MATEC Web of Conferences **139**, 00116 (2017) DOI: 10.1051/matecconf/201713900116
ICMITE 2017

Research on Connection and Function Reliability of the Oil＆Gas Pipeline System

Bo Xu[1], *LinJie Duan*[1,*], *XiangDong Xue* [1], *Hao Lan*[1], *Kaizhi Chen*[2]

[1]Petro China Pipeline Research and Development Center, Lang fang, China
[2]Petro China West-to-East Gas Pipeline Company Wuhan Management Department, Wuhan, China

Abstract. Pipeline transportation is the optimal way for energy delivery in terms of safety, efficiency and environmental protection. Because of the complexity of pipeline external system including geological hazards, social and cultural influence, it is a great challenge to operate the pipeline safely and reliable. Therefore, the pipeline reliability becomes an important issue. Based on the classical reliability theory，the analysis of pipeline system is carried out, then the reliability model of the pipeline system is built, and the calculation is addressed thereafter. Further the connection and function reliability model is applied to a practical active pipeline system, with the use of the proposed methodology of the pipeline system; the connection reliability and function reliability are obtained. This paper firstly presented to considerate the connection and function reliability separately and obtain significant contribution to establish the mathematical reliability model of pipeline system, hence provide fundamental groundwork for the pipeline reliability research in the future.

1 Introduction

Pipeline transport is one of the five main transportation modes in the world, and it is the most suitable way for crudes, refine products and natural gas transportation. Because the pipeline system has the advantages of continuous operation, large capacity and low cost, and it is no limited by the climate and other ground. Taken the natural gas pipeline system within China as an example, it supplies more than 600 cities, feed more than 0.8 billion local citizens each day; it has become a lifeline to secure energy supply in China.

Because the mileage distance of China's natural gas resources and markets is somehow dramatically long, it has many hazards such as geological hazards along the pipeline network, fragile ecological environment and complex humanity environment, with potential to threat the safety and reliable operation of the pipeline. Considering all these factors together, China's pipeline network system becomes the most complicated and the toughest transport task [1-2].

During the period of service, oil＆gas Pipeline pipe often under challenges such as various load, corrosion, and third party damages, which could lead to pipeline system failure, cause unscheduled shutdown. Some hazards, such as pipeline leak will directly cause substantial threat to the natural environment and social security [3-4].

How to effectively assess the risk of oil & gas pipeline network system, work out the weakest point of the system, implement a preventive management for the large scale oil＆gas pipeline network in its whole life cycle, to ensure the safe operation safety and achieve efficient transportation is the key issue in today's pipeline research area. All these are major problems to be urgently solved in pipeline industry [5].

Therefore, it is important to use a well-accepted tool such as the reliability technology to analyse the pipeline system, to satisfy the demands which are presented by the pipeline industry to ensure that the pipeline system could be settled in a safe and reliable state for its life time.

Reliability is a fundamental attribute for the safe operation of any modern technological system. Focusing on safety, reliability analysis aims at the quantification of the probability of failure for the system and its protective barriers [6-7]. It refers to that the ability or possibilities of system to complete the required function within the stipulated time and working conditions.

These barriers are intended to protect the system from failures of any of its components, hardware, and software, human and organizational. These all need to be addressed by the system reliability analysis in a comprehensive and integrated manner [8].

In this paper, the reliability of the pipeline system is calculated and analysed. Through the reliability modelling of the oil and gas pipeline system, the connection reliability and function reliability of the system are analysed separately. The system failure is divided into its physical function failure and process condition failure, which can provide substantial reference for the further study of pipeline system reliability.

* Corresponding author: 270426450@qq.com

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (http://creativecommons.org/licenses/by/4.0/).

2 Pipeline system reliability model

In the pipeline industry, reliability modeling method is not well established. Therefore it need to be started from a simple case study, and then on this basis, to optimization the pipeline system reliability mode and method gradually. According to ISO/TR 12489 which describing pipeline reliability modeling method, it includes the statistical method, Boolean model method and reliability of simulation method for modeling reliability.

Based on the common reliability modeling, reliability block diagram method is relatively straightforward, which would establish a simple physical model for the pipeline system, as shown in figure 1.

