Failure Probability of Corrosion Pipeline with Varying Boundary Condition

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This paper presents the effect of external corrosion, material properties, operation condition and design thickness in pipeline on failure prediction using a failure probability model. The predicted failure assessment for the simulated corrosion defects discovered in corroded pipeline is compared with that determined by ANSI/ASME B31G code and a modified B31G method. The effects of environmental, operational, and random design variables such as defect depth, pipe diameter, defect length, fluid pressure, corrosion rate, material yield stress and pipe thickness on the failure probability are systematically studied using a failure probability model for the corrosion pipeline.

Key Words: Corrosion, Pipeline, Failure Probability, Reliability, Failure Assessment

1. Introduction

The maintenance and management skill of the industrial equipments has been emerged as a very important technique to be properly dealt with since the industrial apparatus becomes more complicated and diversified throughout all kinds of industries according to the development of various mechanical techniques. It has been often reported as an industrial example in that a catastrophic disaster has been caused by the defect like corrosion arisen by aging and/or environmental effect in pipeline transporting gas and oil (Kim, 1997, Choi, 2000).

The technique to predict pipeline failure due to corrosion damage is necessary to determine the corrosion tolerance for the pipeline design. Especially, it could be the inevitable technical information to assess the safety life of aging pipeline. Therefore, systematic investigation which deals with the damage and the failure of pipelines corresponding to varying boundary conditions is needed.

It is generally known that the occurrence of corrosion in pipelines reduces the strength of pipeline material. Thus, the development of reference and/or standard has been required to prevent failure accidents in advance by predicting the stress condition and failure life corresponding to the shape and location of corrosion (Lee and Kim, 1998, 1999, Lee and Choi, 1999, Lee and Cho, 1992).

The codes such as ANSI/ASME B31G dealt with the reference and/or standard for the corrosion pipeline in detail (ANSI/ASME B31-1985, 1985). An assessment procedure in a modified version of existing one, ASME MB31G code, was widely utilized in the oil and gas industries (Hopkins and Jones, 1992, Mohammedi et al, 1985).

The objective of this study is to present an approach to quantify the reduction in safety and hence the remaining life for deteriorating corroded steel pressurised buried pipelines during its
operation period. A failure probability model proposed by Mohammedi et al. (1985) has been used. The effect of varying boundary condition on the failure probability of the buried pipelines is studied systematically using this model.

2. Fundamentals for the Failure Probability Model

The major causes of the failure of pipelines transporting high pressure gas are known as the mechanical damage and the corrosion.

The standards for regular hydrostatic test and corrosion assessment are generally used to assess the effect of mechanical damage and corrosion on the integrity of the pipelines. In order to assess the integrity of corroded pipeline, we need to simplify the geometry in the vicinity of corrosive part.

Figure 1 shows a corrosion model, and which is further simplified as shown in Fig. 2 to analyse easily the given geometric configuration.

2.1 ANSI/ASME B31G code

A failure formula for corrosion pipelines was based on data from the explosion experiment, suggested as follows (Kiefner, 1974):

\[
\sigma_f = \sigma_{\text{min}} \left[ 1 - \frac{(2/3)(d/t)}{1 - (2/3)(d/t) M^{-1}} \right] \tag{1}
\]

Figure 2 shows the cross-section of the external corrosion pipeline (Ahamed and Melchers, 1995) and equation (1) is necessary to determine the failure stresses in corrosion pipeline. Where \( \sigma_f \) is the failure stress (MPa), \( \sigma \) is the flow stress (MPa), \( A \) is the projected cross-section area of corrosion pipeline (mm²), \( A_0 \) is \( L \times t \) (mm²), \( L \) is the projected corrosion length (mm), \( t \) is the wall thickness (mm), \( d \) is the maximum corrosion depth (mm), and \( M \) is the Folias bulging factor (ANSI/ASME B31-1985, 1985).

Equation (1) has been modified by considering the two conditions: 1) the hoop stresses may not be larger than the yield strength of the pipeline material (Kiefner et al., 1992), 2) the relatively short corrosion is assumed to be projected as a parabola by assessing the long corrosion as a rectangular shape. The modified failure formula for parabola and rectangular shape are given, respectively, as follows (ANSI/ASME B31-1985, 1985):

i) Parabola

\[
\sigma_f = \sigma_{\text{min}} \left[ 1 - \frac{(2/3)(d/t)}{1 - (2/3)(d/t) M^{-1}} \right] \quad \text{if, } \sqrt{0.8 \left( \frac{L}{D} \right)^2 \left( \frac{D}{t} \right)} \leq 4 \tag{2}
\]

ii) Rectangular

\[
\sigma_f = \sigma_{\text{min}} \left[ 1 - (d/t) \right] \quad \text{if, } \sqrt{0.8 \left( \frac{L}{D} \right)^2 \left( \frac{D}{t} \right)} > 4 \tag{3}
\]

Where \( D \) is the outer diameter of the pipeline (mm), \( \sigma_{\text{min}} \) is the minimum yielding stresses (MPa) and \( M \) is defined as follows (ANSI/ASME B31-1985, 1985):

\[
M = \sqrt{1 + 0.8 \left( \frac{L}{D} \right)^2 \left( \frac{D}{t} \right)} \tag{4}
\]

\[
M = \infty \quad \text{if, } \sqrt{0.8 \left( \frac{L}{D} \right)^2 \left( \frac{D}{t} \right)} \leq 4
\]

2.2 MB31G (Modified B31G) code

It was noted by Kiefner and Vieth that the flow