Error Analysis of Burst Pressure Model of Corroded Pipeline

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Abstract

This paper compares the burst pressure model uncertainty and model error of corroded pipeline based on the burst test data. The result shows that Shell-92 has the most conservation and model error statistical analysis shows that there are different uncertainties among them. The prediction results of the failure pressure of corroded pipelines are generally conservative for the four models. The results can be used to supervise the practice of pipeline safety evaluation.

Keywords

Error analysis, Corroded pipeline, Burst pressure, Model uncertainty.

1. Introduction

Corrosion is one of the main factors that affect the safety and reliability of the pipeline. It is suggested that the failure pressure model of blasting failure is put forward by experiment and theory. However, there is some error between the forecast result and the actual situation due to the different evaluation models of the establishment of the test conditions, and the theory of simplifying assumptions and ignoring some of the factors which are not important, such as the calculation method of the corrosion area, the influence of the defect ring width, etc.

2. Burst Pressure Model of Corroded Pipeline

2.1 Modified ASME B31G

At the beginning of 1990s, the American Society of Mechanical Engineers (ASME) promulgated the corrosion pipeline safety assessment standard ASME B31G[1], which is one of the most widely used pipeline safety evaluation standards. In practical applications, people gradually found that B31G-1984 is so conservative that it caused unnecessary maintenance or replacement of the pipeline. For reducing the conservation of B31G-1984, the American Gas Association selects 86 pipelines with different defects to develop the B31G-1991standard[2] which is called the modified ASME B31G. The failure pressure according to the modified B31G is as the following:

$$p_b = \frac{2(\sigma_y + 68.95)t}{D}\left(\frac{1-0.85\frac{d}{t}}{1-0.85\frac{d}{t}M^{-1}}\right) \tag{1}$$

p_b —burst pressure(MPa);

σ_y —yield strength(MPa);

M —Folias factor;

d —defect depth(mm);

t —pipe wall thickness(mm);

D —pipe outside diameter(mm).

The Folias factor is as the following:

$$M=\begin{cases}\sqrt{1+0.6275\dfrac{L^2}{Dt}-0.003375\left(\dfrac{L^2}{Dt}\right)^2} & ,\dfrac{L^2}{Dt}\le 50\\ 0.032\dfrac{L^2}{Dt}+3.3 & ,\dfrac{L^2}{Dt}>50\end{cases} \tag{2}$$

L—defect length(mm).

2.2 DNV-RP-F101

In 1999, the British Gas Corporation (BG) and Norway Veritas (DNV) develop the standard of DNV-RP-F101[3] together on the basis of more than 70 full-size pipeline defect blasting test including single and interacting complex defects combined with a large number of three dimensional non-linear finite element analysis results. The failure pressure according to DNV-RP-F101 is as the following:

$$p_b=\frac{2\sigma_u t}{D-t}\left(\frac{1-\dfrac{d}{t}}{1-\dfrac{d}{t}M^{-1}}\right) \tag{3}$$

$$M=\sqrt{1+0.31\frac{L^2}{Dt}} \tag{4}$$

σ_u—tensile strength(MPa).

2.3 PCORRC

As to the PCORRC method[4], the pipeline failure is determined by the ultimate tensile strength. This formula is obtained based on the results of finite element analysis by American Battle laboratory. The failure pressure according to PCORRC is as the following:

$$p_b=\frac{2\sigma_u t}{D}\left[1-\frac{d}{t}\left(1-\exp\left(-0.157\frac{L}{\sqrt{D(t-d)/2}}\right)\right)\right] \tag{5}$$

2.4 Shell-92

In 1995, Ritchie and Last[5] develop the burst failure pressure of defected pipelines calculation method in the tenth session of the trunk pipeline joint technical research conference. The failure pressure according to Shell-92 is as the following:

$$P_b=\frac{1.8\sigma_u t}{D}\left(\frac{1-\dfrac{d}{t}}{1-\dfrac{d}{t}M^{-1}}\right) \tag{6}$$

$$M=\sqrt{1+0.8\frac{L^2}{Dt}} \tag{7}$$

3. Model Error Analysis

According to the published pipeline containing defects burst data[6~9], we calculate the predicted burst failure pressure based on the four model. The model error item is the test pressure divided by predicted pressure as shown in figure 1. Number 1 to number 36 is the low strength steel, and others are the high strength steel. The error coefficient greater than 1 indicates that the predicted pressure is lower than the test pressure, and the prediction result is conservative; the error coefficient is less than

1 indicates that the predicted pressure is greater than the test pressure, and the prediction result is more dangerous. In the low strength of the pipeline, the modified ASME B31G appeared quite conservative results, DNV and PCORRC respectively have 4 cases and 3 cases of unsafe prediction results; in high strength pipeline, ASME B31G, DNV and PCORRC respectively are partial to unsafe results with 10 cases, 8 cases and 4 cases. In the four kinds of models, Shell-92 for all predictions were conservative.

