LEAKAGE DETECTION IN PIPELINES USING SYNCHROSQUEEZE WAVELET TRANSFORM

ABDUL HADI BIN CHE HUSSIN

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2013

ABSTRACT

This research project is focusing on the leakage detection in the pipelines system using synchrosqueeze wavelet transform. The detection of water leakages in water distribution system has always been a challenge in the water industry as most water pipelines are laid foot underground which are normally unseen to human naked eyes until water starts to flow out from roads and creates puddles. The age in pipelines network is a major problem and the reduction of these has become a major priority for pipeline authorities around the world. Although the reasons for these leaks are well known, some of the current methods for locating and identifying them are either complicated or imprecise and most of them are time consuming. The objective in this study is to develop a test rig and conduct the experiment base on pressure transient method by identify and locate the position of the leakage occur in pipeline using signal processing synchrosqueeze wavelet transform. This project method are developed based on pressure transient by using single pressure transducer and analyses on newly method of analysing called "synchrosqueeze wavelet transform". The first technique used the simple test rig pipeline system which in straight shape with one leakage and one outlet pipe system can identify and locate leak up to error 0.75%. The second technique used U-shape design test rig with include two leakage and one outlet pipe system and the show result error 0.3% for leak 1 and 0.25% for leak 2. The effectiveness of the proposed technique has shown great potential to locate a leak. The analysis by using synchrosqueeze wavelet transforms can be considered the first application to leak detection and location. For recommendation in this study by apply the methodology of leakage detection in pipeline at street pipeline site at real distribution network based on transient signal by using single pressure transducer at the pipe hydrant.

ABSTRAK

Projek ini memfokuskan mengesan lokasi kebocoran di dalam perpaipan menggunakan pengubah gelombang kecil pemerahan selaras. Penemuan kebocoran dalam sistem pengagihan air menjadi cabaran dalam industri air. Kebanyakan paip air di letakkan di bawah tanah dan selalunya kebocoran tidak kelihatan pada mata manusia sehinggalah air mula mengalir dan bertakung. Penemuan dan lokasi kebocoran di dalam sistem perpaipan adalah masalah besar dan pengurangan masalah ini menjadi satu keutamaan untuk badan yang bertanggung jawab seluruh dunia. Walaupun sebab kebocoran ini sudah diketahui, ada diantara cara yang ada sekarang mengesan untuk mengesan dan mengenalpasti kebocoran adalah sama ada rumit dan tidak tepat dan kebanyakannya mengambil masa. Kaedah projek ini dibangunkan berdasarkan tekanan fana dengan menggunakan satu tekanan transducer dan di analisis berdasarkan kaedah baharu di panggil pengubah gelombang kecil pemerahan selaras. Obektif dalam kajian ini ialah untuk membangunkan satu ujian eksperimen saluran paip dengan berteraskan kaedah tekanan fana untuk mengenal pasti dan mengesan kedudukan kebocaran yang terdapat dalam saluran paip menggunkan pemprosesan isyarat pengubah gelombang kecil pemerahan selaras. Teknik pertama menggunakan ujian eksperimen saluran paip mudah yang berbentuk lurus dengan satu kebocoran dan salur keluar sistem yang mana dapat mengenal pasti dan mengesan kebocoran pada ralat 0.75 %. Teknik kedua menggunakan ujian eksperimen saluran paip bebentuk U dengan 2 kebocoran dan satu salur keluar system dan keputusan ralat ialah 0.3% untuk kebocaran 1 dan 0.25% untuk kebocoran 2. Keberkesanan teknik ini telah menunjukan potensi besar bagi mengesan kebocoran. Analisis dengan menggunakan pengubah gelombang kecil pemerahan selaras dapat di pertimbangkan untuk mengenal pasti dan mengesan kedudukan kebocoran. Bagi cadangan dalam kajian ini ialah dengan megaplikasikan kaedah kajian ini di rangkaian pengagihan sebenar saluran paip bedasarkan kaedah tekanan fana menggunakan tekanan transducer di paip pili bomba.

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURE

LIST OF ABBREVIATIONS

NRW	Non Revenue-Water
AC	Asbestos Cement
MS	Mild Steel
uPVC	Unplasticised polyvinyl chlorine
HDPE	High Density Polyethylene
MDPE	Medium Density Polyethylene
DI	Ductile Iron pipe
GPR	Ground Penetrating Radar
FFT	Fast Fourier Transform
STFT	Short Time Fourier Transform
WT	Wavelet Transform
IF	Instantaneous Frequency
WVD	Wigner-Ville distribution
TF	Time-frequency
TFR	Time-frequency representation
IA	Instantaneous Amplitude
CWT	Continuous Wavelet Transform
ST	Synchrosqueezee Transform
GI	Galvanized Iron
SDR	Standard Dimension Ratio
MRS	Minimum required strength

PE	Polyethylene Pipe
SIRIM	Standards and Industrial Research Institute of Malaysia
PT	Pressure Transducer
SWT	Synchrosqueeze Wavelet Transform
EMD	Emprical Mode Decompostion
CWT	Continuous Wavelet Transform
LRM	Leak Reflection Method

CHAPTER 1

INTRODUCTION

1.0 GENERAL

Water is a one of the most essential elements on earth to all human being and to be scarce supply in most parts of the world. The world scenario nowadays, water is a global issue. The World Water Vision Report, 2000 acknowledge that there is a global water crisis. The crisis is not about having too little water to satisfy our needs but it is a crisis of water management so badly for billions of people in the world and other words “suffer badlly”. The lack of water services is one of the most important physical signs of extreme poverty. As estimated in Global Water Supply and Sanitation Assessment 2000 Report by World Health Organisation (WHO) and United Nations Children’ Fund (UNICEF) [1], 780 million people had no access to improve water supply and 2.5 billion were without access to improved sanitation. If current trends continue, these numbers will remain unacceptably high in 2015, 605 million people will be without an improved drinking water source and 2.4 billion people will lack access to improved sanitation facilities.

