Impact of Common Geological Disasters on Oil and Gas Pipeline across the River

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Abstract. The article summarizes the development status of oil and gas pipeline and the impact of common geological disasters on oil and gas pipeline across the river. Especially, the article summarizes the current research status of related theory about the impact of earthquake on pipeline. This paper not only summarizes the development of directional drilling technology and the present situation of the theoretical research, also illustrates the advantages and applicability of directional drilling for oil and gas pipelines crossing the river during the construction.

Keywords: oil and gas pipeline, directional drilling, earthquake, geological disasters.

1. Current development and impact of common geological disasters on oil and gas pipeline

1.1 Current development of pipelines

The construction of long-distance oil and gas pipelines in China has entered a period of rapid development in recent years. China has built 60000 km natural gas pipeline, oil pipeline 26000 km, refined oil pipeline 20000 km, the formation of oil and gas pipeline network pattern across the east to West, runs through the north to the south. Pipeline construction promotes China's economic development and benefit people's livelihood. In a large number of pipeline construction projects, it is difficult to avoid building a pipeline across the river. Such as, China-Myanmar oil and gas pipeline is about 3,000 kilometers, crossing the medium-sized rivers in Myanmar more than 30 times, the use of directional drilling about 10 times, through medium-sized rivers in China 36 times, the use of directional drilling about 14 times.

1.2 Impact of common geological disasters on oil and gas pipeline

According to the different laying mode, the construction of oil and gas pipeline across the river is divided into four kinds of methods. It includes nudity through technology, buried trench crossing technology directional drilling technology and tunnel crossing. Long-distances pipeline facing major geological disasters including Landslide, collapse, debris flow dominated mountain disasters, dune, sand ridge moves mainly dominated desert disaster, Hydraulic scour dominated river disaster and so on[1].

Oil and gas pipelines as lifeline engineering take the responsibility of the task for transporting the oil and gas resources. Due to the pipeline distribution range is very wide and the regional natural geographical and geological environment is complex, the pipeline will inevitably threaten and abused by various geological hazards. Once the Geological disaster occurs, it not only will cause the pipeline deformation, fracture and widespread damage, also lead to energy leakage and pipeline shutdown. Meanwhile, it will bring huge economic losses and cause fire, explosion and other accidents. All in all, the disaster will take serious consequences and bring adverse impact on life, property, the natural environment and social stability. Therefore, disaster countermeasures must be implemented to guarantee the safe operation of the pipeline by making the distribution characteristics of geological hazards investigation related piping and studying the failure behavior, evaluation method of pipeline under the action of the disaster.

Table 1 pipeline failure accidents caused by Geological disasters

Pipeline	When	Disaster type	Failure case	consequences
Across Ecuador	In 1983	giant landslide	Pipeline rupture 40km	Loss of $700 million
Nor Andino pipeline (South America)	In 2001	debris flow	Pipeline rupture	Shutdown for 25 days
	In 2002	landslide	Pipeline rupture	Shutdown for 90days
Ma Huining pipeline	In 1982	flood	Pipeline rupture	Leak oil more than 300t, shutdown for 21 days
Golmud-Lhasa pipeline	In 2001	earthquake	Z fold fracture	
Changqing oil production pipeline	In 2002	landslide	Pipeline rupture	More than 50t oil flow into Yan river
Lan Chengyu pipeline	In 2008	Wenchuan earthquake		The earthquake induced landslides formed the lake, shutdown for 48h

1.3 The research situation of relevant theory about the impact of the earthquake on pipeline

Zhu Ji-xiang, Dai Wen-ting, Zhao Shu-de, Liu Chuan-zheng introduced the common adverse geological disasters in detail in their books, such as earthquakes, avalanches, rock piles, debris flows, buried karst collapse, sand snow damage, swamps.

Zhang Zhong-fu, Guo wei-wei, Zhu Xiu-xing, Wang Qi-lei made the research about the impact of one or several common geological disasters on the pipeline and Put forward the corresponding measures for disaster prevention and mitigation.

