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Leak Detection in MDPE Gas Pipeline using Dual-Tree Complex Wavelet Transform

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ABSTRACT

Background: The pipeline system plays the important role in the industry and commonly use as media transport in the piping field on the land or on the sea as well. They are buried underground or situated in the wall of the buildings. The maintenance should be done properly to avoid any leakage to the surrounding. Therefore, the detection of the leak detection is the main investigation issue in order to get the fast and reliable leak detection method. Even though the reasons for these leaks are very well known, some of the current method is quite complicated and not precise. In addition, it is all about time consuming and cost of installment. In this paper, we proposed a leak detection method using acoustic. The chirp signal injected into the pipeline system and the estimation of the leak location from the delay time passing by the reflection in the pipeline if there have a leak. Using Dual Tree Complex Wavelet Transform, the signal filtered and decomposed into five levels. Then, the cepstrum analysis was used to detect the echoes for leak location estimation. When a leak occurred, the new peak shows and identified the presence in the pipeline network. The leak detected at a certain point and the error in this experiment is 0.62 % for leak location and 1.24 % for the outlet., which is nearly accurate to the original leak position. The DTCWT and ceptrum analysis could give acceptable result and possible to identify leaks that are difficult to find by other method.

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INTRODUCTION

In any application of engineering structure, pipelines are almost the main part to complete the media transport. The pipeline can be used to transfer air, water, oil and other fluids because of their cost and safety. Thus, as the main media transport they should be properly maintained, to avoid leaks. Usually, the leaks occur caused by damage from any accidents. The leaking and location of leaks needs to detect early. Monitoring any leaking is important in order to prevent any losses of fluid in term of cost. In addition, it can prevent any hazard to the surrounding. Different methods are used to investigate the leaking and their location. It includes visual inspections, acoustic emission, and dynamic pressure measurement. This paper proposed a signal processing method which is Dual Tree Complex Wavelet Transform (DTCWT). This signal processing tool analysis mainly decomposed the high frequency in low and high frequency. The cepstrum analysis used to find the echoes in the pipeline and as the main component to calculate the leak location with an equation.

Basic Principle Of Acoustic Leak Detection:

In air, sound travels by the compression and rarefaction of air molecules in the direction of travel. However, in solids, molecules can support vibrations in other directions, hence, a number of different types of sound waves are possible. When a leak or ruptures occurred in some places, there will be a change in the pressure balance which generated by friction of the gas or fluid with the wall of the pipeline. The reflection can be detected if there have blockage such as hole, junction, crack and ruptures. This reflection is known as a pressure wave that through inside the pipeline at the speed of sound (Lighthill, 1978). Figure 1 shows the concept of the reflection when a leak occurred. The time of reflected wave can be captured by generating pressure wave at certain location together with single remote sensor (Beck, Williamson, Sims, & Stanway, 2001). The low frequency can propagate for along the pipeline while the higher frequency will attenuate faster. Only the low frequency signal plays an important role in the gas pipeline leak detection. So, low frequency is the focus of this study.

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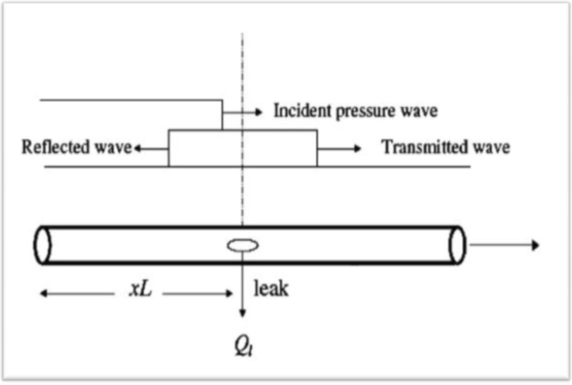

Fig. 1: Conceptual wave reflections at a leak (Hunaidi & Chu, 1999).

Acoustic sensor normally installed outside the pipeline network. The leak generates noise and pick up by these acoustic sensors and the most important thing is to minimize the background noise (Chis & Saguna, 2007; Scott & Barrufet, 2003). The location and size can be determined by using acoustic methods. This method can be used on new as well as on the existing pipe network. The fast and high sensitivity gives advantages in this method compared to others. In addition, this method also offers accurate leak location and low false alarm rate (Meng, Yuxing, Wuchang, & Juntao). But, high background and noise condition will affect the actual leak and also produce a false alarm when the leak is too small (Murvay & Silea, 2012; Scott & Barrufet, 2003; Sivathanu, 2003; Wang, Short, Dawson, & Lennox, 2009).

