Scholars Journal of Engineering and Technology (SJET) **ISSN 2321-435X (Online)**
Sch. J. Eng. Tech., 2016; 4(5):254-257 **ISSN 2347-9523 (Print)**
©Scholars Academic and Scientific Publisher
(An International Publisher for Academic and Scientific Resources)
www.saspublisher.com

Research Article

Seismic Response of Buried Pipeline across the Fault for Two Kinds of Variable-Diameter

Jing-hong Xue, Yan-peng Lou, Xin Wang
School of Civil Engineering and Architecture, Northeast Petroleum University, Daqing 163318, China

***Corresponding author**
Jing-hong Xue
Email: xjh0459@126.com

Abstract: Seismic damage showed that the effect of earthquake damages on urban lifeline system is much larger than other disasters. Shell element model of four nodes was used to simulate the buried pipeline, and the interaction between soil and pipeline was simulated by nonlinear soil spring, seismic response of buried variable-diameter pipeline under strike slip fault was analyzed by using finite element software ADINA. Through studying the influence of concentric and eccentric variable-diameter on seismic response of pipeline, the conclusion was obtained that seismic capacity of concentric variable-diameter pipeline is better than that of eccentric variable-diameter. The results of research provide a certain guiding for the seismic design of buried variable-diameter pipeline across the fault.
Keywords: variable-diameter pipeline; strike slip fault; concentric variable-diameter; eccentric variable-diameter.

INTRODUCTION

Pipe transport is widely used in industrial production and daily life, because it has the advantage of convenience and high transport efficiency and low transportation cost. The system of oil and gas pipeline system is a necessary facility to maintain industrial production and daily life normally. It is called lifeline engineering. Therefore, people pay great attention to seismic research of pipe system. We should make sure that it was safe when earthquake happens [1-5].

In mid nineteenth century, modern pipe engineer construction began to rise. The total length of oil and gas pipeline was nearby 30 thousands kilometers [6]. Research of buried pipeline across the fault dated back to San Fernando earthquake in 1971. The domestic and foreign scholars have obtained a lot of research results from analyzing the seismic response of buried pipeline [7-12]. The obtained theoretical method was mostly based on the same diameter pipe. However, in engineering practice, variable-diameter pipe is inevitable to be used in long pipeline. Therefore, the soil spring model of buried variable-diameter pipeline across the fault was established by the finite element software ADINA. The influence of eccentric and concentric variable-diameter on axial strain peaks of pipeline was studied, which provides a certain guiding for the seismic design of buried variable-diameter pipeline across the fault.

The establishment of calculation model

Soil spring was adopted to simulate the buried variable-diameter pipeline across the fault. The interaction between soil and pipe far from the fault was treated as nonlinear equivalent boundary which Liu Ai-wen proposed [13]. The soil spring model of buried variable-diameter pipeline across the fault was established by the finite element software ADINA. The procedure of analysis in detail was as follows.

Geometric model and meshing

The pipe material was imported steel of API5LX60. Stress-strain relationship adopted model of three lines on seismic design code of oil and gas buried steel pipeline [14], which can be seen from Fig.1. The total length of pipe was one hundred meters. Shell element model of four nodes was used to mesh. Meshes were divided automatically by software ADINA. It was divided into 0.5 meter one unit in axis direction of pipe, and it was divided into 16 units in the radial direction of pipe. Buried variable-diameter pipeline across the strike slip fault was studied as showed in Fig.2. The finite element model of concentric variable-diameter pipeline can be seen from Fig.3. The finite element model of eccentric variable-diameter pipeline can be seen from Fig.4.