Hao Jian-bing [2] introduced three methods of earthquake damage to long distance oil and gas pipelines and points out the failure of the pipeline is mainlycausedby Permanent ground deformation.

Yin Fa-bo [3] summarized the risk factors of earthquake disasters into five aspects based on the analysis of the geological disasters damage to long distance pipeline and reference to the risk assessment methods of the geological disaster, including disaster context, hazard body activity, the affected body characteristics, destruction and loss prevention engineering. Build a complete evaluation index system of pipeline failure consequence through a comprehensive analysis of the factors which may damage the pipeline from the multi angle, multi factor. Furthermore, some indicators were refined aimed to the main form of pipeline damage. To determine the division of seismic damage grade of buried pipeline and the scope of the corresponding failure probability based on the analysis of the earthquake damage ratio. At the same time, risk grade evaluation based on the risk matrix method of long distance natural gas pipeline failure in earthquake region was established.

L.R.-L WANG and K.-M. CHENG [4] studied the earthquake response of buried pipeline. Numerical simulation is carried out through the method of establishing finite element model. Yao Rong-feng[5] use numerical simulation method for oil and gas pipelines in nonlinear dynamic response analysis under seismic load, such as earthquake intensity, damping ratio and variation of the parameters stiffness coefficient. But it is only a simulation for the ordinary buried pipeline.

Wang Xiang-jian [6] sum up and compares the earthquake damage phenomenon of the two kinds of pipe materials (such as steel pipe and PE pipe) commonly used in the construction of gas pipeline and its influence on pipeline system function. He also analyzed the usage and average damage rate of the pipes which can be made of different material and put forward the Countermeasures to reducing gas pipeline damage. It does not consider the soil geological factor, also does not have the quantitative description.

2. Development of directional drilling technology and research status related theories

Due to the special geological condition and construction process of oil and gas pipelines across the large and medium-sized rivers, there is theirs own uniqueness in geological exploration, design, construction, and operation stages after the completion of the pipeline. In addition, the directional drilling technology as one of the priorities of trenchless construction technology has the following features:

(1) Little interference and damage to the transportation and the environment;

(2) All-weather construction and construction safety, efficiency;

(3) High social efficiency, low overall cost, less working hours;

(4) High requirements on the construction site, Gravel layer construction difficulties;

Therefore, the most important in the design and construction stages of the pipeline is to ensure that oil and gas pipelines have reasonable strength and associated design parameters to avoid a security risk by insufficient strength or cost too much caused by large intensity. Especially the pipeline across the river in seismic area, the future safe operation of the pipeline is particularly important.

Table 2 names of constructions which pipelines crossing the river successfully by using directional drilling techniques and related parameters

No.	Crossing Project Name	Length (m)	Diameter (mm)	Wall Thickness(mm)	Exit angle (°)	Entry angle (°)	Radius of curvature (m)	Depth (m)	Pull strength (kN)	Drilling machine
1	Ningbo - Shanghai - Nanjing import crude oil pipeline crossing the Changjiang River	1688	508	9.5	8	11	579	20	2217	CMS 55030
2	Southwest product pipeline directional drilling crossing the Jianjiang River	528	508	7.9	8	10	762	4～9	738	German HBR206 D-150Z
3	The first stage of Kunshan natural gas crossing the Huangpu River	370	610	11.9	5.1	10.8	732	13.5	407	Vermeer D100×120
4	Directional drilling crossing the Qiantang River	2308	273	6.4	9.12	5.15	—	14.7	602	RB—5
5	Changning gas pipeline crossing the Yellow River	1300	426	8.7	11	4	800	23	—	RB—5
6	Yizheng -- Changling crude oil pipeline crossing the Changjiang River	1719	406	10.3	11	6	1500	47.3	2350	CMS 55030
7	Crude oil pipeline crossing the Han River	755	273	7	10.5	8.5	500	23	343	USA Auger DD—330HP

2.1 Origin and the development present situation in China

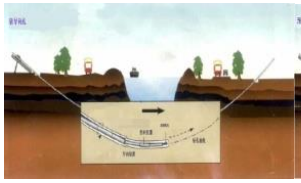
Directional crossing technology is proposed by an engineer named Dayton in California in 1971. Since this method has the incomparable advantages over other crossing means, so the method was applied more and more extensive in the municipal construction and other projects.