Dual Tree Complex Wavelet Transform:

Complex Wavelet Transform (CWT) is the one of the Wavelet Transform (WT) that extend from the Discrete Wavelet Transform (DWT) and generates complex coefficients to obtain real and imaginary parts. It is a two-dimensional wavelet transform which provide multiresolution, sparse representation and useful characterization of the structure of an image. The tree divided into to two parts which are being real tree and imaginary tree (Dewangan & Bhonsle, 2013).

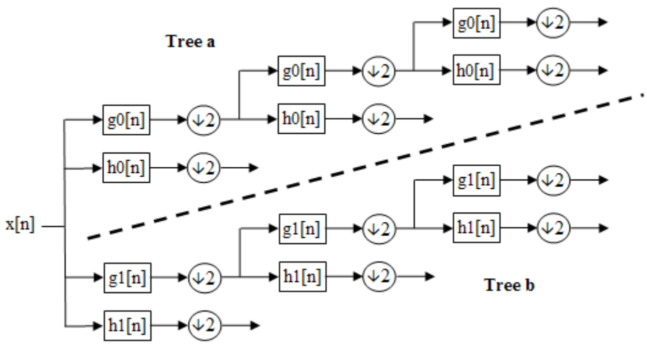

Fig. 2: Block diagram for 3 levels of DTCWT.

The necessary characteristic part that need to concern are (Dewangan & Bhonsle, 2013):-
· The low-pass filters in the two trees must differ by half a sample period.
· Reconstruction filters are the reverse of analysis.
· All filters are from the same orthonormal set.
· Tree *a* filters are the reverse of tree *b* filters.
· Both trees have the same frequency response.

Experimental Design:

The medium density polyethylene (MDPE) pipe was used in this project with length 35.3 m and diameter of 63 mm. MDPE pipe widely uses in gas and water distribution system because of their durability and easy to handle.

For experimental process, the natural gas, which is air will be induced in the pipeline as input. The compressor is the main component to force the air to flow in the pipe. The gas will flow in the pipe and the hole that drilled at 14.75 m from the front pipe to simulate leak point. The total length of this MDPE pipe is 35.3 m. The diameter of the hole is 10 mm. For excitation signal, the speaker used in order to give good propagation. The speaker with closed end and sealed together with a waveguide lens to decrease the noise from surrounding. It has made sure to get the useful signal or output of leakage from the hole. The signal acquired from the wave that catch by microphone and then collected in data by DasyLab. The distance between the speaker and the microphone assumed to be negligibly small. Figure 3 shows the basic experimental setup for this study. National Instrument (NI) is the component to collect data and DasyLab is the also known as Data Acquisition System Laboratory to save the data. DasyLab will act as a filter of noise. The NI_DAQ would be synchronized with the transducer and DasyLab using NIDAQ-MX software. The chirp signal injected into the MDPE pipeline with 20-600 Hz as the input signal. The block size set up at 2000 and the sampling rate is 20 KHz.

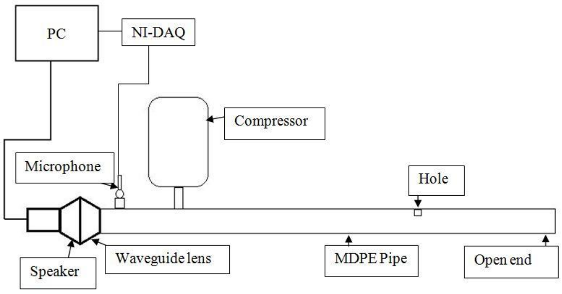

Fig. 3: Basic experiment setup.

RESULT AND DISCUSSION

The raw data acquire from the Dasylab and analysis in Matlab using DTCWT for filtering method. Figure 4 shows the original signal for leak and no leak for MDPE pipe and then reconstructed. This filtering method applies two types of filter which are raw data filtering used by 1st level and signal filtering for next level (2nd level to 5th level). The first filter called 'legall' and second filter is 'qshift_32' type.