Due to the complexity of station structure, the paper firstly presents a typical station structure for the gas station as shown in Fig. 2 in order to make the complex structure simpler. Further the station valves, compressors and other equipment within station needs to be initialized with its own reliability model.

3 Pipeline system reliability calculation methods

According to the established pipeline system reliability model, system reliability is calculated. It is known that if m compressor units in the n stations are available, that meets the production requirement. In this paper, pipeline failure mode can be divided into connection failure and function failure.

Connection failure describe the physical structure in the pipeline system to a fault, by any means that cannot form effective pathway, cause physical truncation pipeline system; Function failure is the piping system under the condition of can mutually connected to form pathways, due to the technological equipment but cannot meet the required by the process conditions such as transporting the required amount of volume's

When calculate system reliability, different failure modes should be taken into account. Connection and function reliability of system is calculated respectively. Given compressed station as an example, if it is categories according to the different failure mode, then all of the devices within the station will be divided into function devices and connectivity devices, and then the compressor unit will be regarded as a function device.

3.1. Pipeline system connectioned reliability calculation

By the system reliability block diagram, pipeline system is series system that consists of station, pipe and valve chamber. The pipeline system reliability formula can be written as:

$$R_{SC} = R_{Csti} \cdot R_{Pi} \cdot R_{vsi} \tag{1}$$

Where, R_{SC} is system connectioned reliability, R_{Csti} is the i-th connectioned reliability of station i, R_{Pi} is the pipe segment reliability, R_{vsi} is the valve chamber reliability.

Pipe segment inside the pipeline system can be divided into pipes in the station and pipes outside the station. For the pipes in station section, due to the short distance, inspections in a timely manner and the maintenance level is high, the reliability is relatively high, close to 1,when calculating the pipe reliability is not considering. Pipes outside the station is used to connection all kinds of pipe between the station and valve chamber. Based on section reliability of literature at home and abroad, found that pipe fault time obey to the exponential distribution, indicators for the constant failure rate. The available section failure rate:

$$\lambda_i = \frac{1}{MTBF_i} \tag{2}$$

According to the index distribution function, pipe reliability calculation formula can be written as:

$$\mathrm{R_{Pi}} = \exp(-\lambda_i \mathrm{t}) \tag{3}$$

To analsye the station shown in Fig 2，compressor unit equipped with a bypass circuit, and station has the bypass station processes. So compressor unit is considered to keep confectioned all the time when calculating the station connect reliability. The compressor reliability is 1. The Station connection reliability formula can be written as:

$$R_{CSTi} = \left[1 - \left(1 - R_{filt}R_{bypass}\right) . \left(1 - R_{trans}\right)\right] . R_{pullin} . R_{output} \tag{4}$$

Where, R_{inpart} is pull in part reliability, R_{bypass} is by pass valve reliability, R_{filt} is filtering part reliability, R_{trans} is the trans station part reliability, R_{output} is in put part reliability.

3.2 Pipeline System Function Reliability Calculation

Under the condition of meet the component form interconnection pathways, pipeline system may still fail. This is mainly due to the process equipment cannot reach the required process conditions. This kind of failure is called the function failure. It is need to calculation and analysis of system function reliability.

For pipeline system, satisfy the technological conditions of n in any m stage compressor in the available state that meet the production requirements. The pipeline system reliability function can be written as:

$$R_{SF} = R_{Fsti} \cdot R_{Pi} \cdot R_{vsi} \tag{5}$$

Where, R_{SF} is system function reliability, R_{Fsti} is the i-th function reliability of station i, R_{Pi} is the pipe segment reliability, R_{vsi} is the valve chamber reliability.

The compressor and its corollary equipment are the main function components of the station. In the process of calculation, for possible to simplify the model, other provisions different compressor station used are the same type, performance indicators. Because the station function realization based on system connection, the station function reliability can be defined as:

$$R_{Fst} = R_{Cst} \cdot \sum_{k=m}^{n} C_n^k \cdot R_{com}^k \cdot \left(1 - R_{com}\right)^{n-k} \tag{6}$$

Where, R_{Fst} is station function reliability, R_{Cst} is station connection reliability, R_{com} is compressor unit reliability.

According to the vendors to determine parameters and historical operation data, compressors and its components reliability index is determined.

