Stress Analysis of The West -East gas pipeline with Defects Under Thermal Load

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Abstract

Natural gas is one of the most clean energy sources, the transportation way is usually for pipeline transportation. In order to meet the transport capacity and improve the safety performance of the pipeline in the West to East Gas Transmission Pipeline, a large number of high strength and high grade pipeline is adopted. In order to suppress the generation of natural gas hydrate, the heating station will be set up to improve the temperature of natural gas, and under the common action of internal pressure and thermal stress, the pipeline will be more likely to invalid. In this paper, the model of the West-East gas pipeline with defects is established, and use ANSYS software to carry on the finite element analysis of the thermal-solid coupling in different temperature and different defects. The results showed that under normal temperature,The maximum allowable amount of the defect depth is half the thickness of the pipe wall.When the natural gas temperature is heated to 30 degrees Celsius,the allowable defect depth is 0.2 times to 0.3 times the thickness of the pipe wall.If the temperature reached 40 degrees Celsius or even higher, the allowable corrosion depth is only 0.1 times the wall thickness of the pipe.Therefore, in the project of West-East gas transmission, it is suitable for controlling the gas temperature at 30 degrees, which can effectively inhibit the formation of gas hydrate, and prolong the service life of the pipeline.

Keywords

West to East Gas Transmission Project, gas pipeline, defect, thermal-solid coupling, finite element method.

1. Introduction

As one of the cleanest energy, with the development of the national economy, the demand is also increasing. The most common natural gas transportation is pipeline transportation, which is the most representative of the West-East gas transmission project, in the project use a large number of X70 and X80 pipeline[1], which is characterized by high toughness, can meet the gas output and improve the safety performance of the pipeline.

Due to the special nature of the soil, the stray current can cause the metal pipeline corrosion. At present, there are many international standards to evaluate the pipeline containing corrosion defects, such as: ASME B31G [2], DNV-F101 [3], API579[4] etc. But most of the evaluation criteria have not considered the influence of thermal stress on the pipeline containing defects. In order to ensure that the output and the inhibition of gas hydrate, heating station will be set up in the process of gas transmission, so the temperature of natural gas in the pipeline will continue to change, so the above criteria are very conservative, and cannot accurately describe the impact of temperature on the pipeline. For high temperature gas transmission pipeline, Liu Jin Mei [5] etc established a finite element model based on steady state heat transfer. The results show that the thermal stress is the main cause of the failure of the pipeline. Du Ming Jun [6] etc set up a numerical model of hot oil pipeline, analyzed the influence of internal and external temperature difference on pipeline. Li Mao Hua [7] etc established the thermal stress model for the second line of West-East gas transmission line. Concluded that the safety of the pipeline should be ensured by adding a fixed pier and elbow pipe near the outlet of the heating station.

The pipeline size is Φ1219×18.4mm and the material is X80, the finite element model is established. The force of thermomechanical coupling [8-9] analysis pipeline with ANSYS software in different temperature and defects, and provide a basis for pipeline maintenance and safety analysis.

2. model building

2.1 basic assumption

According to the characteristics of long distance gas pipeline, make the following assumptions on the basis of ensuring calculation accuracy:

1) Only considering the internal pressure and the temperature of the pipe, ignoring the interaction between the tube and soil.

2) The heat transfer is stable at work.

3) The internal pressure of the pipeline is constant, and there is no pressure loss.

4) The pipeline material is uniform, and the influence of the outer coating layer on the pipeline is negligible.

5) Neglect of radiation heat transfer.

2.2 Finite Element Modeling

The concrete analysis of the X80 pipeline of Φ1219×18.4mm is carried out, the specific parameters of the pipeline are shown in Table 1.The operating pressure of the pipeline is 12MPa, and the gas temperature of the west east gas pipeline is usually 10 ~ 50.

Table1. Basic parameters of pipe

physical quantity	numerical value
modulus of elasticity/E	2.06×10^5MPa
Poisson's ratio/μ	0.26
yield strength/σ_y	620MPa
tensile strength/σ_b	688MPa
Thermal conductivity/α	16W/(m·℃)
coefficient of thermal expansion/β	1.02×10^6W/(m·℃)

According to Saint Venant theorem, the stress concentration phenomenon will only lead to corrosion area. Therefore, just select the 3000mm pipe section for stress analysis, and assume that the defects in the middle of the pipeline. Using ANSYS finite element program for pipe stress analysis, using SOLID 70 3D hexahedral eight node model, intelligent grid is used to ensure the accuracy of the calculation. The discrete model of pipeline is shown in Figure 1.

