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Leak detection in medium density polyethylene (MDPE) pipe using pressure transient method

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Abstract. Water is an essential part of commodity for a daily life usage for an average person, from personal uses such as residential or commercial consumers to industries utilization. This study emphasizes on detection of leaking in medium density polyethylene (MDPE) pipe using pressure transient method. This type of pipe is used to analyze the position of the leakage in the pipeline by using Ensemble Empirical Mode Decomposition Method (EEMD) with signal masking. Water hammer would induce an impulse throughout the pipeline that caused the system turns into a surge of water wave. Thus, solenoid valve is used to create a water hammer through the pipelines. The data from the pressure sensor is collected using DASyLab software. The data analysis of the pressure signal will be decomposed into a series of wave composition using EEMD signal masking method in matrix laboratory (MATLAB) software. The series of decomposition of signals is then carefully selected which reflected intrinsic mode function (IMF). These IMFs will be displayed by using a mathematical algorithm, known as Hilbert transform (HT) spectrum. The IMF signal was analysed to capture the differences. The analyzed data is compared with the actual measurement of the leakage in term of percentage error. The error recorded is below than 1% and it is proved that this method highly reliable and accurate for leak detection.

1. Introduction

Water is an important part of an economic growth of a country that would provide. Even through precaution steps have been taken, technical faulty is still exist during their transmission upon reaching the users as a part of the supplied water are loss due to the various problems for example leakage [1]. Leakage is due to high pressure of water flowing through the underground pipe. In addition, such catastrophes can have significant social and environmental influences [2]. Non-revenue water (NRW) program has been implemented in Malaysia for the precaution from water lost. NRW is the difference between the water supply volume in water distribution system and the volume that is billed to consumer [3].

To serve the purpose of supplying the demand to consumer, water is supplied from production facilities i.e. rivers, reservoir, damns, tanks and it is important to ensure that the supplied water would reach to the consumer accordingly [4, 5].

NRW could be a result from theft, pipe leakage, meter inaccuracy, and other uncountable losses once its leaves the water treatment. The problem that caused from the pipeline leakage would contribute a big loss to the company as it would increment maintenance and operating costs. In fact, it will give negative impacts on the water supply services and to the nation's total economic growth [6].



Since there are various methods that can be used to detect pipe leaks, this paper is focused on the method that based on internal inspection method which required a vibration approach upon conducting the leakage in the pipeline [3]. It is proved that EEMD method can obtain significant results on the pipe leaks experiments by using Piezoceramic Transducer [7].

2. Experimental setup

The experiment used various types of the pipeline network which can be constructed in various methods in collecting the acquired data. It is almost impossible to experimentally fabricate and simulate the actual situation as it requires a very big and longer pipeline test rig that consumed massive space. Therefore, most of the researchers are conducting experiment on pipeline model based on the actual size of the pipeline that is easy to fabricate and easy to be manipulated throughout the test setup.

The pipeline was connected to a series of pipe features such as 90°-angle, T-junction, and different types of pipe diameters. The outlet of the pipe is kept connected to a free surface tank such that the water from the pipe ends discharged underwater as shown in figure 1. This is to prevent the sudden expansion of the pressure waves and the negative pressure of the waves could be minimized as it will affect the collected data from the transducer.

