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EXPERIMENTAL STUDY ON BLOCKAGE DETECTION IN GAS PIPELINE BY USING PRESSURE PLUSE WAVE METHOD

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ABSTRACT

The partial blockage in gas pipeline due to solid deposition is one of the major risks for the pipelines transportation system. Determining the location and severity of blockage is the key to mitigate or remove it with a high efficiency. In this year, the pressure pulse wave method has been considered as a promising method for blockage detection for their operational speed, maneuverability, and long detection range. However, the application results of this method showed the low accuracy of detecting blockages in pipelines. In this work, a series of tests was performed in a 106 m pipelines with a 22 mm pipe diameter, the experimental result indicated that the blockage location predications based on pressure pluse wave method have an acceptable accuracy. The cross-sectional shape of the blockage will greatly affect the intensity of the reflect wave. It is necessary to consider the cross-sectional shape when calculating the blockage percentage.

Keywords: oil and gas transportation, pressure pulse wave, blockage detection, multiple blockage types.

1. INTRODUCTION

The partial blockage in gas pipeline due to solid deposition like hydrate is one of the major risks for the pipelines transportation system[1]. The continuous accumulation of this deposition material may lead to fire explosion, pollution, or other ecocatastrophes without remove it in time[2]. Determining the location and severity of blockage is the key to mitigate or remove it with a high efficiency. Several studies have been conducted in the literature to find out the best method for blockage detection in gas pipes. Scott et al.[3] applied the backpressure technique for blockage, but this method only provides rough estimations about blockage. Acoustic technique was applied blockage detection by Koyama et al.[4] and major limits of this method is signal interference and degradation. Another technique is the frequency-response method[5] which detect the blockage by analyzing resonant frequencies shift, but no experiments have shown that this method can be used in gas pipeline.

In recent years, the pressure wave method is considered as a promising method for early partial blockage detection on account of its short response time, less intrusive, economical and high detection accuracy. This method involves the injection of a pressure pulse into the pipeline, and if there are any discontinuities in the pipe cross-sectional area, such as caused by: blockage, t-pees, valves, and orifice plate, there will be partial reflection and transmission of the pressure incident wave at the interface of these features. Meanwhile, transducers that are mounted along the pipe are used to measure the transmission and reflection pressure waves as they propagate across the pipe. Afterwards, the time difference between the reflected wave and the incident wave are evaluated to calculate the blockage location, the ratio of the reflected wave amplitudes and the incident wave amplitudes are evaluated to calculate the percentage of blockage area. Adewumi et al.[6] proposed a model that describes pressure pulse propagation through gas pipeline containing blockages and proved the feasibility of this method by a series of numerical experiments. Adeleke et al.[7] improved the mathematical model which proposed by Adewumi and the viscous effects was taken into account, but it only validated by the numerical experiments.

In this paper, a series of tests was performed in a 106 m pipelines with a 22 mm pipe diameter, the experimental result indicated that the blockage location predications based on pressure pluse wave method have an acceptable accuracy and cross-sectional shape of the blockage will greatly affect the intensity of the reflect wave.

2. EXPERIMENTAL APPARATUS

In order to investigate the pressure pulse wave method for gas pipelines blockage detection experimentally, an experimental apparatus was built.

Fig. 1 shows the experimental facility. It consists of the gas supply system, main pipeline section, pressure wave generator and partial blockage section. The compressed air from the screw air compressor was injected into the pipe. The main pipeline section made up of a ppr horizontal pipe with 106 meters in length and 22 mm in internal diameter. The pressure wave was generated by a quick-acting valve when the production stream was released for a very short period of the time at the outlet. The tubes at the partial blockage section are replaceable, so we can replace the tubes with different diameter in different place to simulate the partial blockage with different location and severity.

