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EXTENDED ABSTRACT

Evaluation and Compression of Burst Pressure for High/Mid-Grade Corroded Pipelines Using Finite Element Model

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1. Introduction

The applications of steel pipelines for oil and gas transportation have grown over the past three decades. Due to the biological, service life performance, economical issue and human safety, it is important to keep a safe performance for oil/gas pipeline and to evaluate their serviceability under uncertainties including environmental issues (i.e. corroded defects) and applied loads (i.e. internal pressure). The accurate estimation of structural performance as load capacity-based burst pressure of steel pipes under corroded defects can be provided a robust design in service life. Therefore, predicting the residual strength of pipelines with corrosion defects is an important problem in these kinds of industrial structures. A one of oriented design relation of corroded burst pressure models is the ASME B31G which was presented by the American national standard Institution (ANSI). In the term of PCORRC criterion, Stephens and leis (2000) presented a mathematical model based on exponential nonlinear function using experimental results for low and moderate-strength steels. Generally, the shape of corrosion was considered as a rectangular form using DNV RP F101 (2004) for low and moderate-strength steels. Zhu and Leis (2005) applied the material hardening behavior in the mathematical model for prediction of corroded burst pressure. The presented model is extracted from X80 steel grade while it may be not covered the vast categories of steel pipes. (Ma et al., 2013) applied the Ramberg-Osgood relationship for material in finite element models (FEM) of steel pipes under single corrosion. However, they did not discuss the different yield strains of materials. The FEM have been used for computing the strength capacity of corroded pies by (Mechri et al., 2016), (Hieu et al., 2017) and (Shuai et al., 2017), but the Ramberg-Osgood nonlinear martial model has not considered with different yield strains.

In this paper, The Ramberg-Osgood model has been used with three levels of yield strain 0.2, 0.5, and 1% (Kamaya, 2015). The results show that FEM have highly accuracy compared to the existing mathematical models. The best prediction using the finite element simulation for burst pressure of corroded pipes is captured using the Ramberg-Osgood model with a yield of 0.2% where the mean square error is 1.329 and the mean absolute error is 1.113 with correlation index of 0.912.

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2. Methodology

2.1. Experimental models

In order to calculate the brust pressure of the corroded pipes, the empirical models is generally computed using two terms as pressure capastiy of pipes without corroded defects (P_{int}) and the pressure and reducing strength factor (K) by the following relation:

$$P_{corr} = P_{int} \times K \tag{1}$$

For computing the *P_int*, it is used different ultimate yield stress criteria such as Von Mises (Ma et al., 2013), Tresca (Shuai et al., 2017; Hieu et al., 2017; Mechri et al., 2016; DNVRP-F101., 2004) and average yielding yield criteria (Zhu and Leis, 2005; Keshtegar and Miri, 2014; Zhu et al., 2015). The factor K is given by relation proposed by B31G and PCORRC to consider the corroded defects (Ma et al., 2013).

2.2. Finite element model

To obtain the burst pressure of the corroded pipes based on nonlinear static analysis of FEM, three points (outer, mid and inter surface points at corroded position) are selected for approximating the burst pressure (Ma et al., 2013). For two types of steel i.e. X60 and X80, the burst pressure is shown in Fig. 1. where the burst pressure is equal the Mises stress of three points corroded together for first time.

