H K . N C C P

International Journal of Civil Engineering and Machinery Manufacture
ISSN: 2518-0215, Volume 6, Issue 3, September, 2021

Analysis of Seismic Reliability for Buried Pipelines Crossing Strike-Slip Fault

Kaier Tao, Xiaoxia Xu, Lin Zhu
ShenYang Branch, China Petroleum Pipeline Engineering Corporation, Shenyang, 110000, China

Abstract: According to Newmark-Hall method, this paper proceeds the seismic reliability contrastive analysis of buried pipeline crossing fault, mainly based on different pipeline with fault crossing angle and buried depth by using Monte-Carlo method. The analysis result shows: seismic performance is highest when the pipeline with fault crossing angle reaches between 80 degree and 100 degree; the reliability performance will be improved when pipeline buried depth decreases.

Keywords: Buried pipelines crossing fault; Monte-Carlo Method; Seismic reliability

1. Introduction

When earthquake occurs, the fault movement is the main cause of damage for buried pipelines crossing fault [1], the seismic analysis and design for buried pipeline resistance of the fault movement is significant, but the seismic reliability analysis under the fault movement has not been studied yet. This paper build up the function of structural performance for buried pipelines crossing fault by Newmark-Hall method, the seismic reliability of buried pipelines crossing fault has been proceeded by using Monte-Carlo Method, according to the analysis results for buried pipelines crossing fault, the seismic suggestions has been proposed.

2. The Function of Structural Performance for Buried Pipeline Crossing Fault

According to Newmark-Hall method [2], the function of structural performance for buried pipelines crossing fault could be established.

Tension:

$$Z_t = R_t - S_t = [\Delta L_t] - \Delta L_t = 2\left(L_e e_e + L_p e_p\right) - \left(\Delta X + \frac{\Delta Y^2 + \Delta Z^2}{4L_t}\right) \quad (1)$$

Compression:

$$Z_c = R_c - S_c = [\Delta L_c] - \Delta L_c = 2L_c e_c - \left(\Delta X + \frac{\Delta Y^2 + \Delta Z^2}{4L_c}\right) \quad (2)$$

In the formula:

L_e: The sliding length of the pipeline's elastic part;

e_e: The average elastic strain;

L_p: The sliding length of the pipeline's plastic part;

e_p: The average plastic strain;

L_t: The sliding length of one side of fault when the pipeline is under tension;

L_c: The sliding length of one side of fault when the pipeline is under compression;

ΔH : Horizontal fault displacement;

ΔX : The fault displacement parallel to the axial direction of the pipeline, $\Delta X = \Delta H \cos b$;

ΔY : The fault displacement to normal direction, $\Delta Y = \Delta H \sin b$; ΔZ : The fault displacement of vertical direction, for the strike-slip fault, $\Delta Z = 0$.

3. Random Variable Parameters

The engineering design ground motion empirical statistical formula [3] and seismic intensity magnitude relation as follows:

$$\lg \Delta H = 0.4646M - 3.0190 \quad (3)$$

$$I_0 = 0.24 + 1.29M \quad (4)$$

According to the above formula, the relation between seismic intensity and fault movement can be derived as follows:

$$\Delta H = 10^{(0.3602 I_0 - 3.1054)} \quad (5)$$

Different seismic intensity distribution parameter [4] has been listed in Table1.

Table1 Different seismic fortification intensity distribution parameter

Seismic design intensity	6	7	8	9
Mean value	4.8200	5.8200	6.8100	7.8000
Standard deviation	0.8800	0.8800	0.8900	0.9000
Shape parameter	9.7900	8.3300	6.8700	5.4000
Variation coefficient	0.1800	0.1500	0.1300	0.1100

In china, the intensity distribution agrees with extreme value type-Ⅲ distribution [5], this article assumes the seismic design intensity is 9 degree. The random variable parameters of seismic reliability analysis for buried pipeline crossing fault are given below in Table 2. The random variable parameters *d* is the thickness of buried pipeline; D is the outside diameter of buried pipeline; I_0 is the seismic fortification intensity.

Table2 Random variable parameters

Parameter	Mean Value	Standard deviation	Distribution pattern
d	0.0156	0.0007	Log-normal distribution
D	0.5080	0.0200	
I_0	7.8000	0.9000	Extreme value type-III distribution

4. The Different Pipeline and Fault Crossing Angles Effects on the Seismic Reliability of Buried Pipelines Crossing Fault

In order to study the different pipeline crossing angle of seismic reliability for buried pipeline crossing fault, this paper uses Monte Carlo method, set the number of sampling 106 times. This paper conduct 9 different groups to proceed comparative analysis, the results are shown in table3 and figure1.When the pipeline and fault crossing angle reaches between 80 degree and 100 degree, the seismic reliability index is highest, the seismic performance is best.