4 Application

According to the above method, combining the reality of an active pipeline, selection of calculation and analysis a particular operating conditions. The pipeline system consists of four stand five valve chamber and confectioned section of each length of pipe section list as shown in table I. First (ST1) and station 3 (ST3) for compressor station, station is equipped with three the same type compressors. Under the selection of operation condition, the compressor work plan for 2 in 1 case.

Table 1. The length of each pipe

pipe	**length（km）**	**pipe**	**length（km）**
1	21.2	5	22.8
2	27.6	6	18.6
3	29.7	7	18.7
4	7.2	8	14.7

The pipeline system physical model is selected from the SCADA system, as shown in figure 3. Modeling method based on reliability, reliability modeling was carried out on the pipeline, selection of pipeline reliability model as shown in figure 4.

The pipeline system connectioned reliability is calculated based on the above method.

$$R_{SC} = R_{CST1} \cdot R_{P1} \cdot R_{VS1} \cdot R_{P2} \cdot R_{VS2} \cdot R_{P3} \cdot R_{CST2} \cdot R_{P4} \cdot R_{VS3} \cdot R_{P5} \cdot R_{VS4} \cdot R_{P6} \cdot R_{CST3} \cdot R_{P7} \cdot R_{VS5} \cdot R_{P8} \cdot R_{CST4} \tag{7}$$

Station connectioned reliability:

$$R_{CST1} = R_{CST3} = R_{output} . R_{pullin} \cdot \left[1 - \left(1 - R_{filt} R_{bypass}\right) . \left(1 - R_{trans}\right)\right] \cdot R_{P7} \cdot R_{VS5} \cdot R_{P8} \cdot R_{CST4} \tag{8}$$

Pipeline System Function Reliability:

$$R_{SF} = R_{FST1} \cdot R_{P1} \cdot R_{VS1} \cdot R_{P2} \cdot R_{VS2} \cdot R_{P3} \cdot R_{FST2} \cdot R_{P4} \cdot R_{VS3} \cdot R_{P5} \cdot R_{VS4} \cdot R_{P6} \cdot R_{FST3} \cdot R_{P7} \cdot R_{VS5} \cdot R_{P8} \cdot R_{FST4} \tag{9}$$

Station Function Reliability:

$$R_{FST1,3} = \left[R_{com}^3 + C_3^2 \cdot R_{com}^2 \cdot \left(1 - R_{com}\right)\right] \cdot R_{CST1} \tag{10}$$

Equipment unit reliability data information was got by historical statistics, as shown in table II.

Table 2. The length of each pipe Equipment unit reliability data information

name	**Reliability**
valve	0.9902
Compressor	0.9775
natural gas filter	0.906
Trans station valve	0.999
Pipe failure rate	0.00032time/km•year

Pipeline System connection and function Reliability is 0.85223 and 0.84968 respectively.

$$R_{SC} = 0.85223$$
$$R_{SF} = 0.84968$$

5 Conclusions

This article simplifies the extreme complicated oil and gas pipeline system and it is the first paper to establish the reliability model of pipeline system based on its typical structure. Based on these achievements, the system connection reliability and function reliability calculation method are presented. This paper can provide significant reference for the future research in the area of pipeline system reliability. However it did make some assumptions, as follows:

First，the pipeline system described in the paper is inherent with the real pipeline system to establish a simplified virtual pipeline system, but the modeling process involves only the key components, ignore other trial components.

Second, in this paper, the calculation is based on the relatively normal working condition; it did not include

DOI: 10.1051/matecconf/201713900116

all kinds of operation conditions, where the computation will be much more difficult. But the strategy and the methodology would be the same, and it can be dialed with the model and algorithm proposed in the paper.