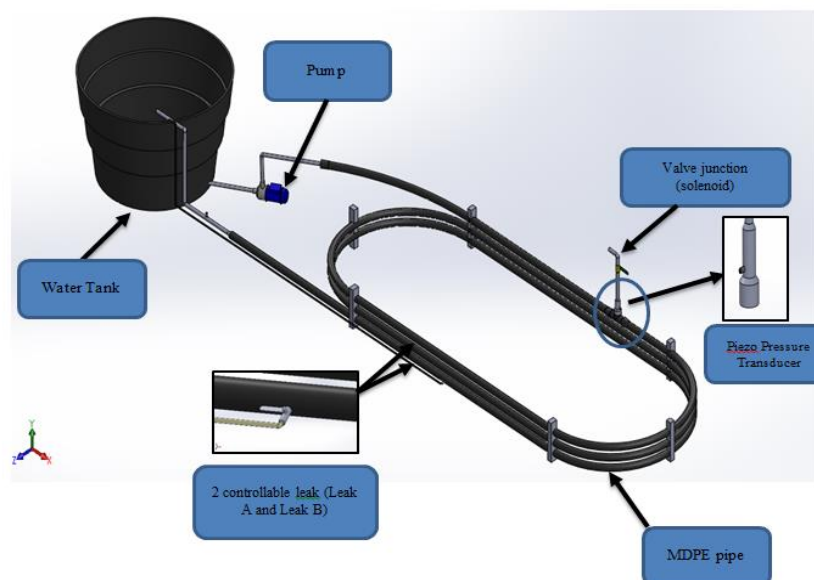


Figure 1. Design of test rig.

In some cases the unit will shut down in crisis, and the "water hammer" existence will inevitable occur in the pressure pipeline. This phenomenon may take place in all of pressure pipe system, frequently causing about strong vibration and destruction on the pipeline system [8]. Solenoid valve used as to create a water hammer through the pipe. This is order to create a same phenomenon happen in real life when there is pressure disorder occur through the underground pipe. Solenoid valve was controlled by a switch so that people in charge can control whenever to create the water hammer.

PresSystems (NI-DAQ) to collect data when the pressure changes occurred in the pipelines. The water is commuted in the system as long as the pump operates continuously. The total length of the MDPE pipe is 57.90m; where it started from the inlet of the pipeline i.e. from the pump until the outlet of the pipe that is located at back of the water tank.

The pipeline is attached with a few pipe features that will affect the pipeline behaviour. The signal response from this behaviour will be retrieved from the transducer. Even though this signal response will influence the analysis of the experiment data, this study is mainly focused on the leakage that is

exist in the pipeline. The distance of the leakage “A” is measured to be 27.08m. The leak was created by drilling a hole at some distance in the pipeline where this leakage can be control either to be opened or closed.

2.1. Ensemble empirical mode decomposition (EEMD)

Ensemble Empirical Mode Decomposition (EEMD) has more suitability in extracting a broad range of signals for a rich data of non-linear signal and non-stationary systems. The key idea on EEMD relies on averaging the modes obtained by EMD applied to several realizations of Gaussian white noise added to the original signal. The resulting decomposition solves the EMD mode mixing problem, however it introduces new ones. In the proposed method, a particular noise is added at each stage of the decomposition and a unique residue is computed to obtain each mode. It can be concluded that EEMD method is basically based on Empirical Mode Decomposition (EMD) but the problems of the mode mixing have been alleviate by introducing noise-assisted method [4].

The single Intrinsic Mode Function (IMF) that acquired is either having signals of widely disparate scales or a signal with a same scale reading in different IMF components. The mode mixing could result in a serious data aliasing with the time frequency distribution, and caused IMF data to be suppressed and unclear [9]. In other word, that can be summarized in the form of equations are stated as below:-

$$x_m(t) = x(t) + w_m(t), \quad m = 1, 2, \dots, n \quad (1)$$

$$x_m(t) = \sum_{i=1}^L c_{m,i}(t) + r_{m,L}(t), \quad m = 1, 2, 3, \dots, n. \quad (2)$$

$$x(t) = \frac{1}{N} \sum_{i=1}^L \sum_{m=1}^n c_{m,i}(t) + \frac{1}{N} \sum_{m=1}^n r_{m,L}(t) \quad (3)$$

where $x(t)$ is the original signal, $w_m(t)$ is the m th term added white noise, $xm(t)$ is the noisy signal of the m th trial, L is the number of IMFs from the EMD method, and N is the ensemble number of the EEMD method.

