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Influence of Leak Location on Small Leak Detection System of Gas Pipeline

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Abstract

The pipeline inspection using dynamics pressure has been continuous development with the advantages on low noise, long range, accessible, and no electrical spark occurred. However, a small leak rate was a limitation of this inspection method which depend on sensor sensitivity. Besides, the leak identification method of dynamics pressure transducer works on the capture of signal propagated in gas medium, the leak location would be sensitive to the turbulence. The scaling-square method is a mathematical based signal processing which can amplify leak signal and noise reduction at the same time. This research compared the proposing method to the conventional (threshold and cross-correlation). On the results, the advantage of scaling-square method was improved leak detection ability with the calculation on leak location present the 0.8% error for highest accuracy.

Keywords: *Dynamics Pressure, Leak Detection, Leak Location.*

1. Introduction

The use of pipeline as fuel transmission method is the most convenient, fast, and safe. Nevertheless, the pipeline network was constructed underground and the deteriorated did not easy to observe. The lacking of schedule inspection and lifetime prediction should make a harmful accident which affected to environment, life, and asset. Online monitoring system has been proposed for the first decision aid such as automatic shut off the main valve and given a notification to confederate. However the SCADA has been designed to support this incident, but the function will work only the instant change of pressure or the large pressure drop and unable to detect a small leakage and cannot locate the leak location accurately. There are some of non-destructive testing technique capable to solve this problem, the small leakage was detect instantaneously and able to specify the leak location. As the previous literature, the effective and popular used the online pipe leak detection system is the acoustic emission method (AE) and dynamics pressure method (DP). These method capable to use with the pre-installed pipeline and safe from the explosion cause.

The leak occurred produce acoustic signal and propagating along the pipeline to the sensor, with the using principle of acoustic and simple law of motion, the leak location has been calculated. Unfortunately, the acoustic emission method was inappropriate to use with the long pipeline application. Because, the highly attenuation of acoustic signal, AE sensor need to install too many points through pipeline length and have to install during pipeline arrangement. The dynamics pressure method was outstanding cause of the signal propagated in fluid instead of pipe wall. So, the long distance leak detection was capable also in easy installation [1-4]. For the leak location processing, inter-station communication was necessary, with the timing parameter and sensor installation location as minimum information to locate leak position.

The small leak affect to the signal-to-noise ratio (SNR) and make the leak detection is too difficult. Besides, the nature of leak location estimated, the difference of time of signal captured by each sensor would be sensitive to the location of leak point. The leakage near the transducer will cause turbulence and make the leak signal distort. This study will simulate leak point along the pipeline and capture the leak indication signal for calculate the leak location and find out the influence of leak location to the leak detection and locating.

2. Research Background

2.1 Dynamics Pressure Transducer

Dynamic pressure transducer is the pressure measurement device that measuring pressure transients or instantaneous change of pressure in fluid. The fast response with micro-second rise time fetch the bandwidth of transducer response in range of kHz and over, so it capable to detection of leak in pipeline. When leak occurred, the pressure instant change and propagate as wave through

fluid to the transducer. The advantages in low interference, low signal attenuation, and easy installation make the dynamics pressure transducer popular in leak monitoring system.

2.2 Leak Locating

The location of the leak was calculated based on the velocity of pressure wave that propagate in the fluid, by examining the difference between indication signal's arrival times (Δt) at the two opposing transducers (S1 and S2), and the length of the pipeline segment, as shown in the equation below

$$x = (l - \Delta t \cdot v)/2 \quad (1),$$

Where x is the distance between the first sensor and the leak point,

l is the distance between sensors installation,

Δt is the time difference of the two sensors captured leak indication signal,

v is the velocity of negative pressure wave propagation.

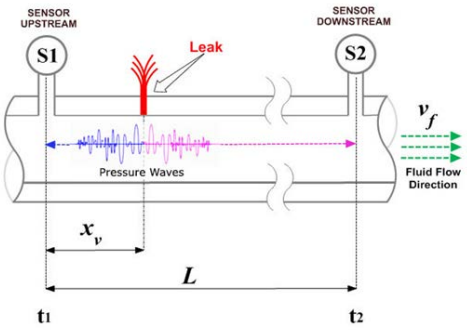

Fig. 1 pipe leak locating using negative pressure wave method [5]

Cross-correlation is the one of signal processing method for locate the leak point, with the two sound recordings of the noise produced by the leak, delayed in time by a different unknown amount, the time delay can be found by determining the time offset for which the cross correlation product has a maximum value. This approach is able to detect several leaks at the same time [6].

$$r(k) = \sum_{-\infty}^{+\infty} p(n)q(n+k) \quad (2),$$

where r is the correlation result between two signals,

p is the signal from first pressure transducer.

q is the signal from second pressure transducer,

n, k are the point of time.