References

1. Huang Weihe. Reliability of large-scale natural gas pipeline network [J]. Acta Petrolei Sinica, 2013 Vol. 34 (2): 401-404.
2. Ai Muyang. Discussion on issues regarding the reliability of large-scale oil and gas pipeline network systems [J]. oil & gas storage and transportation, 2013 Vol. 32 (12): 1265-1270.
3. Kariyawasam S, Peterson W. Revised corrosion management with reliability based excavation criteria. In: Proceedings of IPC 2008, IPC2008-64536. Cal-gary: ASME; 2008.
4. Stephens M, Nessim M. A comprehensive approach to corrosion management based on structural reliability methods. In: Proceedings of 6th International Pipeline Conference, IPC2006-10458. Calgary, Canada: ASME; 2006.
5. Huang Weihe. Transportation technigue for oil&gas pipoeline[M]． Beijing： Petroleum Industry Press，2012：9-11．
6. Reason J. Managing the risk s of organisational accidents. Aldershot: Ashgate Publishing Ltd.; 1998.
7. Baraldi P, Zio E. A combined Monte Carlo and possibilistic approach to uncertainty propagation in event tree analysis, risk analysis; 2008.
8. Flage R, Aven T, Zio E. Alternative representations of uncertainty in system risk and reliability analysis: review and discussion. In: Proceedings of ESREL2008, Valencia Spain, 22–25 September 2008.

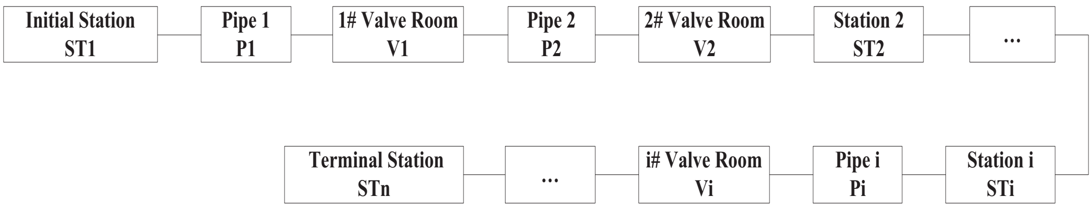

Fig. 1. Brief diagram for Oil ＆ gas pipeline system reliability model.

Fig. 1.   .

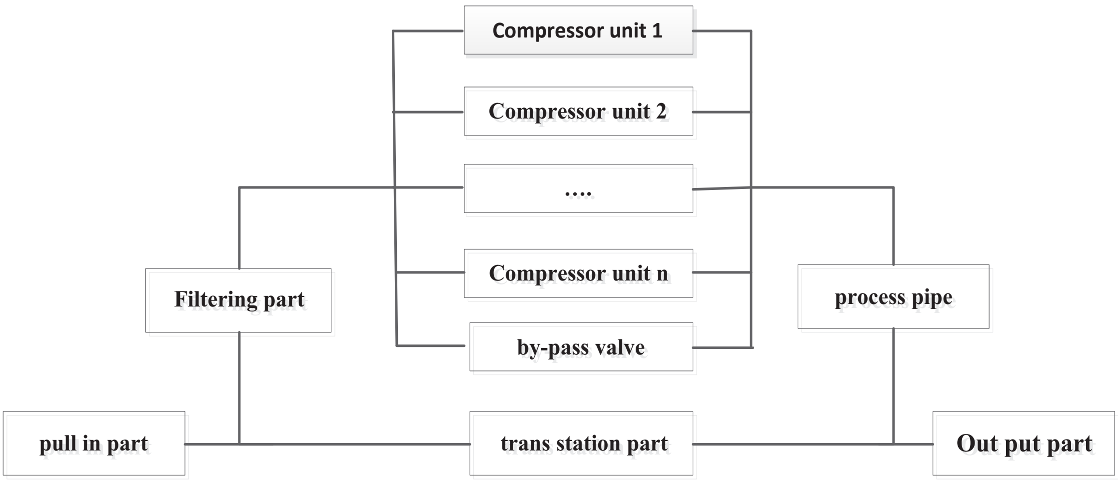

Fig. 2. The compressed air station reliability model.

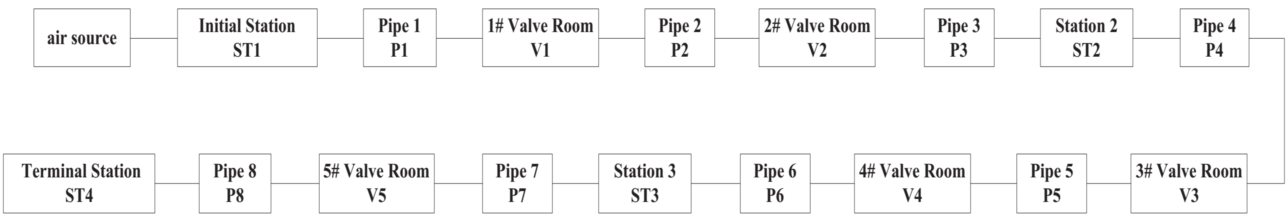

Fig. 3. The pipeline system physical model.

