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The effect of corrosion defects on the burst pressure of pipelines

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Abstract

The loss of metal in a pipeline due to corrosion usually results in localized pits with various depths and irregular shapes on its external and internal surfaces. The effect of external corrosion defects was studied via a series of small-scale experiments and through a nonlinear numerical model based on the finite element method. After calibration was conducted, based on the experimental results, the model was used to determine the burst pressure as a function of material and geometric parameters of different pipes and defects. This paper briefly summarizes these results, which are subsequently used to develop a simple procedure for estimating the burst pressure of corroded pipes.

Keywords: Pipeline; Corrosion; Burst pressure

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1. Introduction

As a pipeline ages, it can be affected by a range of corrosion mechanisms, which may lead to a reduction in its structural integrity and eventual failure. The economic consequences of a reduced operating pressure, loss of production due to downtime, repairs, or replacement can be severe and, in some cases, not affordable. Thus, there are several pipelines kept in operation even though signs of corrosion are visible on their external surface. Most of these pipelines are allowed to operate after recalculating the maximum admissible internal pressure of the product being transported. To this end, reliable criteria

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Nomenclature

P_b	burst pressure of the corroded pipe
P_{bi}	burst pressure of intact pipe
D	outside diameter of the pipe
t	wall thickness of the pipe
L	length of the pipe
d	maximum depth of the defect
c	maximum width of the defect
l	maximum length of the defect
E	Young's modulus
ε_o	yield strain (σ_o/E)
ε^p	plastic strain
ν	Poisson's ratio
σ_p	proportional stress
σ_o	0.2% strain offset yield stress
σ_y	stress at a strain of 0.5% (API yield stress)
σ_r	tensile strength
$SMTS$	specified minimum tensile strength
γ_d	partial safety factor for corrosion depth
γ_m	partial safety factor for model prediction
$\left(\frac{d}{t}\right)_{med}$	measured relative corrosion depth
ε_d	factor defining fractile value for corrosion depth
$StD\left[\frac{d}{t}\right]$	standard deviation of measured (d/t) ratio (based on the specification of the inspection tool)

are useful for readily checking the residual strength of pipelines without the need for sophisticated analyses.

Among the existing criteria for evaluating the residual strength of corroded pipelines, the ASME B31G code [1], originally developed many years ago, is still the most widely used criterion. Kiefner and Vieth [2,3] recognized later that the corrosion assessment methods in the B31G code could be over-conservative for some kinds of defects found in practice. They modified the code to develop what is known as the $0.85dL$ method. Like for the original version, the length of the defect l and its depth d are the only parameters needed to define the defect. Single defect equations like these form the basis for predicting the failure loads of more complex problems such as combined internal pressure and compressive longitudinal stresses, the interaction of single defects, and the actual complex shape of a corrosion defect. More recently, DNV [4,5] has published