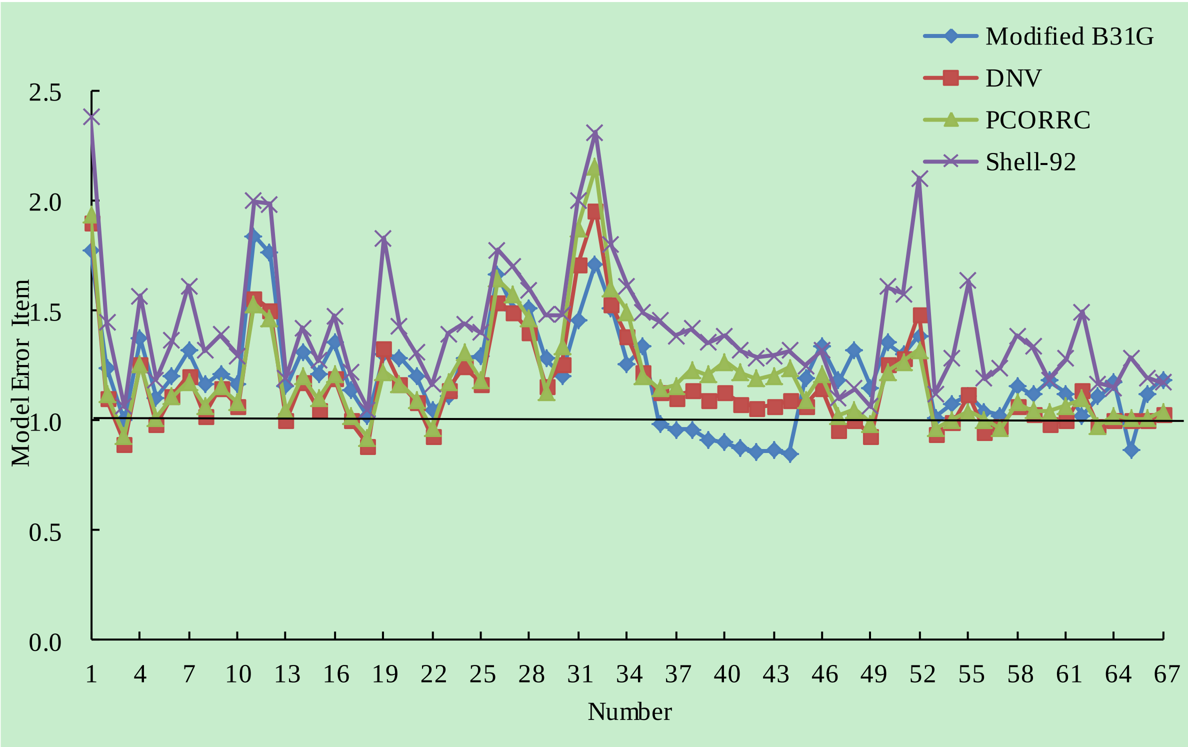

Fig. 1 Model Error Item

In order to compare the uncertainty of the model, we make the statistical analysis as shown in table 1. Error coefficients of four kinds of model average values were more than 1, indicating that the model prediction results generally were partial to be conservative. Error coefficient of average values from small to large, followed by DNV and PCORRC, modified B31G and Shell-92. The conservative of DNV model is minimum, and the conservative of Shell-92 model is supreme and the prediction results are the most safety.

Model uncertainties are reflected by the model error coefficient of standard deviation and coefficient of variation. Modified B31G model has the smallest uncertainty, and Shell-92 model has the largest uncertainty.

Table 1 Statistical Analysis

Method	Mean	Standard Deviation	Coefficient of Variation/%
B31G	1.207	0.225	18.6
DNV	1.163	0.226	19.4
PCORRC	1.197	0.24	20.1
Shell-92	1.431	0.287	20.1

4. Conclusion

By comparing the predicted failure pressure of the modified B31G, DNV, PCORRC and Shell-92 models with the test failure pressure, the four models can predict the failure pressure of corroded pipeline we can figure out that the prediction results of the failure pressure of corroded pipelines are generally conservative for the four models. The results of variance analysis show that the modified B31G model has the smallest uncertainty, and the uncertainty of the Shell-92 model is the largest. For all the four models, the prediction failure pressure of high strength pipeline has the smaller uncertainty, and for the high strength pipeline there is the greater uncertainty.

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