DOI: 10.1051/matecconf/201713900116

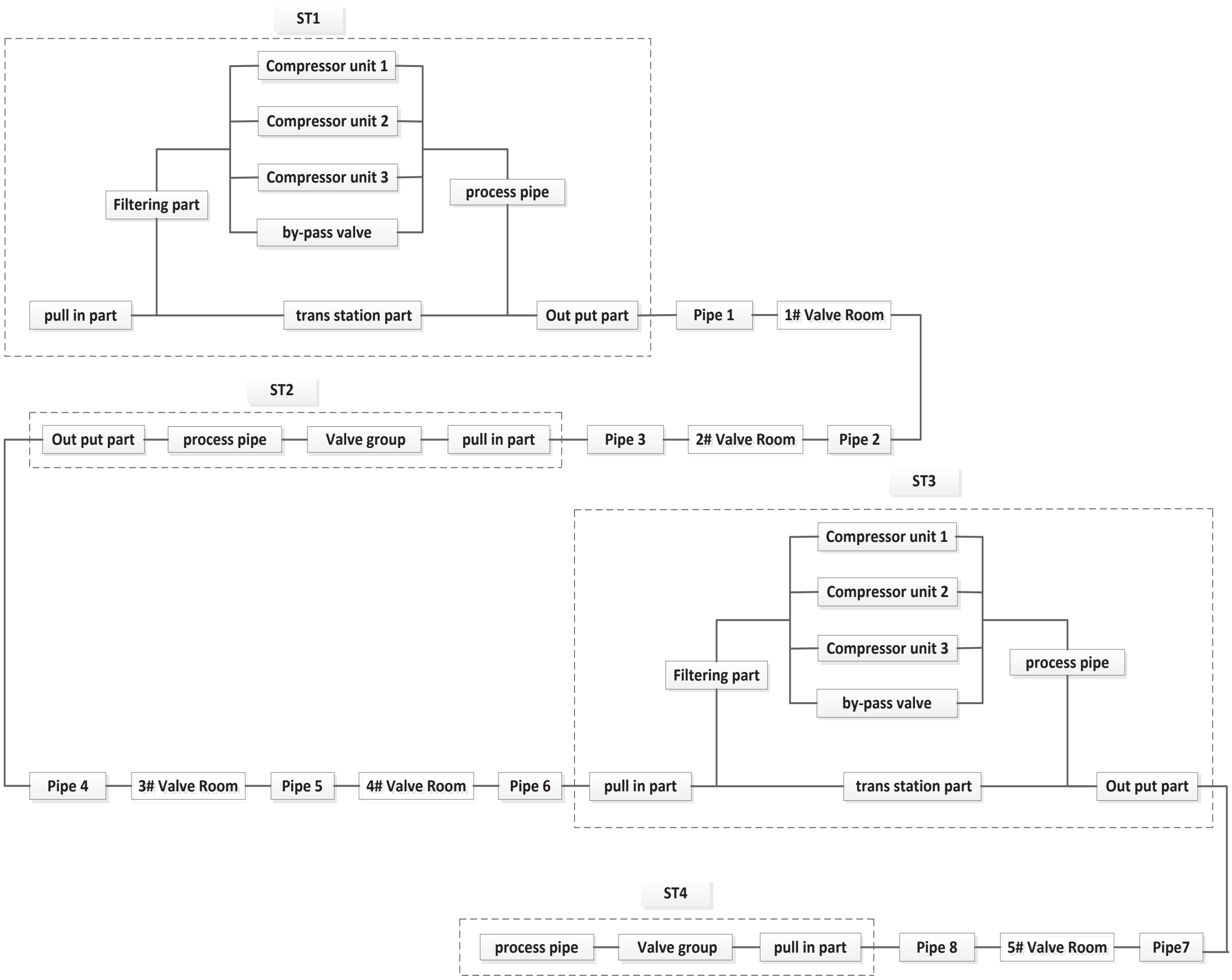

Fig. 3. The pipeline system reliability block diagram.

* Corresponding author: 270426450@qq.com