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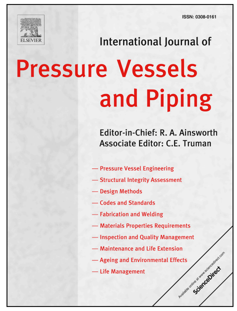

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Contribution of Finite Element Analyses to Crack-Like Flaw Assessments in a Gas Pipeline

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Abstract

When defects reach a critical size, failure occurs in engineering components. The criticality assessment of defects is hence a key aspect of the structural integrity of gas pipelines in service. Fitness-For-Service (FFS) assessments are generally employed for evaluating the criticality of a crack-like flaw in structures using simplified assumptions in relation to geometry and material properties. Whilst the errors resulting from these modelling simplifications prove acceptable in many cases, there are situations where it will be necessary to take into account the nonlinearities in geometry and/or material behaviour. This can be either to avoid excess conservatism or, on the contrary, to ensure the results are safe. In such cases it becomes essential to develop a finite element model of the structure to account for such real-engineering complexity. Welding, the most prevalent technique to join pipe, often brings about a misalignment between two pipes and hence complex crack shape is formed. The aim of this study is to develop an elastoplastic finite element model of a gas pipeline possessing a crack in a misaligned weld. The remaining life of the pipeline is determined using a Failure Assessment Diagram (FAD) and the Paris law. The results obtained from the finite element method to determine the stress intensity factors are compared to results derived using the API-579 for stress intensity factors calculations.

Keywords: Gas Pipeline, Hi-Lo Misalignment, Crack, Fracture, Steel, API-579;

1. Introduction

Pipeline plays a significant role in the energy sector and whose structural integrity is a key issue for the safe production. In-service pipes are generally subjected to complex loading regimes. While the internal pressure is the primary source of loading, additional loading due to ground movements such as landslide can compromise the integrity of a pipeline and result in fatalities or damage to the environment.

During the life of a gas pipeline, non-destructive testing is performed on a regular basis to determine the presence and size of defects. Stress cycles (mostly due to the cyclic internal pressure loading of the pipeline) can lead to the progression of the cracks and can hence accelerate failure. In order to ensure the integrity of the pipeline and to avoid catastrophic failure, an assessment needs to be performed each time a defect is found. If the defect is deemed “unacceptable”, the affected portion of the pipeline is repaired or replaced.

In steel welded structures, crack-like flaws are of particular importance as the welding process tends to induce such defects. The API 579-1/ASME FFS-1 “Fitness-For-Service” (API-579) [1] and the BS-7910 “Guide to methods for assessing the acceptability of flaws in metallic structures” [2] are the two standards typically used in the industry to assess crack-like flaw in a steel structure. In both standards, the Failure Assessment Diagram (FAD) approach is used [1], [2]. The assessment point corresponding to the analysed defect under the applied loading is placed on the FAD using semi-analytical formulae from the standards. The position of this point on the diagram allows determining of the acceptability of a crack and estimating the number of stress cycles leading the defect to an unacceptable region.

However, these standards are commonly appropriate in an elastic material and in general deemed conservative. In the case of having more complicated cases such as material non-linearity, a finite element model has to be developed to predict failure in the pipeline.