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Leakage Detection in Pipelines Using Ensemble Empirical Mode Decomposition Analysis

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ABSTRACT

There are many numbers of possible approaches to detect leaks. Some leaks are simply noticeable when the liquids or water appears on the surface. However many leaks do not find their way to the surface and the existence has to be check by analysis of fluid flow in the pipeline. The first step is to determine the approximate position of leak. This can be done by isolate the sections of the mains in turn and noting which section causes a drop in the flow. Next approach is by using sensor to locate leaks. This approach are involves strain gauge pressure transducers and piezoelectric sensor. The method implies steady-state and transient signal wave as a benchmark between normal and chaotic fluids flow. From the data set of signal recorded, the data will be display as one set data with certain time frame. The data in decomposed and filtered by using ensemble empirical mode decomposition analysis method into many signal time frame known as intrinsic mode function in addition of signal residue.

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INTRODUCTION

From the end of the rural area, right down to the big city, each individual need clean water supply with best guaranteed quality. Currently, over 1.4 billion people live near water resources where the use of water already exceeds minimum recharge level resulting depletion of ground water (Crisis; 2006). History proves that every generation of human were always trying to produce the best and efficient water supply system. As time goes, every generation tries to improve the previous system and existing.

Pipe leaking can be happen in many forms such as burst, hole and cracks. In global world water loss or water leaking can vary between 10 to 40% of total water volume produced, which can be great economic importance [5]. In Malaysia, there had been recorded 21.90% of physical and 14.70% of commercial water loses in year 2009. According to statistic, Pahang have the highest percentage water loses that is 59.9% followed by Sabah (49.41%). The other states also have high percentage that is exceed 20% of loses (kewangan ; 2010). Leakage of water usually occurs from mains and service connections at joints and fittings. The leaking occurrence can't be taken lightly because it may cause great loses in economy and environment.

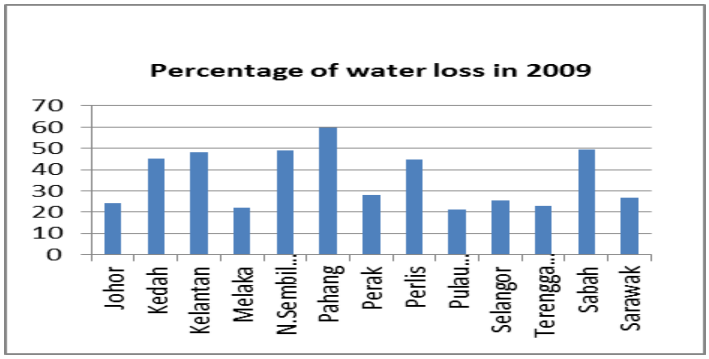

Fig. 1: Percentage graph for water loss in each state in year 2009 (H.M. Salleh 2010).

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Transient-based leak detection method:

Transient method is based on properties of transmission and reflection at pressure wave. When flow propagates, pressure wave will change the wave and then customized by friction forces resulting the damping and smoothing of pressure peaks. Pressure wave will transmit along the pipe and reflected back and if leakage is occur the amplitude signal will increase according to leakage dimension. Pressure transient or water hammer occur when there have fluctuation in pipeline due to a change in a system as for example sudden closed off valve in straight line pipes.

To operate this method, two sensors will be placed oppositely between the leaks. To detect the leak, there will need the present of noise but not all the time and all sensors can detect the noise. As the new techniques occur, this problem can be solving by just placing only one sensor (pressure transducer/piezoelectric) at the pipeline. When the pressure transient moves along the pipe and found the leaks, a reflection of the signal is created. This signal will be collected by the pressure transducer. Pressure and time information is measured. Then the data will be analysed by using another method of signal processing (S.B.M. Beck, M.D. Curren, N.D Sims, and R. Stanway, 2005). The noise from signal is filtered. Distance of signal to each feature must be calculated by the equation:

Distance to each feature = (Incoming reflection time) x (speed of wave)