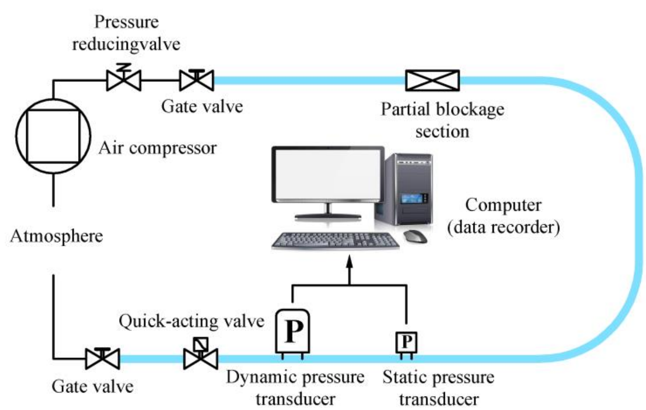

Fig. 1. Schematic diagram of the experimental facility

The transient dynamic pressure was measured by a dynamic pressure transducer close to the quick-acting valve. The static pressure was measured by a static pressure transducer. The tubes at the partial blockage section are replaceable, so we can replace the tubes with different diameter in different place to simulate the partial blockage with different location, length and severity. The outlet of the pipe was open to the atmosphere and restricted by a gate valve. Pressure wave signals from each transducer were synchronized in a LabVIEW® data acquisition program.

3. EXPERIMENTAL RESULTS AND DISCUSSION

To evaluate the feasibility of applying pressure wave propagation method for blockage detection, a series of experiments have been performed in the experimental facility as shown in Fig. 1.

Firstly, the metal rings with different inner diameters are mounted on the partial blockage section to simulate the partial blockage with different blockage percentages, The length of the metal ring is 15 mm, the distance between the partial blockage section and the dynamic pressure transducer is 59.4 m. nine blockage tests with different blockage percentages from 96.9% to 22.0% are performed, the tests results as shown in Fig. 2. The reflect wave cause by blockage can be seen within the blockage percentages range of 96.9% - 50.1%, and when the blockage percentage decreased to 36.8%, the reflect wave became indistinct.

The static pressures of these nine tests are range from 0.8 MPa to 0.85 MPa, and the temperatures are about 20 ℃. According to the previous study by the Yingfeng Meng et al.[8], the calculation results of the blockage locations and blockage percentages as shown in Table 1. The cases 1 through 7 represent that the blockage location predications based on pressure pluse wave method have an acceptable accuracy, the maximum error was -4.9%. However, the blockage percentage predications are not accurate enough, the maximum error was -20.6%. The main reasons for this result are energy dissipation due to elbow pipe and wave reflection process and wave distortion due to nonlinear effect.

Then, the gate valve is mounted on the partial blockage section with different opening degree. The distance between the partial blockage section and the dynamic pressure transducer is 76.7 m. nine blockage tests with different blockage percentages from 86.2% to 19.9% are performed, the tests results as shown in Fig. 3. The reflect wave cause by blockage can be seen within the blockage percentages range of 86.2% - 26.9%, and when the blockage percentage decreased to 19.9%, the reflect wave became indistinct.

Same as the previous test, the static pressures of these nine tests are range from 0.8 MPa to 0.85 MPa, and the temperatures are about 20 ℃. The calculation results of the blockage locations and blockage percentages as shown in Table 2. The cases 1 through 8 represent that the blockage location predications are accurate, the maximum error was -4.1%. The blockage percentage predications are not accurate enough, unlike the metal ring blockage, the predicted values of

