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.

Table 1 Basic parameters of pipeline

Name		Unit	Value
Pipe diameter		mm	711
Wall thickness	General section	mm	10.3
	Cold bend	mm	10.3

Cold bending Angle	/	9
Pipe material	/	API-5L X60
Design pressure	MPa	4.0
Operation pressure upon floating	MPa	0.3

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[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, ΔX, refers to horizontal displacement component along axial direction of pipeline (the reference direction is supposed as from point 5 to point 1); ΔY refers to the horizontal displacement component in direction perpendicular to the pipe axis (the reference direction is supposed as to the arc side); ΔH refers to the pipeline displacements in vertical direction (the reference direction is supposed as upward).

Table 2 Pipeline displacement, in m

SN.	Position description	Displacement component			horizontal component	Total displacement
		ΔX	ΔY	ΔH		
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

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[3][4] and GB50470-2008[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)[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.

Table 3 Checking results for 4Mpa of design pressure

Positions	The axial stress (MPa)	Allowable stress (MPa)	Check results	S_E (MPa)	S_A (MPa)	Checking results
Unearthed point 1	394.385	311.25	Don't meet the requirements	5.910	34.615	Meet the requirements
Cold band	143.883	311.25	Meet the requirements	5.509	285.117	Meet the requirements
Unearthed point 2	100.657	311.25	Meet the requirements	4.441	329.341	Meet the requirements
The most adverse point	394.385	311.25	Don't meet the requirements	5.910	34.615	Meet the requirements

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[7]. 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.

Table 4 pipeline displacement after relocation, in m

SN. of coordinate points	Instructions	Displacement component			Horizontal displacement	Total displacement
		ΔX	ΔY	ΔH		
1	Unearthed point	-0.017	-0.052	0.067	0.055	0.086
2	/	0.030	-0.069	0.042	0.075	0.086
3	Elbow	/	/	/	/	/
4	/	0.169	0.017	0.098	0.170	0.196
5	/	0.238	0.208	0.052	0.316	0.320
6	Unearthed point	0	0	0	0	0

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.

Table 5 Checking results under 4Mpa of design pressure after relocation

Position	Aaxial 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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