Development of a Probabilistic Model Structure for Reliability Assessment of Pipeline Degradation Due to Corrosion-Fatigue Cracking

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Abstract

The overall objective of this study is to propose and validate a probabilistic-mechanistic empirical model based on the underlying corrosion-fatigue degradation phenomena whose parameters are estimated from the observed field data and experimental investigations. Uncertainties about the structure of the proposed model itself and parameters of the model are to be characterized. Because of its relatively simple form, the proposed empirical model will assess pipeline's health and prognosis. The existing corrosion-fatigue models are complicated to run, with many variables (over 30 parameters) whose values are deterministic and highly subjective.

1. Introduction

Wei's Model [1] is a Physics of Failure (PoF) model which represents the corrosion-fatigue degradation in oil pipelines. This is a leading model in the literature and used in this study as a benchmark to develop the empirical model. The use of this model is computationally cumbersome, involving many parameters whose values are uncertain and therefore its usefulness in practice is very limited. By assigning a probability distribution to the parameters of the Wei's model and with the aid of a Monte Carlo computer routine, large numbers of corrosion-fatigue trajectories were created, each associated with an instance of the many parameters involved. The pitting corrosion phenomenon is assumed to initiate a crack, which subsequently grows by fatigue-enhanced corrosion. To achieve a more realistic resemblance, the characteristics of the pipeline material and flow environment have been accounted for through a correlation process assuming independency among the parameters such as loading stress, loading frequency, and corrosion current. By a careful examination of the Monte-Carlo results, an empirical model structure was proposed having only two unknown parameters to be treated as uncertain and estimated using generic, field, and experimental data.

2. Results

Simple empirical parametric models were estimated from least square curve fitting of data obtained from the computer simulation, as shown in **Error! Reference source not found.**.

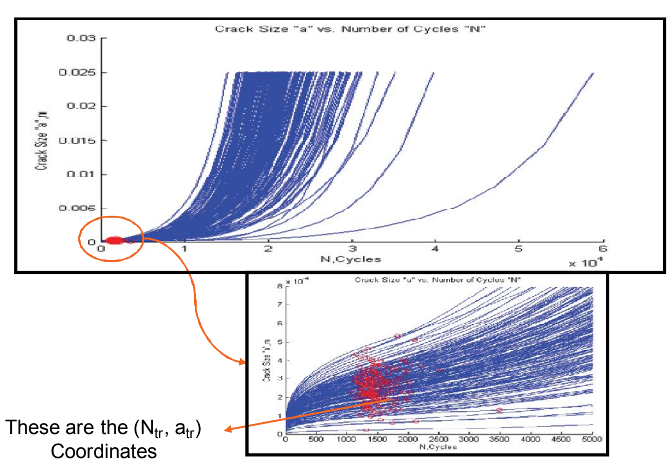

Figure 1. Results of the simulation using Wei's model.

The literature has shown that four environmental factors dominate the results: frequency υ, temperature T, Cyclic Stress σ, & Corrosion Current I_p. These are generally independent of each other; therefore the model describing the environmental degradation factors as a function of damage (i.e., stress-damage model) is:

$$a = A \cdot \sigma^{0.182} \cdot \nu^{-0.288} \cdot I_p^{0.248} \cdot N^{1/3} \quad + \quad B \cdot \sigma^{3.24} \cdot \nu^{-0.377} \cdot I_p^{0.421} \cdot N^2 \cdot e^{(4\times 10^{-10} \cdot \sigma^{2.062} \cdot \nu^{0.024} \cdot N)}$$

This model was checked against Wei's model that has shown a reasonable match as shown in Figure 2.

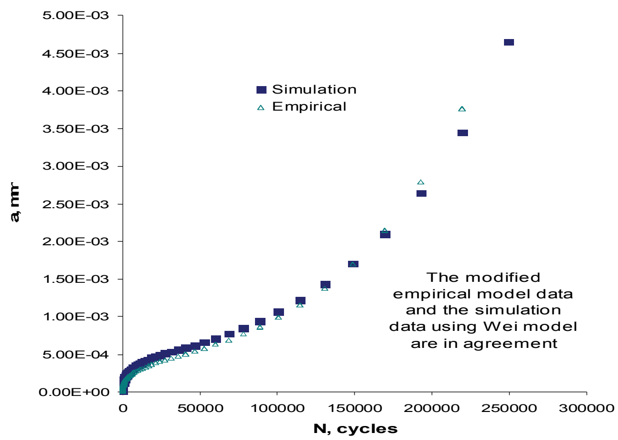

Figure 2. The graph of the simulation (Wei model) and the modified general proposed empirical model.

3. Conclusions

The research reported in this paper proposes a simple empirical corrosion-fatigue model consisting of only two parameters to be determined from field and experimental data. The process of pitting corrosion leading to initial crack forms the first term of the empirical model, while the second term accounts for the dominating degradation process of fatigue crack growth. The physical parameters in the proposed model reflect the actual pipeline conditions. The generic data collected from the open literature helped in the model development; however the field and experimental data need to supplement this data. An actual application of the model for field collected data has shown that this model is useful and reasonable. Additional field data and experimental data will be needed to conclusively validate the proposed model. This is part of the ongoing research.

4. References

1. Wei, R. P., and Gao, M., "Reconsideration of the Superposition Model for Environmentally Assisted Fatigue Crack Growth," *Scripta Metallurgica*, Vol. **17** (1983), pp. 959-962.

Author Biographies

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