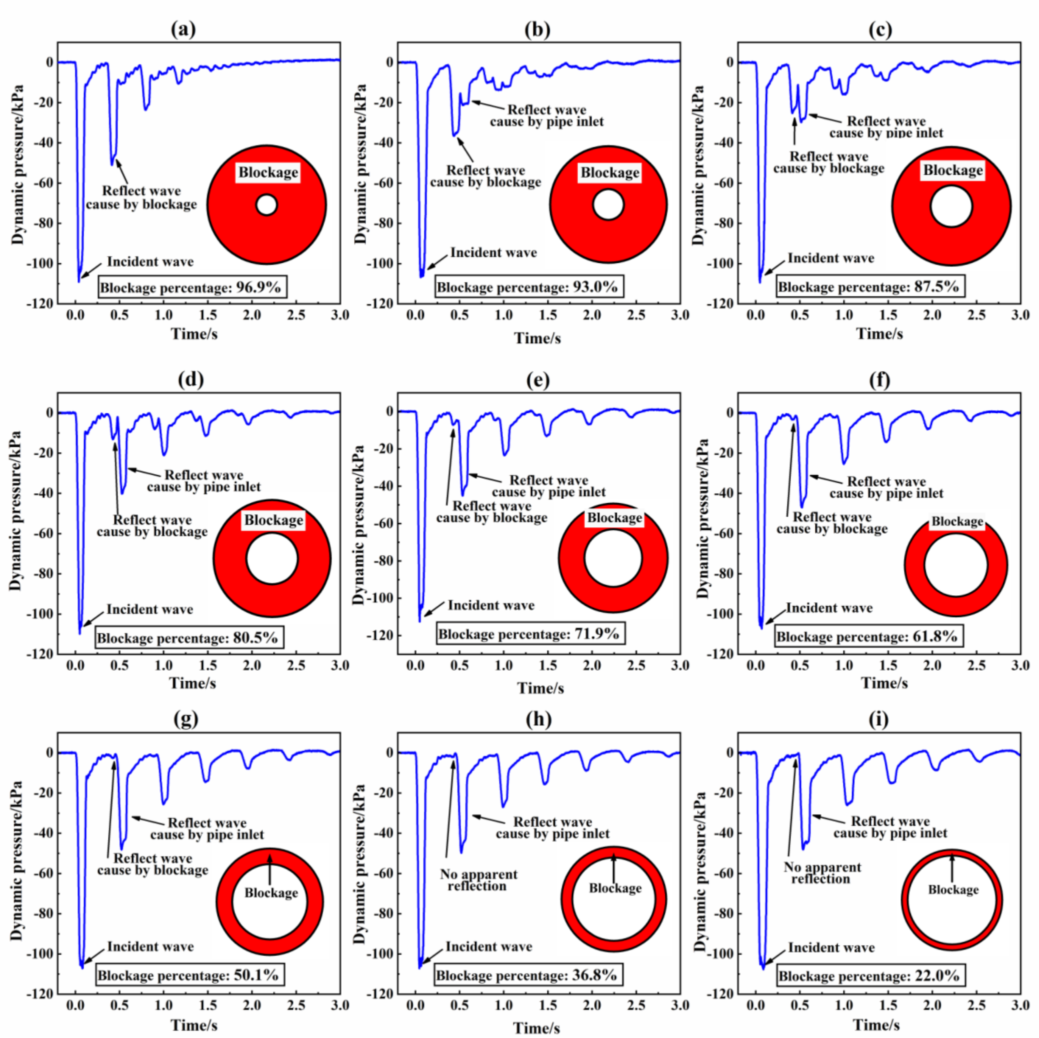

Fig. 2. The results of the blockage detection test with nine different blockage percentages cause by metal rings.

Table 1. The calculation results of the blockage detection test with seven different blockage percentages cause by metal rings

Case	Blockage location			Blockage percentage		
	Real.(m)	Pred.(m)	%Err	Real.	Pred.	%Err
1	59.4	60.5	-1.9	96.9%	93.6%	-3.6
2	59.4	61.1	-2.8	93.0%	88.7%	-4.8
3	59.4	60.7	-2.3	87.5%	81.7%	-7.1
4	59.4	61.9	-4.2	80.5%	70.1%	-14.8
5	59.4	62.3	-4.9	71.9%	61.2%	-17.5
6	59.4	60.2	-1.5	61.8%	51.2%	-20.6
7	59.4	61.4	-3.4	50.1%	48.1%	-4.0

Table 2. The calculation results of the blockage detection test with seven different blockage percentages cause by metal rings

Case	Blockage location			Blockage percentage		
	Real.(m)	Pred.(m)	%Err	Real.	Pred.	%Err
1	76.7	77.4	-0.9	86.2%	92.1%	6.5
2	76.7	77.8	-1.4	77.1%	85.2%	9.5
3	76.7	77.8	-1.4	68.1%	76.1%	10.6
4	76.7	77.1	-0.4	59.2%	70.8%	16.3
5	76.7	79.9	-4.1	50.6%	58.9%	14.1
6	76.7	79.9	-4.1	42.3%	51.1%	17.2
7	76.7	79.5	-3.6	34.4%	46.5%	26.1
8	76.7	79.9	-4.1	26.9%	41.6%	35.4