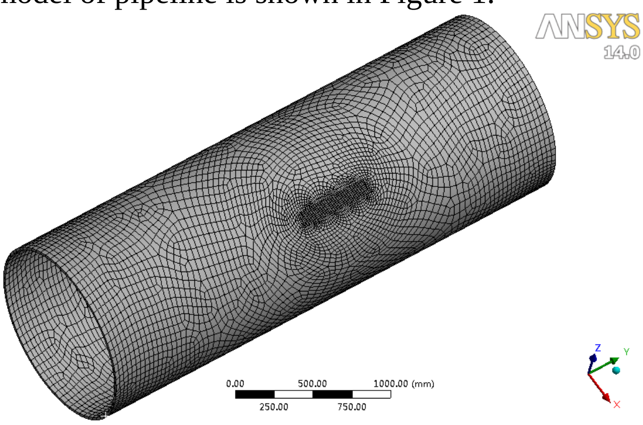

Figure 1. Pipeline discretization model

2.3 failure criterion

Failure criterion is used to judge the failure of the pipeline, according to different failure mode to select the appropriate criteria. According to the elastic limit criterion, it is considered that the pipeline is in a safe state when the Mises Von of the corrosion zone is less than the yield strength of the pipe, the failure criterion will limit the stress in the pipeline in the elastic range, and is more conservative[10].Because the X80 pipe has good toughness, in order to ensure the safety of the pipeline operation, while preventing the calculation is too conservative, so the allowable stress is the average value of the yield strength and ultimate tensile strength.

$$\sigma_M = \sqrt{\frac{1}{2}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right]} < [\sigma] \quad (1)$$

Upper type: $[\sigma] = \frac{\sigma_y + \sigma_b}{2}$;

σ_y —yield strength, MPa;

σ_b —Tensile strength,MPa;

σ_M —Von Mises is the equivalent stress, MPa;

σ_1 —X axis direction principal stress, MPa;

σ_2 —Y axis direction principal stress, MPa;

σ_3 —Z axis direction principal stress, MPa.

3. Results and analysis

3.1 Transport at room temperature

The length of the pipe defect (l) is half of the outer diameter of the pipe(D),the value of 609.5mm,the width is 200mm.The defect depth(d) is 0.1, 0.2, 0.3, 0.4, 0.5, 0.6 times of the wall thickness of the pipe(t), simulation of natural gas temperature is 20 degrees Celsius, the operating pressure of the pipeline under the condition of 12MPa.A total of 6 sets of simulation tests are conducted, and the maximum Mises stress values at the pipe defects are shown in Figure 2.

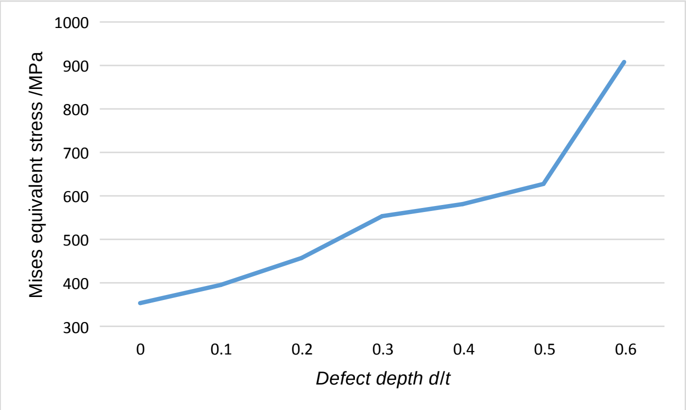

Figure 2. Equivalent stress of pipe under normal temperature

By Figure 2, when the temperature of natural gas is 20 degrees Celsius, the Mises stress is increasing with the depth of the defect. The defect depth is less than 0.5T, and the equivalent stress increases with the depth of defect. After the defect depth in 0.5T, the equivalent stress will be mutated. The results show that the equivalent stress is greater than the allowable stress and the pipeline will fail when the depth of the defect reaches 0.6T.Therefore, when the defect depth of 0.5T should take measures to repair the pipeline, or adjust the gas pressure to ensure the safe operation of the pipeline according to the residual strength of the pipeline.