2.3 Scaling-Square Method

The Scaling-Square is the proposing technique to detect the leak signal for the small leak rate. The small leak caused the small pressure change and difficult to detect. This technique using the conventional method to find out the signal's arrival times (Δt) and signal processing technique to improve signal-to-noise ratio (SNR). "Square" is the common mathematic that able to amplified and distorted at the same time (Eq. 3).

$$x^2 < x \text{ ; when } x < 1 \quad (3).$$

Consequently, we can use the constant as the proportional gain to achieve the benefit of Square's criteria.

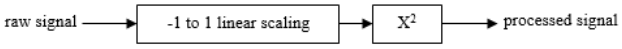

Fig. 2 Scaling-Square processing method

3. Experimental Setup

The experimental was set on the linear 2-inch diameter steel pipe 23 meters long with solenoid-controlled leak for 3 positions as shown on Fig. 3. The 3 positions of leak have been set with pin hole nozzle at volume flow rate 0.2 lt/min (at 0.4 MPa) and can be describe the location and propose as follows.

NR is the leak point near the pressure transducer. At this point we can test for the signal threshold to detect leak indicator.

AC is the leak point for testing the leak detection accuracy and use this point as the reference to calculate the location error.

CT is the leak point at near the center between the 2 sensors. At this location, signal's arrival times (Δt) would close to zero. So, we can test for the time resolution.

Fig. 3 experimental setup for the small leak detection

4. Experimental Results

On the experiment, the pressure has been set to 0.3, 0.4, and 0.5 MPa with simulate for leakage individually on each pressure. The test of leak indication has been tested 10 times of every points and show the abbreviation for leak detection ability.

n/a : there is no signal indication to indicate leak.

F : there is leak indication signal but the results lack of repeatability.

A : there is leak indication signal and repeatable.

Table 1: Comparison on leak detection ability

Leak Simulate	NR			CT			AC		
Pipe Pressure	0.3	0.4	0.5	0.3	0.4	0.5	0.3	0.4	0.5
Conventional Threshold	n/a	n/a	F	n/a	n/a	F	n/a	F	F
Cross Correlation	F	A	A	F	A	A	F	A	A
Scaling-Square Method	F	A	A	F	A	A	F	A	A

On the testing with conventional method, we cannot detect leak indication signal because the leak signal has amplitude close to the background level. For the Cross-Correlation method, there was the leak indication signal only the pipeline pressure over 0.4 MPa. likewise the Scaling-Square method.

Moreover, the leak location calculating has been tested for the accuracy of each processing method. the testing criteria has been set only 0.4 MPa which is the lowest pressure of the testing system that able to indicate leak signal. The results shown that the accuracy of leak location on the NR point is lowest and AC point is highest accuracy. That because the leak at NR point caused turbulence near the transducer and produce signal distorted. For the CT point, there is no turbulence to interfere the leak indicator and the locating accuracy have only depend on the time resolution.

However the Cross-Correlation method have lower percentage error in leak location calculating, but the number of miss detection is over than the Scaling-Square method. Hence, the Scaling-Square method leading advantageous for a small leak detection in practical.

Table 2: Comparison on leak locating ability

Leak Simulate	NR		CT		AC	
	Miss Detect	%error	Miss Detect	%error	Miss Detect	%error
Cross Correlation	1	14.38	4	0.92	0	0.56
Scaling-Square	1	11.52	0	1.24	0	0.8

5. Conclusions

From the experiment, time domain data had collected for leak exploration. The leak was simulated by the using of pin hole nozzle and solenoid valve vent to atmosphere. The leak location has been set to 3 points along the pipeline to test with 3 ranges of pipeline pressure. The results shown that the accuracy of leak location on the NR point is lowest and AC point is highest accuracy. Although the Cross-Correlation method have advantageous on the leak locating accuracy, but the number of miss detection is over than the Scaling-Square method. So, the Scaling-Square method is the better method for a small leak detection.

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