3. Results and discussion

3.1. Single leak detection signal using water hammering method

This signal response is recorded using the solenoid valve to induce a water hammering method. Compared to the manual method of opening and closing the valve, this method shows a better way to obtain the signal as it regulates the water flow and reduce the oscillations in the pipeline during water hammering process. The condition of the solenoid valve is in a normally closed condition valve and thus caused water hammer by closing the valve with three consecutive times for each of the data were recorded by the DASyLab Software.

3.2. Signal response for closed valve on the leakage of the pipeline

The experiment data that is obtained from the transducer response shows the behaviour response of the pipeline. The signal that is recorded does also retrieve the characteristic of the whole pipeline network itself. This pressure pulse travels in both directions away from the burst origin at the speed of sound in water (wave speed of the pipe) [10].

Figures 2(a), 2(b), and 2(c) indicate on the original responses of the pressure transducer that were obtained from the experimental process with a variation of pressures (P) with data retrieved from the

transducer. The original response was recorded at three different level of pressures: 1mmHg, 2mmHg, and 3mmHg. The original responses are contrast due to the differences in pressure levels. The higher the pressure creates higher frequency of signal and this causes the higher amplitude of signal.

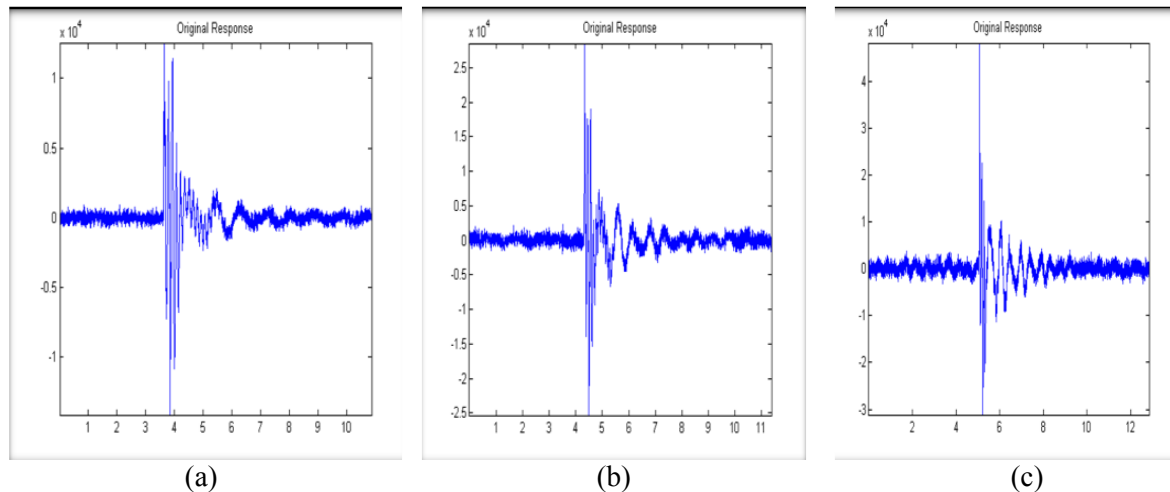


Figure 2. Signal responses for (a) 1mmHg (b) 2mmHg and (c) 3 mmHg with no leakage in the pipeline.

Results based on the original responses obtained from analysis on EEMD method with signal masking showed inconclusive value which indicates that the pipeline is associated with any kind of leakage. Thus, signal response from 2mmHg data is then analyzed through the EEMD with signal masking method using the MATLAB software where this signal is being decomposed into a series of IMFs that would be later converted into instantaneous frequency (IF) for further analytical calculation.