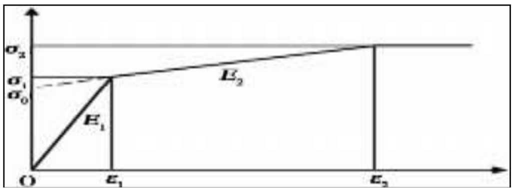


Fig-1: Simplified diagram of three line model of stress-strain relationship

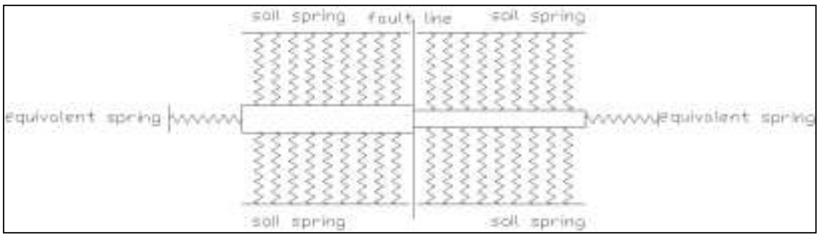
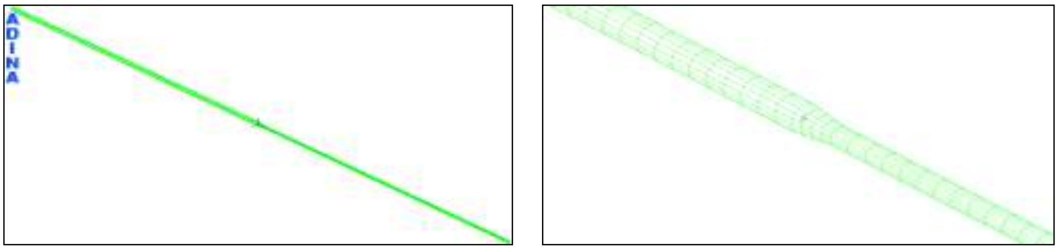
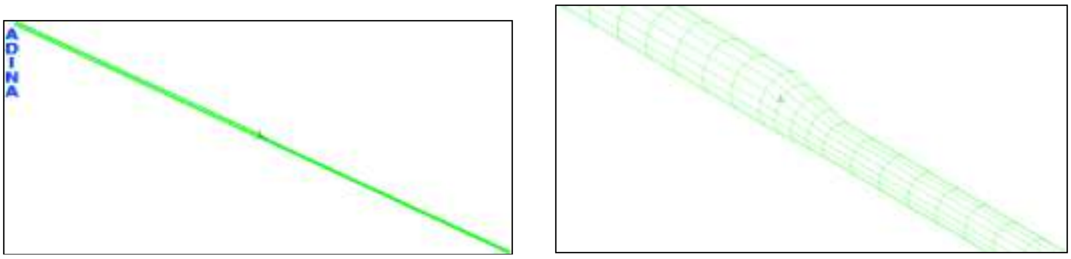


Fig-2: Schematic diagram of buried variable-diameter pipeline across the fault



(a) Model of concentric **(b) Model of concentric connection**

Fig.3 Finite element soil spring model of concentric variable diameter pipeline



(a) Model of eccentric **(b) Model of eccentric connection**

Fig-4: Finite element soil spring model of eccentric variable diameter pipeline

Input of seismic wave

Displacement-time was used to input seismic load and second class field of Chi-chi seismic wave was used to calculate. Displacement wave was applied on the soil spring of both sides of the fault opposite direction in the process of calculating.

Simulation of soil spring

Establishment of finite element model of soil spring

Tension and compression spring was used to simulate soil around pipe. Soil spring of horizontal direction and vertical direction and axial direction was established respectively on per node. And the spring was nonlinear spring.

Numerical value of soil spring

The nature of soil spring of horizontal direction and vertical direction and axial direction mainly depends on the nature of soil. It is usually selected by 《guide for seismic design of oil and gas pipelines》 of ASCE. Medium dense sand was selected in this paper. Internal friction angle is 35°, and shear wave velocity is 250 m/s. The numerical values of soil spring three different directions yield force P_u and yield displacement X_u are showed in table1.

