117 (2023) 205083

Contents lists available at ScienceDirect

Gas Science and Engineering

journal homepage: www.journals.elsevier.com/gas-science-and-engineering

System reliability of corroded pipelines considering spatial and stochastic dependency in irregular zones

Mourad Nahal [a,*], Yacine Sahraoui [a], Rabia Khelif [b], Alaa Chateauneuf [c]

[a] *Laboratory of Research on Electromechanical and Dependability, University of Souk Ahras, BP 1553, Souk Ahras, 41000, Algeria*
[b] *Badji-Mokhtar University, BP 12, Annaba, 23000, Algeria*
[c] *Université Clermont Auvergne, CNRS, SIGMA Clermont, Institut Pascal, F-63000, Clermont-Ferrand, France*

ARTICLE INFO

Keywords:
System reliability
Irregular zone
Pipeline
Spatial variability
Karhunen-loeve expansion

ABSTRACT

This paper presents a probabilistic methodology for assessing the system reliability of corroded pipelines subjected to spatial and stochastic dependency, taking into account irregular zones (elbows, weld joints, and flanges). The space-variant corrosion and residual stress are considered by the mean of Karhunen-Loève expansion in order to take into account spatial variability of residual stress and soil aggressiveness over the pipe's entire length. The failure probability is evaluated by a series system combination using Monte Carlo simulations. Finally, the proposed model is applied to gas pipeline crossing several soil types in order to show the effects of the main parameters of the system, where the irregular zones have a significant influence on the pipeline system reliability and that the developed model can provide valuable information for decision-makers to improve system reliability performance.

1. Introduction

Pipelines are ideally designed for transporting oil and gas products, where their management is a vitally important function of government. During its expected long service life, the ageing pipeline can suffer from several degradation mechanisms, mainly due to soil aggressiveness and environmental conditions (Ait Mokhtar et al., 2016). Corrosion damage is one of the most frequent causes that affect the long-term reliability and integrity of metallic underground pipelines, except for some sectors where third-party damage is the most cited cause (Lam and Zhou, 2016). Consequently, developing precise predictive degradation models is necessary for pipeline risk assessment. Then, the predictive models can be used to optimize pipe network inspection and maintenance planning in the face of uninterrupted trade and a functioning economy (Ahmed Soomro et al., 2022; Zhao et al., 2022).

Additionally, pipeline maintenance operators frequently perform periodic diagnostics aiming to detect localized pipe metal losses, i.e. the depth, length and width of a corrosion defect should be determined for more recognition of the deterioration evolution in time (Witek, 2018; Tee and Pesinis, 2017; DNV-RP-F101, 2010). In recent decades, several approaches, such as deterministic, empirical, numerical and probabilistic, have been developed for assessing metal loss due to corrosion which can be defined by the electrochemical reaction between metallic structure and environmental conditions dealing inevitably with structures destruction (Beavers and Thomson, 2006; Uhlig, 1971) that explains the numerous essential researches existing in the literature. Different approaches' advantages and disadvantages can be found with more discussion elsewhere (Beavers and Thomson, 2006; Abyani, 2021; Kiswendsida and Qindan., 2022), and the improvement of previous models is still in continuous evolution.

In general, pipeline networks usually cover extensive distances; their routes can reach distances up to 5000 km (Algerian oil and gas pipeline). These structures inevitably contain irregular zones (Nahal et al., 2019), such as elbows, flanges, and welding joints, also called singular areas, which raised several efforts regarding their modeling, maintenance, and repair. The reliability analysis and risk assessment have been performed to determine the remaining time in service of such pipelines. In latest years, intensive research reflecting this issue's importance has been developed, where many theoretical reliability methods, including the first-order reliability method (FORM), second-order reliability method (SORM), Monte Carlo simulation, response surface method, and other approaches, have been considered, more detail and discussion can be found in numerous relevant papers such as (Zelmati et al. (2022), Q. Li et al. (2015), Pandey (1998), Bernt J. Leira et al. (Bernt, 2016), Nahal

* Corresponding author.
E-mail address: m.nahal@univ-soukahras.dz (M. Nahal).

https://doi.org/10.1016/j.jgsce.2023.205083
Received 5 December 2022; Received in revised form 11 June 2023; Accepted 4 August 2023
Available online 6 August 2023