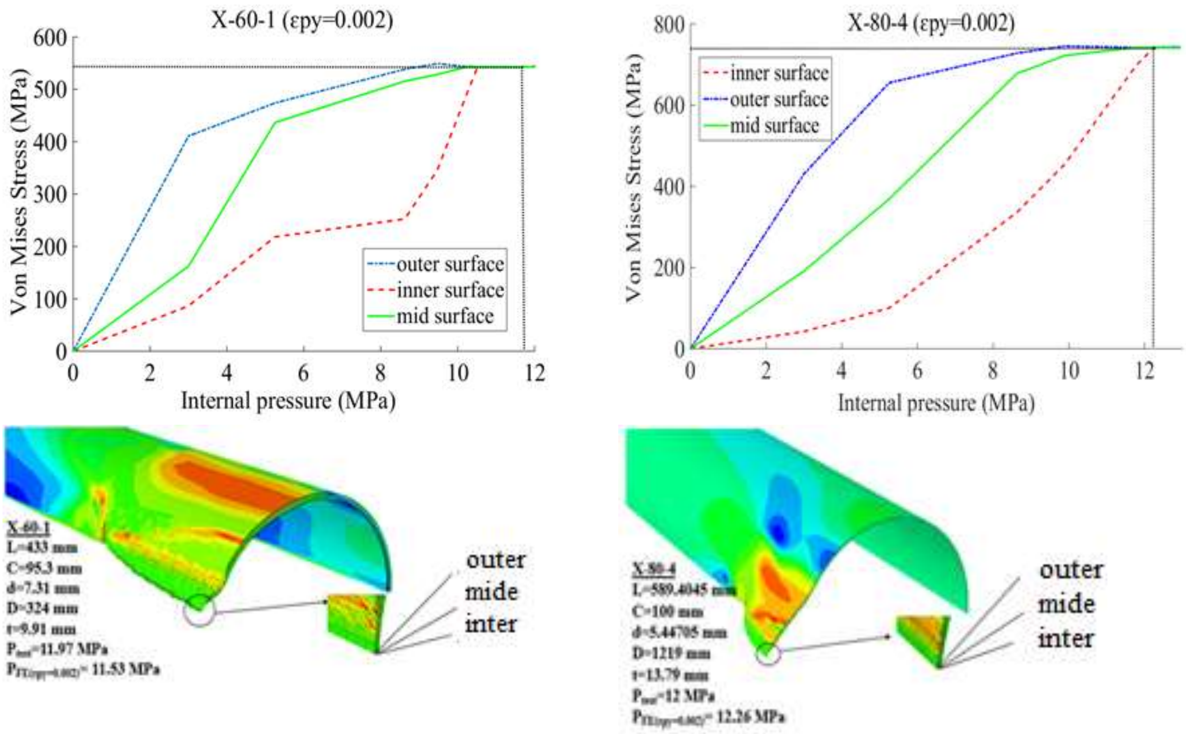

Fig. 1. The burst pressure of corroded pipe according FEM based on the Ramberg-Osgood relationship

3. Results and discussion

The confidence index to mean absolute error (d/MAE) factor for different empirical and FEMs is presented in Fig. 2. The highest d/MAE for a model is related to the accurate model with highest tendency compared to the other models. The FEMs are computed based on the Ramberg-Osgood relationship 0.2, 0.5 and 1%. It can be extracted that with the yield strain of 0.2% has lowest errors with highest tendency compared to empirical models for these empirical data. By comparing criteria of root mean square error (RMSE), mean absolute error (MAE), efficiency coefficient (NSE) and confidence index (d), we are respectively obtained 1.329, 1.113, 0.813 and 0.912 for RMSE, MAE, NSE and d using yield strain of 0.2%. The FEM with yield strain of 0.2% has superior prediction for burst pressure compared to other studied models. It can be seen from the results presented in Fig. 2, DNV RP-F101 (2004) and Shuai et al., (2017) empirical models are better than other suited empirical models while the Mehri et al., (2016) model showed the worst result. All finite element models based on the

Ramberg-Osgood relationship are the capable approach to predict the accurate burst pressure of corroded steel pipes. The RMSE and d statistics are improved form of 1.78-3.03 and 0.89-0.82 using empirical models to 1.33 and 0.91 using FEM, respectively.

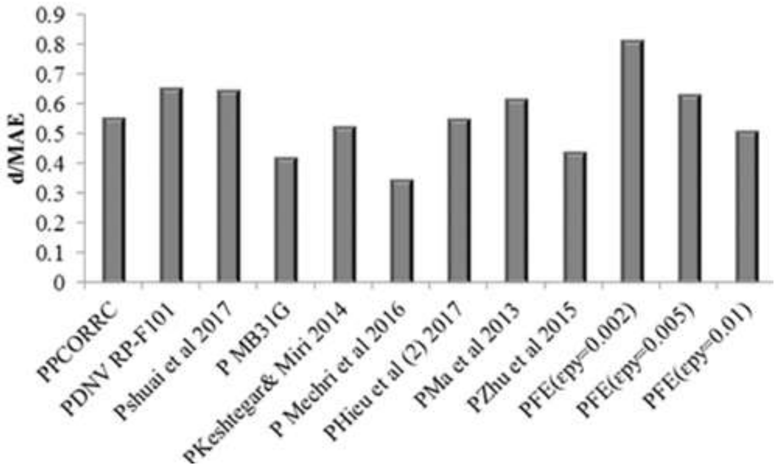

Fig. 1. Comparison diagram of finite element models based on Ramberg-Osgood relationship with experimental models using d/MAE criterion

4. Conclusions

In this paper, finite element models model using nonlinear behavior of corroded pipes with high and moderate-strength materials as four material strength levels of X60, X65, X80 and X100 is evaluated. The accuracy and tendency of the corroded burst pressure using FEM are compared with several empirical relations. According to Ramberg-Osgood nonlinear relationship for the three yield strains of 1, 0.5 and 0.2%, the FEM for 40 experimental data of steel pipes with different corrosion defects, diameters and thicknesses are computed. Nine empirical models given from the well-known design codes and researchers were selected to compare the accuracy and tendency of the FEM. the results showed that the FEM with strain of 0.2% has higher accuracy than other methods. The nonlinear model of the materials with a yield strain of 0.2% can be used to simulate the high and moderate-strength steel pipes under complex corrosion conditions in the future.

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