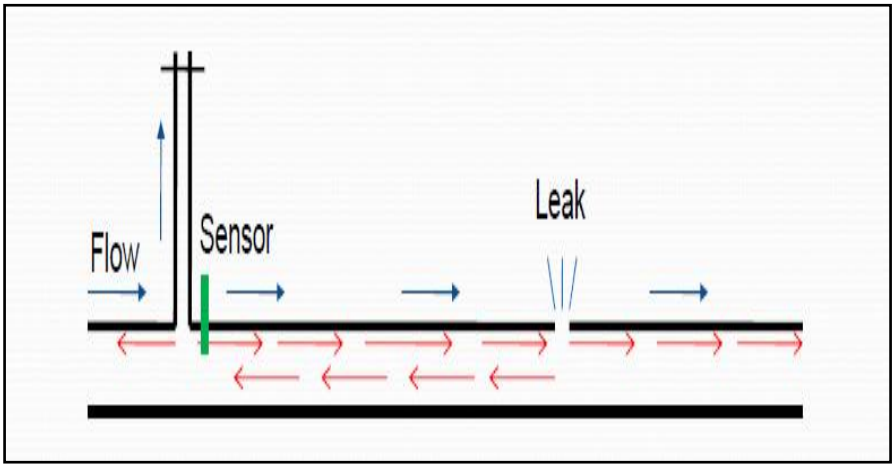

Fig. 2: Pressure transient detection operation (A.Seth., J. Shucksmith.;2012).

As a result of the pressure signal analysis extended to all tests, the mean value of the velocity of the water hammer wave should be estimated *(a)* m/s has been estimated; small differences in the *a* value from test to test can be explained with the existence of small trapped air volumes.Transient of Fig.3 corresponds to the intact-pipe condition. In these graph, it is show that the pressure wave reflected at the leak modifies the pressure signal and the presence of the leak causes a faster damping of the pressure signal (B. Brunone. 2001).

2. Development of Exeperiment:

The experiment is involving 1 inch MDPE pipe. Test rigs were connected to hydraulic bench which consist water tank and average power water pump. The experiment was designed by followed schematic diagram as in Fig. 3, where involve U-shaped pipeline with features.

Based on Fig. 3 the experiment was conducted to find calibration value. Leak was created based on pin hole type and this was controlled by ¾ inch valve. The captured signal was transferred to data acquisition. For the study of MDPE pipeline, 1600 sample size and sampling rate at 1600 Hz. Other tools that been used was DASY lab software where strain value and transient graph was recorded.

RESULT AND DISCUSSION

Ensemble empirical mode decomposition (EEMD) analysis:

Ensemble empirical mode decomposition also known as noise assisted signal analysis (NASA) (Z. Wu., N.E.Huang. 2009) has three basic theory for signal analysis process. First theory is to destroy the adaptive nature of EMD, secondly is make sure white noise gives uniform frames of scales and lastly cancel the white noise with sufficient number of ensemble.

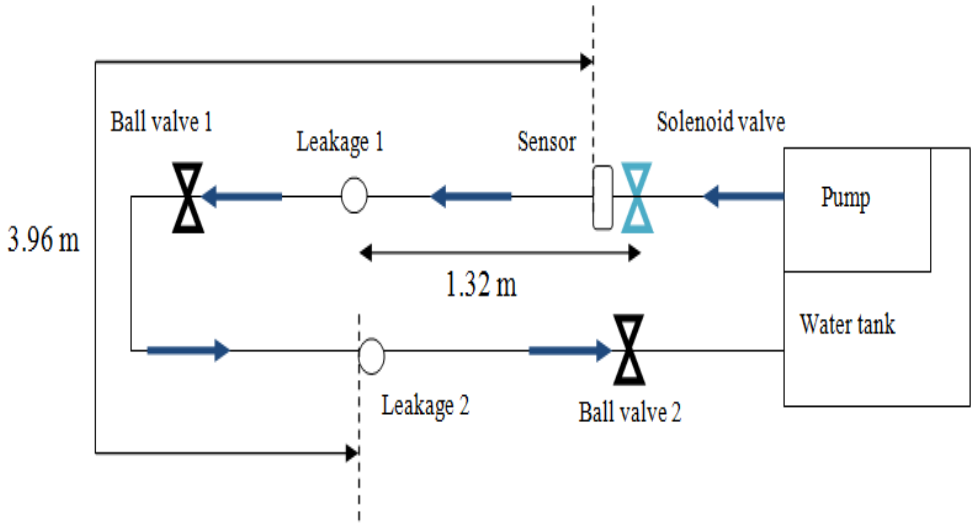

Fig. 3: U-shape pipeline with features schematic diagram for MDPE pipeline.

Sample size 1600 with first leakage in the MDPE pipelines:

Fig.4 shows the signal captured in MDPE pipeline with leakage within 15 seconds. The signal is decomposed into seven IMF with the final component indicating the residual of the signal. Transient of signal was stimulated by solenoid valve at zero seconds. From the signal data set, it shows an obvious signal transient at 4.63 seconds. The transient was unable to be recorded in signal wave data without leakage, so the data is assume as a potential leakage that happen at 4.63 seconds.