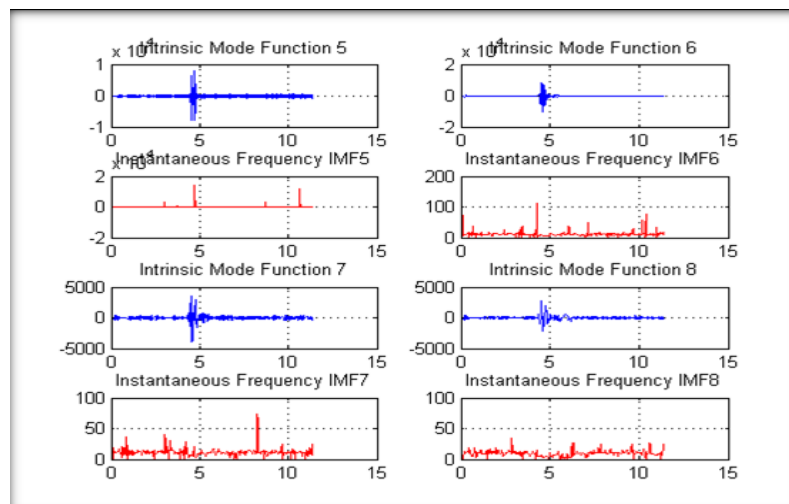


Figure 3. The analysed leak “A” signal of the 5th IMF until the 8th IMF with their respective IF (2mmHg).

Figure 3 shows the analysis of signal based on IMF with their respective IF for 2mmHg pressure level. This analysis was done using the MATLAB software in order to decompose the signal from the original response. The results obtained from 5th IMF until 8th IMF with respective IF were observed in order to select the best IF for further analysis. Compared to all IF, the 5th IF shows the most appropriate response to be used as reference for the further analytical calculation.

Figure 4 shows the response from the 5th IF with the detected leakage on leak “A” at pressure level of 2mmHg. All peaks in 5th IF response was observed because when there is a leakage through the pipe, the pressure disorder will occur and create fluctuated response in detected signal. So, the time difference is calculated for every peaks in 5th IF response.

Based on the collected data and analyses, each signal can have a few different readings compared to the actual measurement of the leakage distance.

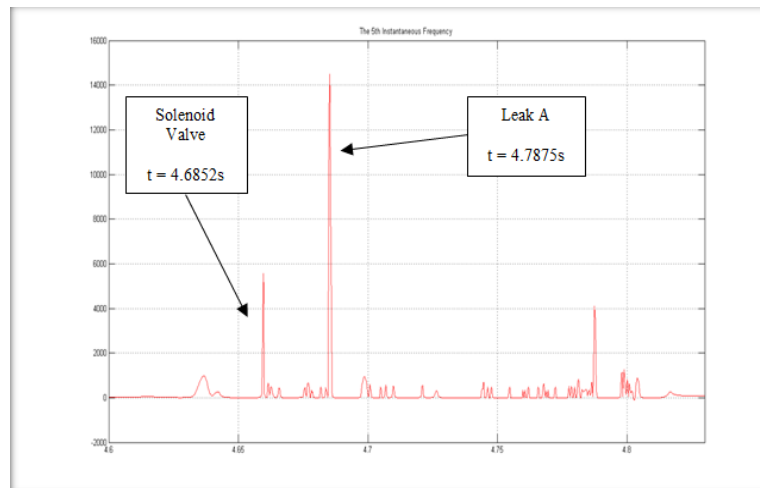


Figure 4. The 5th instantaneous frequency with the detected leakage on leak “A” (2mmHg).

With the calculated speed of sound of the fluid in the pipe are 524.3005 ms^{-1} . The time difference for 2mmHg read is 0.1044s and is identified at 26.82m from the located pressure sensor. The percentage error is 0.96%. Thus, table 1 summarized the data gathered for 2mmHg pressure during experiment and the calculated data from signal response obtained from the transducer.

Table 1. Theoretical and actual leak distance.

Pressure (mmHg)	Leak distance (m)		Percentage error (%)
	Theoretical	Actual	
2	27.08	26.82	0.96

4. Conclusion

In this paper, it was endeavoured to detect the leaking through medium density polyethylene (MDPE) pipe by using a transient method. This method was verified due to the percentage error between the analytical and theoretical just below than 1%. In this study, the ensemble empirical mode decomposition (EEMD) method was used in order to decompose the response from the original response. The leakage was successfully detected through the pipe with only small tolerance of error.

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