Horizontal directional drilling techniques was introduced in china from the beginning of 80s; the constructions by utilizing this technology have been successfully through more than 30 large and medium-sized rivers within the territory of China so far. Constructions Includes the Yangtze River, Yellow River, Huangpu River, Songhua River and several other well-known rivers. The single crossing length of the construction is over 2000 meters and its depth is over 25 meters. All the constructions were successfully completed within a short period of time. These crossing projects play an important role in long distance construction of oil and gas pipeline at present. The names of constructions which pipelines crosses the river successfully by using directional drilling techniques and related parameters are in chart 2-1 below:

2.2 Research Status on Directional drilling technology-related theory

In the 1970s, Americans were the first to adopt directional drilling technology, implements the gas pipeline crossing river, "directional drilling method" is established. This technology can be widely used in crossing the road, river, railway and airport runway and other types of pipeline construction. Due to the technology was limited, can only be implemented in crossing the alluvial layer. With the progress of technology, now it has been able to use in crossing the complicated geological, such as sand, gravel, and moraine and rocky areas.

The program is that drill pilot hole in the bottom of river with directional drilling machine, after the drill unearthed in the other side, connect reamer, reamer rotating, and with high pressure mud punching. At the same time, the rig floor chuck moving up, pulling the reamer, through broaching many times, make hole slightly bigger than diameter. Finally, connect the cross section behind the reamer, pull the reamer and the cross pipeline, make the pipeline lying in the drilled hole. The following is the main construction process diagram:



Fir.1 Drill guide whole

Fir.2 Pre reaming

Fir.3 Dragging pipelines

XieBin[7] combined with the engineering example, detailed introduced the construction process of large diameter pipeline crossing, technical features and technical measures, as well as construction technology problems should be paid attention to.

Ming-hui zhu, Tang Xinghua[8] summarized the technical development of oil and gas pipeline crossing river and the construction methods in crossing, then compared the advantages and disadvantages of the crossing technology, such as ditch buried, directional drilling and tunnel etc.

Zhu Bo [9] introduced the determination of design element that radius of curvature, exit angle, entry angle, diameter and wall thickness in horizontal drilling, analyzed the characteristics and calculation methods of guide whole, reaming and dragging force.

Li Wenyong [10] described the characteristics of directional drilling technology, system components, the construction process, and theoretical analysis of the crossing curve design and calculation in pullback load. By using ANSYS software and APDL language, established the finite element simulation model of directional drilling pipe dragged back, completed the finite element simulation analysis on different radius of curvature, exit angle, entry angle, diameter and wall thickness, as well as different crossing rock and dragging pipeline. Summarized the changing rule of the pipe mechanical properties and completed the theoretical analysis on pipe bend under the weight.

2.3 The practicability of directional drilling technology

The scope of the directional drilling techniques can be obtained based geotechnical, geological characteristics and other information. Details follow:

(1) Clay stratum very soft to soft
(2) Clay stratum medium hard to hard
(3) Hard clay stratum and high density weathered shale
(4) Moderate to dense sand
(5) Hard soil layer
(6) Weathering rock layer

3. Conclusion

This paper reviews the development and the impact of geological hazards common to pipe oil and gas pipelines, especially the analysis of the theory about the impact of earthquakes on the pipeline. If the relevant aspects of the theory and techniques increase research can provide guidance for the actual project. If the relevant aspects of the theory and techniques can be understood deeper, the research can provide guidance for the actual project.

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