Table-1: Soil spring yield force P_u and yield displacement X_u

parameter	horizontal direction	axial direction	vertical direction upward	vertical direction downward
H=1.454m	P_u=15218N/m	P_u=869N/m	P_u=1476N/m	P_u=25700N/m
D=0.762m	X_u=0.07336m	X_u=0.0381m	X_u=0.018m	X_u=0.0762m
H=1.454m	P_u=7070N/m	P_u=579N/m	P_u=983N/m	P_u=15522N/m
D=0.508m	X_u=0.06828m	X_u=0.0381m	X_u=0.018m	X_u=0.0508m
H=1.835m	P_u=9395N/m	P_u=731N/m	P_u=1231N/m	P_u=20178N/m
D=0.508m	X_u=0.08356m	X_u=0.0381m	X_u=0.018m	X_u=0.0508m

Analysis of numerical simulation results

Buried variable-diameter pipeline across the fault in ground of medium dense sand was established and analyzed. The friction between pipe and soil was 0.4. The pipe material was imported steel of API5LX60. The diameter of bigger pipe was 0.762 m and the diameter of smaller pipe was 0.508 m. The thickness of both pipes was 0.0238 m. The intersection angle between fault and pipe was 90°. Chi-chi seismic wave was used in this paper and its fault stagger was 5 m. buried concentric and eccentric variable-diameter pipeline across the fault was established and analyzed respectively. The way how to change the diameter was showed in Fig.5.

The strain cloud of buried variable-diameter pipeline across the fault was showed in Fig.6 and Fig.7 respectively. The maximum tensile (compressive) strain was showed in table 2.

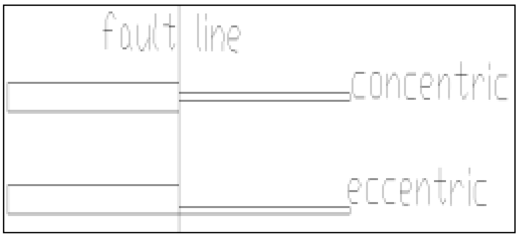
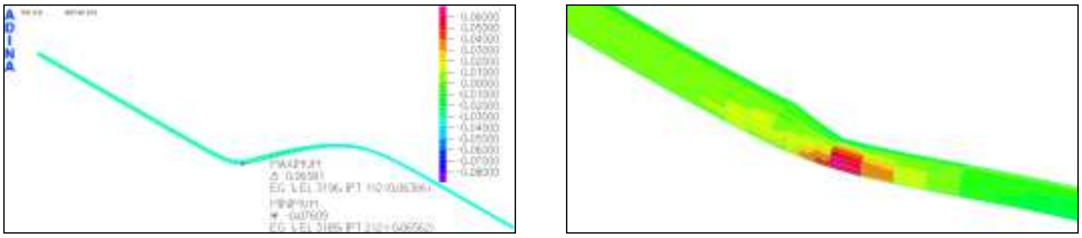
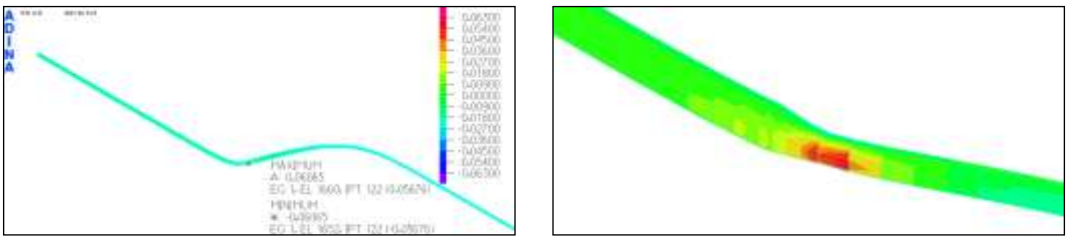


Fig-5: Schematic diagram of variable-diameter way



(a) Global strain cloud **(b) Locally amplified Strain cloud**

Fig-6: Strain cloud of eccentric variable-diameter pipeline



(a) Global strain cloud **(b) Locally amplified Strain cloud**

Fig-7: Strain cloud of concentric variable-diameter pipeline

It can be seen from the strain cloud that both the biggest tensile (compressive) strain of buried concentric variable-diameter pipeline across the fault and buried eccentric variable-diameter pipeline across the fault was approximately at the joint of variable-diameter device and small diameter pipeline.

