however, looks to be a comprehensive theoretical and experimental evaluation of existing overall operated pipeline conditions using different available tools like intelligent pigging, regular internal inspections of corrosion occurrence and its growth, pressure cycle induced fatigue crack growth assessment and other tools, as published in the 27th Pipeline Pigging and Integrity Management Conference (2015), followed by a dedicated research programme dealing with a specific technical problem of damage to the pipeline, either local or of a fairly global character.

Estimation of safety and reliability of engineering structures and components containing cracks or crack-like defects is one of the most important application field of fracture mechanics particularly in cases, where limited defects can be accepted due to the component size, their high costs and loading character. In such cases, safety and reliability of further operation, residual life assessment, eventually specification of interval of damage development inspections are important issues. This also applies to the high-pressure pipelines.

Linear fracture mechanics is a powerful tool enabling, with a considerable extent, to transfer results measured in standard laboratory specimens to actual structures in operation. In case of cyclic loading, the damage process is described by the well known Paris-Erdogan equation of fatigue crack growth (FCG) rate on stress intensity factor range $da/dN = C\ \Delta K^m$. If inaccuracies caused by different constraint factors are not considered, such transfer of results is basically quite correct.

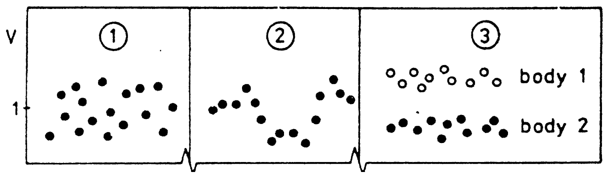

Fig. 1:.Schematic diagrams of FCG rates for a constant ΔK at different positions along the crack: (1) fine or intermediate variability, (2) rough and (3) extremely rough variability

There is, however, a problem consisting in different type and extent of material inhomogeneity and related scatter of local FCG rate values. In Figure 1, taken from Lauschmann (1987), three different characters of material variability are schematically shown, namely low, medium and high variabilities, whereas this classification is dependent on specimen size, where FCG rate is evaluated. For example, in small size specimens, the case 3 occurs much more frequent than in large scale components of the same material. Therefore, data basis of FCG rate has to be evaluated using more than one specimen and mean FCG rates are eventually statistically evaluated with regression line. An application of purely deterministic crack growth assessment and evaluation of residual life in a real component just on the basis of the regression line is dangerous and irresponsible, because due to the material inhomogeneity and scatter of local FCG rates, such the assessment can be several times more optimistic than the reality. Therefore, probabilistic approaches have been recently further intensively studied and applied particularly for service life of structures and components exploited to the maximum extent, which is typical for recent years – Seyedi and Hild (2004), Bagaviev (2004), Bielak et al. (2004), Le Mat Hamata and Korouš (2004), Beretta and Regazzi (2016), Romano et al. (2016).

In this paper, an example of crack-like defects in recently analysed high pressure pipeline section is shown. In the second part, probabilistic assessment of residual life of a pipe section made of different typical high pressure