Table 3 The reliability index of buried pipeline under different pipeline and fault crossing angle

Pipeline and fault crossing angle	Failure probability	Reliability index	Pipeline stress state
20°	0.1423	1.0700	Tension State
40°	0.0822	1.3904	
60°	0.0172	2.1154	
80°	0.0002	3.5401	
100°	0.0010	3.0902	Compression State
120°	0.0087	2.3781	
140°	0.0209	2.0355	
160°	0.0285	1.9033	

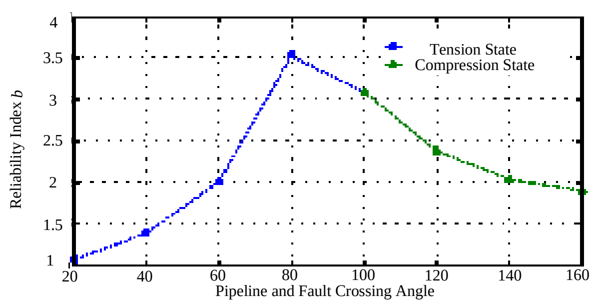

Figure 1. The reliability index comparative analysis under different

Pipeline and Fault Crossing Angle

5. The Different Buried Depth Effects on the Seismic Reliability of Buried Pipelines Crossing Fault

In order to study the pipeline buried depth of seismic reliability for buried pipeline crossing fault. This paper conduct 7 different groups to proceed comparative analysis, set the number of sampling 106 times. The results are shown in table4 and figure2. Through the seismic reliability index contrast analysis under the different buried depth: with the continuous increase of pipeline buried depth, the seismic reliability index of pipeline is reduced, so the buried pipelines should be shallow buried.

Table4 The reliability index of buried pipeline under different buried depth

Buried Depth （m）	80-degree angle		100-degree angle	
	Failure probability	Reliability index	Failure probability	Reliability index
2.0	0.0002	3.5401	2.0	0.0002
2.5	0.0023	2.8338	2.5	0.0023
3.0	0.0052	2.5622	3.0	0.0052
3.5	0.0168	2.1248	3.5	0.0168
4.0	0.0275	1.9189	4.0	0.0275
4.5	0.0472	1.6726	4.5	0.0472
5.0	0.0699	1.4765	5.0	0.0699

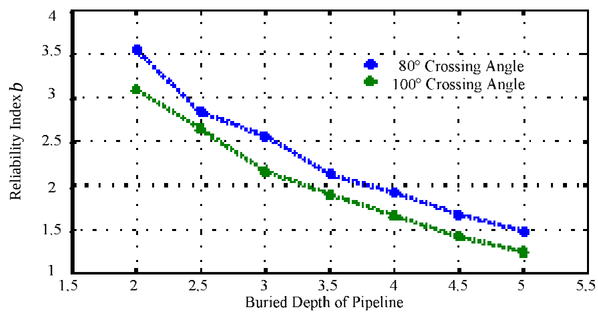

Figure 2. The reliability index comparative analysis under different

buried depth of pipeline

6. Conclusion

This paper based on Newmark-Hall method to establish function of structural performance under two conditions, the permissible tension & compression length deformation of buried pipeline crossing fault by using Monte-Carlo method, taking pipeline and fault crossing angles and buried depth into consideration to proceed seismic reliability analysis, some useful conclusions are drawn:

(1) The pipeline and fault crossing angle should reaches between 80 degree and 100 degree, regardless of the pipeline in the tension or compression state, the seismic reliability is highest. Therefore in the process of pipeline

design and construction, this suggestion should be taken into consideration to increase pipeline seismic performance.

(2) The buried pipelines should be shallow buried, regardless of the pipeline in the tension or compression state, it could improve the seismic performance of pipeline effectively.

References

[1] Newmark N M and Hall W J Pipeline design to resist large fault displacement. Proc. U. S. nat. conf. Earthquake Eng. U. S. University of Michigan. 416-425.

[2] Bin Wang, Study on analytical methods of buried steel pipelines under active faults. Dalian University of Technology Doctoral Thesis. 2011, 4-6.

[3] Jisheng Zhao, Xiaxin Tao and Lijing Shi. Earthquake ground surface rupture estimation. fourth international conference of earthquake engineering and seismology. Tehran, Islamic Republic of Iran. 2003.

[4] Jinping Ou, Yubo Duan, Huiyi Liu, Structural ramdom earthquake action and its statistical parameters. Journal of Harbin Architecture and civil engineering Institute. 1994, 1-10.

[5] Xiaowang Gao, Aibin Bao, Probabilistic model and its statistical parameters for seismic load. Journal of Earthquake engineering and engineering vibration. 1985, 13-22.