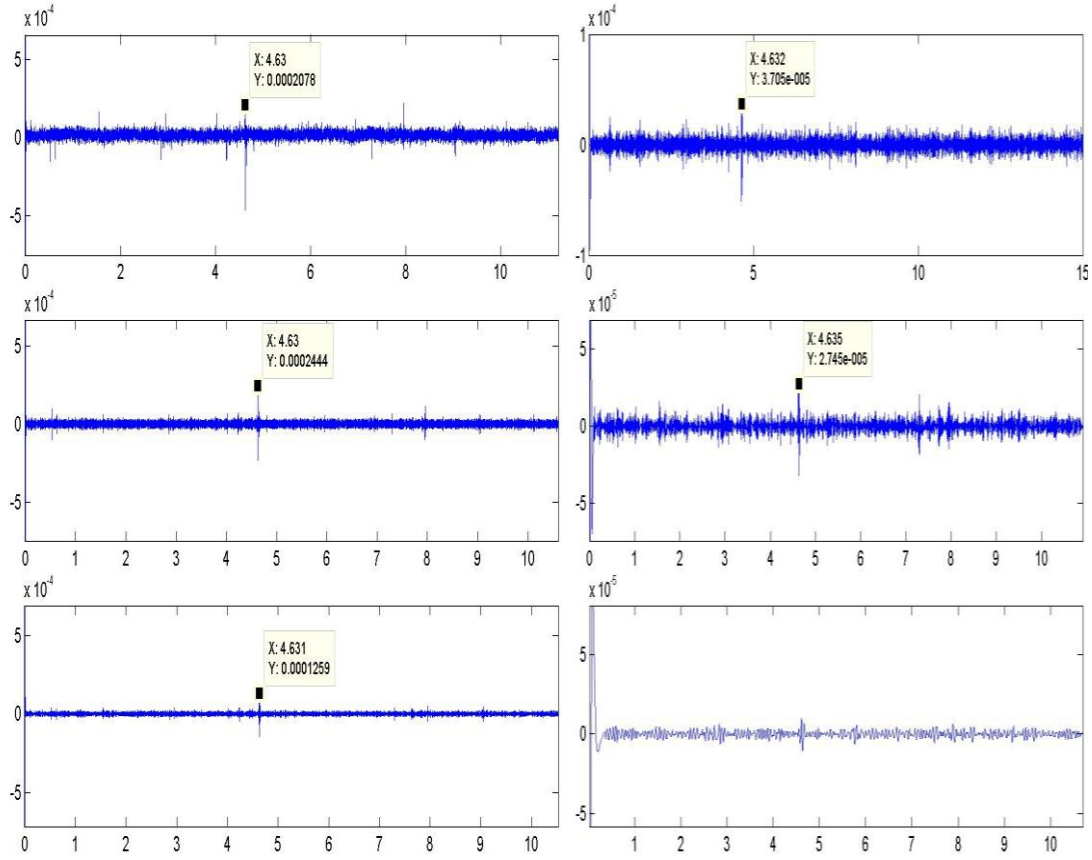

Fig. 4: EEMD analysis graph with first leakage for MDPE pipeline.

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The Fig.4 also shows other transient signal waves that happen in time frame 15 seconds but after been decomposed by using ensemble empirical mode decomposition with addition of 0.2 amplitude of white noise and 100 ensemble, the signals were removed. The transient signal at 4.63 seconds still can be detected until at six IMF. The transient signal 4.63 seconds was calculated into following equation.

$$s_\ell = \frac{\Delta t_\ell \; a}{2} \quad (1/1600) \tag{1}$$

Where:

s_ℓ is distance of pressure wave produced and leakage.

ΔT_ℓ is changes time between initial and reflected wave.

A is wave propagation speed. $\frac{m}{s}$ In MDPE pipeline, the propagation speed is 950 and time change is 4.63. The equation needed to divide with 1600 because of the data was recorded in sample rate 1600 in one second. The result is 1.374 m which is nearly accurate to measured leakage distance that is 1.32 m. It can be concluded that the existed transient wave signal at 4.63 seconds is the first leakage in time frame 15 seconds and there only 4.09% of error occurred in the analysis and measurement. The error may causes by additional noise influenced by motor pump that was located not far away from the leakage, undetectable leakage at joint of figure and lag happen when the data was captured and recorded.

Conclusion:

In this paper, the data obtained then was calculated in leakage detection equation influence by sample size of the signal was recorded. From the study, EEMD analysis predict satisfactorily the location of MDPE as it can detect and locate the leak up to error of 4.09% and 0.61% for leakages in MDPE pipeline. The EEMD method had perform the best and already produce an acceptable result.

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