Table-2: The maximum tensile (compressive) strain of different pipe diameter way

method	maximum tensile	maximum compressive
eccentric	6.36619E-02	-6.81047E-02
concentric	5.67589E-02	-5.67592E-02

It also can be seen from the maximum tensile (compressive) strain that under the effect of seismic wave of displacement, the tensile (compressive) strain of buried eccentric variable-diameter pipeline across the fault was bigger than that of buried concentric variable-diameter pipeline across the fault.

CONCLUSION

Through analyzing the simulation results of buried eccentric variable-diameter pipeline across the fault and buried eccentric variable-diameter pipeline across the fault, it could find that the ability to resist earthquake of buried concentric variable-diameter pipeline across the fault was better than that of buried eccentric variable-diameter pipeline across the fault. Hence, when variable-diameter is essential, concentric variable-diameter is chosen firstly as far as possible. No matter which one is chosen, the joint where variable-diameter device and small diameter pipeline connect should be strengthened.

REFERENCES

1. Su Xin, Chen J, Yang H; Discussion on Seismic Design of Se-Ning-Lan Double Gas Pipelines. Natural Gasand Oil, 2009; 27(3): 14-18.
2. Liu A, Zhang S, Hu Y; A Method for Analyzing Response of Buried Pipeline due to Earthquake Fault Movement. Earthquake Engineering and Engineering Vibration, 2002; 22(2): 22-27.
3. EERI; Northridge Earthquake of January 17. 1994 Preliminary Reconnaissance Report. Earthquake Spectra, Supplement, 1995; C -11.
4. Hisashi, Sunitomo; System analysis of earthquake damage on water supply networks in Kobe City. Proceeding of the 4th International Symposium on Water Pipe Systems, 1997; 137-145
5. Wang RL, Shim JS, Ishibashi I; Dynamic responses of buried pipeline during a liquefaction process. International Journal of Soil Dynamic – sand Earthquake Engineering, 1990; 99(1):44-45.
6. Ha D, Abdoun TH, O'Rourke MJ, Symans MD, O'Rourke TD, Palmer MC, Stewart HE; Earthquake faulting effects on buried pipelines–case history and centrifuge study. Journal of earthquake engineering, 14(5); 646-669.
7. Bolvardi V, Bakhshi A; A study on seismic behavior of buried steel pipelines crossing active faults. In Pipelines 2010@ sClimbing New Peaks to Infrastructure Reliability: Renew, Rehab, and Reinvest. ASCE, 2010; 1-12.
8. Jin L, Li H; Nonlinear Response Analysis of Buried Pipeline Crossing Thrust Fault. Journal of Disaster Prevention and Mitigation Engineering, 2010; 30(2): 130 -134.
9. Zhao L, Tang H, Peng X, Li X; Failure Modes of Steel Buried Pipeline Crossing Reverse Fault. Journal of Basic Science and Engineering, S1. 2010.
10. Yan X, Zhang L, Yang X; Strain Response Study of Oil-Gas Pipeline Crossing Earthquake Fault Based onPipeline-soil Coupling and Large Deformation Shell Model. China Civil Engineering Journal, 2010, 43(8): 132-139.
11. Xue X, Wang C, Tao K; Analysis of the interaction between the pipe end and the soil mass in the cross fault isolation pipeline. Low temperature construction technology, 2014; 195(9): 108-110.
12. Hu Y; Earthquake Engineering. Beijing：Seismological Press, 1988;1-4.
13. Liu A; Response Analysis of a Buried Pipeline Crossing the Fault Based on Shell-model. Beijing: organization of geophysics, China Earthquake Administration, 2002.
14. Seismic design code of oil and gas buried steel pipe line GB 50470-2008.