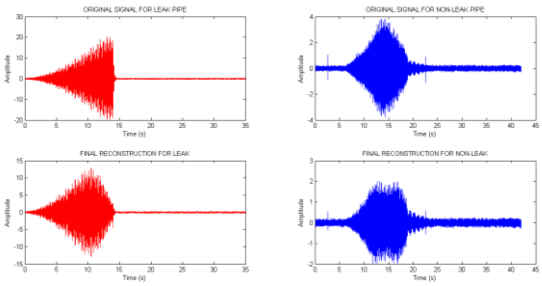

Fig. 4: Original signal and final reconstruction for leak and no leak.

The next step is decomposition part which is DTCWT will decompose the signal into high and low frequency. Only low frequency gives useful data for analysis. The decomposition up to 5th level as shown in Figure 5 and Figure 6.

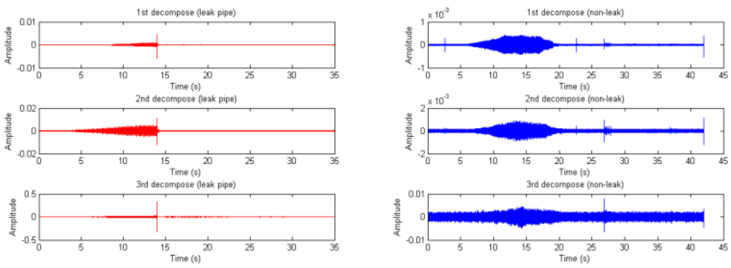

Fig. 5: 1st level until 3rd level of reconstruction of leak and no leak.

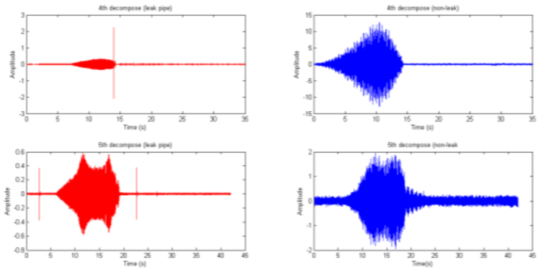

Fig. 6: 4th level until 5th level of reconstruction of leak and no leak.

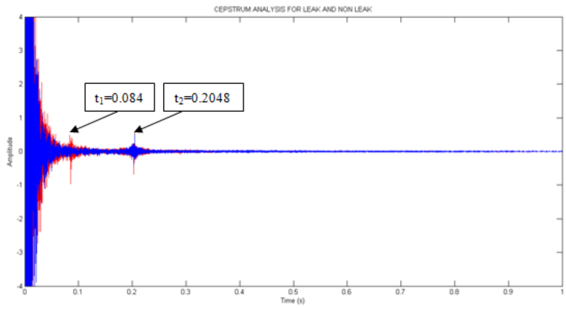

Fig. 7: Comparison between leak and no leak for ceptrum analysis.

Using spectrum analysis, the echoes detected at certain times as shown in Figure 7. The echoes detected at t_1= 0.084 s and t_2=0.2048. t_1 represent leak and t_2 is the outlet that clearly detected using cepstrum. As informed, the leak was simulated at 14. 75 m and total length 35.3 m. The distance of the leak can be calculated using the following equation:-

$$s = \frac{\Delta t \; x \; a}{2} \qquad (1)$$

where:-
s= distance of the leak (m)
Δt= change time (s)
a=speed of sound (m/s)

It is totally worth to mention the speed of sound is 349 m/s when the distance of the leak detected at 14.658 m and outlet at 35.7376 m which is nearly accurate to the experimental parameter which is leak at 14. 75 m and outlet at 35.3 m. The error for leak location is 0.62 % and for the outlet is 1.24 %. The error may caused by additional noise and also lag happen during data was captured.

Conclusion:

In this paper, a filtering method which is Dual Tree Complex Wavelet Transform was introduced to detect leak from MDPE pipeline. An acoustic method based on pressure wave through a gas pipeline investigated and analyzed using cepstrum analysis to detect the echoes in the pipeline. It is an effective filtering method which can decompose the high frequency and low frequency. The features in the pipeline simulated by hole as the leak. The result shows that the leak detected at 14. 658 m and outlet detected at 35.7376 am which is nearly accurate to the experimental parameter. The error is about 0.62 % for leak and 1.24 % for an outlet. Work is continuing to improve the accuracy and reliability of the method. The experiment should also be tested for longer pipeline and other features such as junctions and ruptures.

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