Stress analysis and mitigation measures for floating pipeline

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Abstract. Pipeline-floating is a kind of accident with contingency and uncertainty associated to natural gas pipeline occurring during rainy season, which is significantly harmful to the safety of pipeline. Treatment measures against pipeline floating accident are summarized in this paper on the basis of practical project cases. Stress states of pipeline upon floating are analyzed by means of Finite Element Calculation method. The effectiveness of prevention ways and subsequent mitigation measures upon pipeline-floating are verified for giving guidance to the mitigation of such accidents.

1. Introduction

Natural gas pipelines in mountains, hills, and river valley area may likely be washed out of the trenches to make the pipes bare due to rainstorm or running water in the rainy season. In addition, collection of many streams is easy to incur pipeline-floating accident at locations where the pipelines are exposed. Upon pipeline-floating, the changed position of pipeline imposes additional stresses to pipeline, which make the pipeline in bad stress state. For example, after a heavy storm, a 150 meters long pipeline section was washed out from the trench and pipeline-floating event shown in figure 1 occurred.

Fig. 1 Site photo of floating pipeline

2. Basic parameters of the pipeline

Basic parameters of floated pipeline are shown in table 1.

| Name             | Unit | Value |
|------------------|------|-------|
| Pipe diameter    | mm   | 711   |
| Wall thickness   | General section mm | 10.3 |
|                  | Cold bend mm | 10.3 |
3 Stress analysis on floated pipeline

3.1 Pipeline displacement data
For buried pipeline, spiral ground anchors may be used to fix the pipeline on the bottom of trench with belted anchors to thereby prevent the pipeline from floating\cite{1,2}. Five coordinates are measured on site. By comparing the position coordinates before and after floating, horizontal and vertical displacement of each measured point can be obtained and summarized in table 2. In table 2, displacement component, \(\Delta X\), refers to horizontal displacement component along axial direction of pipeline (the reference direction is supposed as from point 5 to point 1); \(\Delta Y\) refers to the horizontal displacement component in direction perpendicular to the pipe axis (the reference direction is supposed as to the arc side); \(\Delta H\) refers to the pipeline displacements in vertical direction (the reference direction is supposed as upward).

| SN. | Position description | Displacement component | Horizontal component | Total displacement |
|-----|----------------------|------------------------|----------------------|-------------------|
| 1   | Unearthed point      | 0.072 -0.364 0.524     | 0.371                | 0.642             |
| 2   | /                    | 0.165 -0.091 0.589     | 0.188                | 0.619             |
| 3   | Cold bend            | -0.553 -0.105 0.532   | 0.563                | 0.775             |
| 4   | /                    | 0.071 -0.097 0.512     | 0.120                | 0.526             |
| 5   | /                    | 0.269 -0.151 0.461     | 0.309                | 0.555             |
| 6   | Unearthed point      | 0 0 0                 | 0 0                 | 0                 |

3.2 Finite element calculation model
ANSYS finite element software is used for analyzing and calculating the stress state of pipeline. The calculation procedure adopts following mechanical models: (1) the pipeline is simulated with elastic-plastic nonlinear material, soil body is simulated with nonlinear soil spring and the pipeline can subject to large deformation; (2) pipe-soil interaction is simulated with spring, the selection of parameters of soil spring is as per ASCE\cite{3,4} and GB50470-2008\cite{5}; (3) 200m long of pipeline model is established along the outside of exposed section of floated pipeline to simulate the constraint action of buried pipeline to floated pipeline section; (4) rigid constraints are imposed on both ends of model; applying displacement is applied to the model to simulate displacement of the deformed pipeline; (5) two operation conditions, 4MPa of design pressure 0.3MPa of operation pressure after floating, is employed for checking.

3.3 Checking Specification
The exposed floating pipeline becomes unconstraint. It can be checked according to the definition and methodology for unconstraint pipeline in Gas Transmission and Distribution Piping Systems (ASME B31.8-2010)\cite{6} (hereinafter referred to as ASME B31.8).

3.4 Stress checking results
Table 3 shows the stress states of pipeline after checking using the finite element software ANSYS according to ASME B31.8.
According to the checking result, the stresses of pipeline under 4 Mpa of pressure/design pressure exceed the stress requirement for constraint pipeline in ASME B31.8 such that measures should be taken to reduce the stress. The results indicate that decompression operation after floating is helpful for reducing piping stress and ensuring the safety of pipeline.

### 3.5 Mitigation measures

The additional stress is caused by displacement. In order to reduce the stress and displacement of pipeline should be resumed as soon as possible. Following measures can be taken:

1. **Excavation**
   Carry out manual excavation under the exposed pipeline section. During excavation, measures should be taken to prevent the coating and the pipeline from injuring by excavation tools. At the same time, close attention should be paid on the change of the piping to lest damage of personnel during pipeline relocation.

2. **Pipeline relocation.**
   The personnel simultaneously excavate the residual soil in the trench at left side of the flow direction of media in the pipeline to make pipeline naturally lower to original position with gravity.

3. **Coordinates relocation**
   After relocation of pipeline, the coordinates of pipeline should be measured again. Each run of joint should subject to RT and UT test again after confirming the coordinate data. Coating should be patched after qualification and the pipeline should be backfilled in layers.

### 3.6 Pipeline processing effect

By comparing the coordinates of pipeline after relocation with original coordinates, it is shown that the displacement of pipeline is obviously reduced, as shown in table 4.

The personnel should subject to RT and UT test again after confirming the coordinate data. Coating should be patched after qualification and the pipeline should be backfilled in layers.
It is indicated from the checking calculation according to ASME B31.8 that the stresses of pipeline under 4MPa of design pressure can meet the stress requirement for constraint pipeline after relocation. Table 5 summarizes the checking results.

| Position                  | Axial stress (MPa) | Allowable stress (MPa) | Checking results | $S_E$ (MPa) | (MPa) | Checking results |
|---------------------------|--------------------|------------------------|------------------|-------------|------|------------------|
| Unearthed point 1         | 151                | 311                    | Meet the requirements | 6.590       | 278  | Meet the requirements |
| Cold bend                 | 190                | 311                    | Meet the requirements | 4.739       | 239  | Meet the requirements |
| Unearthed point 2         | 133                | 311                    | Meet the requirements | 0.597       | 323  | Meet the requirements |
| The most adverse point    | 267                | 311                    | Meet the requirements | 6.590       | 278  | Meet the requirements |

4. Conclusion
Mitigation measures for pipeline-floating accident are summarized in this paper on the basis of project cases. The effectiveness of these measure are verified through finite element analysis and calculation, and following conclusions are drawn: (1) pipeline relocation is helpful for reducing the stress of pipeline; (2) detailed construction measures should be made during pipeline relocation and close attention should be paid on the tendency of pipeline deformation prevent the uncontrolled pipeline deformation.

Reference
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