3.2 Heat transfer

In order to suppress the generation of natural gas hydrate, it is usually arranged on the way to set up the heating station to increase the transmission temperature of natural gas. And the joint action of internal pressure and thermal stress on the pipe production is the focus of the study. The purpose is to obtain the maximum corrosion depth of the pipeline at a delivery temperature, which provides the basis for the maintenance of the latter.

Also take the length of the pipeline defect is half of the diameter of the pipe, the width is 200mm,the defect depth is 0.1t, 0.2t, 0.3t, 0.4t, 0.5t.After investigation, the temperature range of natural gas transmission is between 20 and ~40, therefore, 20 sets of simulation tests were conducted at 25, 30, 35 and 40 respectively.

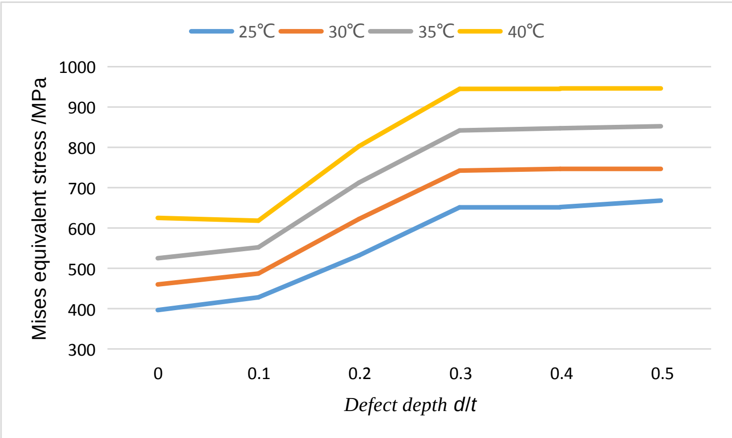

Figure3.Equivalent stress of defective pipeline at different temperatures

By Figure 3, when the temperature is 25, the depth of the defect is 0.5T, the equivalent stress is less than the allowable stress, and the pipeline is still in the safe range. When the temperature increases to 30, the pipeline is damaged by the pipeline defects between 0.2T to 0.3T. When the gas temperature is maintained at 35 and above 35, allow the depth of the defect is only 0.1T.

According to figure 2 and figure 3, the thermal stress of the pipe has a great influence on the pipeline. Under normal temperature conditions, only guarantee the depth of the defect is not more than half of the wall thickness of the pipe. With the increase of gas temperature, the thermal stress will increase the damage of the pipeline. Transport at higher temperatures can inhibit the formation of natural gas hydrates, it also limits the permissible range of defects in the pipeline at the time of operation. If the defect depth is controlled in 0.1t, and the defect detection is very strict.

In most cases, when the pipe defect reaches a half of the wall thickness of the pipe, it needs to be repaired and maintained. According to the results of finite element calculation, if the temperature of gas transmission is controlled at 30, temperature makes the failure of the pipeline will not be significantly increased, at the same time, it will not cost a lot of cost to heat the natural gas.

4. Conclusion

Based on the West-East gas pipeline, the pipeline size is Φ1219×18.4mm and the material is X80, built a pipeline model with defects. The thermal stress analysis of the pipeline is carried out by using ANSYS software. The results are as follows:

(1) Under the condition of normal temperature transportation, when the pipeline defect depth is less than 0.5T, the equivalent stress increases in proportion to the depth of the defect. When the defect depth is greater than 0.5T, the equivalent stress will be mutated. When the depth of the defect reaches 0.6T, the equivalent stress is greater than the allowable stress, at this point need to repair the pipeline.

(2) When the gas temperature at 25, the depth of the defect reaches 0.5T, the equivalent stress is less than the allowable stress, the pipeline is still in the safe range. When the temperature increases to 30,

the pipeline is damaged by the pipeline defects between 0.2T to 0.3T.When the gas temperature is maintained at 35 and above 35, its allowable defect depth is only 0.1T.

(3) Control gas temperature at 30 degrees Celsius, at this time, the thermal stress has little effect on the pipeline, not only can effectively inhibit the formation of gas hydrate, but also to extend the service life of gas pipelines.

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