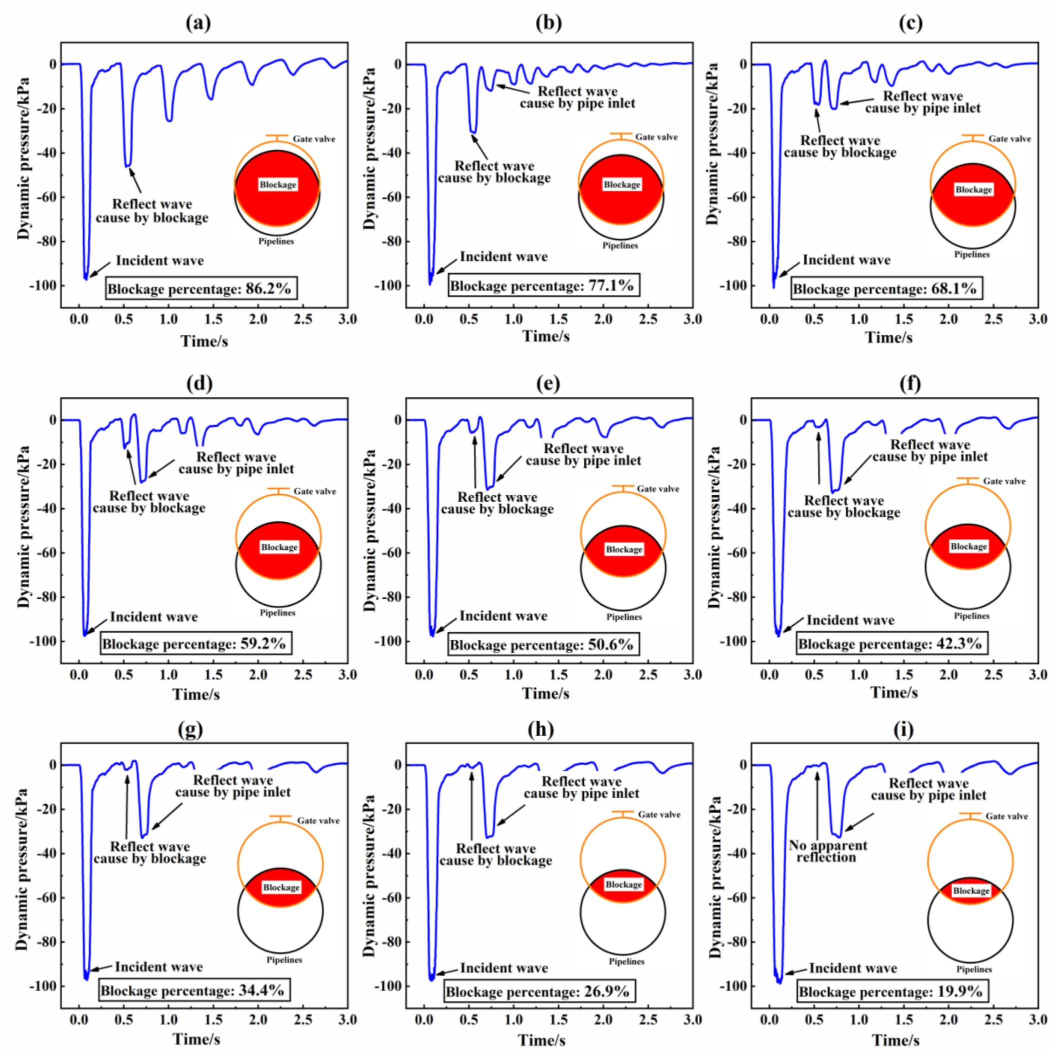

Fig. 3. The results of the blockage detection test with nine different blockage percentages cause by gate valve.

blockage percentage are greater than the real values of the blockage percentage, the maximum error was -35.4%. It is obviously that the gate valve blockage produced a stronger reflected wave than the metal ring blockage when their blockage percentages are equal. One explanation for this phenomenon is that the gate vlave has longer blockage length (the blockage length of gate valve is 20mm) than metal ring blockage. Furthermore, different cross-sectional shapes of these two types of blockage are probably the main cause of this phenomenon.

4. CONCLUSIONS

In this study, we performed a series of blockage detection tests in a self-built experimental facility. The experimental results indicated the blockage location predications based on pressure pluse wave method have an acceptable accuracy. Due to the energy dissipation in wave reflection process and wave distortion caused by nonlinear effect in wave propagation process, the blockage percentage predications need to be improved. Our experimental also found that the cross-sectional shape of the blockage will greatly affect the intensity of the reflect wave. It is necessary to consider the cross-sectional shape when calculating the blockage percentage.

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