Water loss is common problem that occurs in all water supply system. To management the water reducing is special concern of every water supply company. Most urban areas throughout the world are losing 30 to 50% of their water supply to leakage. An investment in repairing leaks, purchasing new pipes and maintaining existing and new pipe structures would pay for itself in conserved water in a few years.

For example, Mexico City's water system loses 1.9 billion cubic meters of water every year due to leakage [2].

The growth in population and expansion in urbanization, industrialization and irrigated agriculture are imposing growing demands and pressure on water resources, besides contributing to rising costs and have a face rigorous scrutinisation from environmentalists and conservations. The fact that the volume of water available is finite and increasing indicates that the supply approach in water management is unsustainable [45].

The problem is well known, Malaysia is the rich in water resources, but the demand for clean water is increasing throw over the years. The water crisis faced by most residents in the central of region the country during 1998. Due to the increasing demand of water, an efficient water distribution network is the key to prevent the repetition of such water crisis.

1.1 PROBLEM STATEMENT

The detection of water leakages in water distribution system has always been a challenge in the water industry as most water pipelines are laid foot underground which are normally unseen to human naked eyes until water starts to flow out from roads and creates puddles. The detection and location of leaks in pipelines network is a major problem and the reduction of these has become a major priority for pipeline authorities around the world. Over the past few centuries, various equipment's had been improvised in order to aid the related body to detect and locate the leak in water distribution system. Although the reasons for these leaks are well known, some of the current methods for locating and identifying them are either complicated or imprecise and most of them are time consuming. In the current study, the method is developed based on synchrosqueeze wavelet transform is viable approach to location in pipeline network and used for pressure wave.

The method uses pressure waves causes by quickly opening and closing a valve and known as water hammer that a pressure fluctuation in pipeline due to a change in the system. However these methods are hard to control valve by quickly opening and closing with hand of human being because have not the actual time. By using the solenoid valve is the perfect solution to create pressure transient by opening and closing a valve rapidly.

1.2 OBJECTIVE

1. To develop a test rig and conduct the experiment base on pressure transient method
2. To study the practical implementation signal processing of synchrosqueeze wavelet transform method for leakage detection in pipeline.
3. To identify and locate the position of the leakage occur in pipeline.

1.3 SCOPE

1. Design the experimental leakage detection test rig.
2. Perform the experimental laboratory for the data measurement.
3. Perform the signal analysis using synchrosqueeze wavelet transform.

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

Pipelines are the most important way of transporting fluid from one place to another place through a pipe. They operate over many years and providing a safe means of conduit. These pipes are ubiquitous and may have to operate under adverse conditions (weather, soil chemical, vibration, pressure or bad installation method) [4]. Leakage detection system is an application used for industrial application as well as for pipe networks for solving the problem of pipe leakage and pipe burst that can make industrial lost many money or production in fluid or gas. In industrial applications each leg or pipe segment is handled separately. Measurement of pressure or discharge is taken at both end of the pipe segment to simulate the flow in this particular leg. This, in fact makes such of leak detection system costly. The leakage detection in water networks usually uses or more less for industrial application [5].

According to survey conducted by Selangor Water Management Company (PUAS Bhd) survey show 20-40 % of water lost in the pipes network is due to leaks. Figure 2.1 shows that about 23000 customer complaints of pipeline leaks at Selangor in 2000[6].

No.	Type Of Complaint	No. Of Complaints			Total
		Jan – Mar	April	May	
1	Pipe Burst	1,938	776	766	3,480
2	Pipe Leak	13,843	5,781	5,923	25,547
3	Low Pressure	1,048	515	473	2,036
4	Dirty Water	444	160	274	878
5	Odour	78	31	1	110
6	No Water	2,424	1,086	1,280	4,790
7	High Bill	2,124	1,374	1,362	4,860
8	No Water Bill	97	34	17	148
9	Meter Lost/Stolen	265	124	96	485
10	Pilferage/Illegal Connection	262	145	215	622
	TOTAL:	22,523	10,026	10,407	42,956

Figure 2.1: The various types of complaint received for the past five months at Selangor in 2000 [6].

To determine the position and leakage rate form pipelines is unpredictable, many company of pipelines are looking for the simple and high accuracy method in order to find the exact location of leaks, burst and blockages impurity in their pipelines. For the best method to determine or locate any leak detection method should be fast and accurate and cheap to use the technique. The method should be able to detecting and located the existence and position from the very small leaks. In addition the method proposes for detection should not interfere with the normal job method or the operation of pipeline processes [4].

2.1 NON-REVENUE WATER

Over the past decades, the water companies face growing challenges to maintain reliable supply while meeting growing demand. The water situation for the country in Malaysia has changed from one of relative abundance to one relative scarcity. This is because the population growth and rapid urbanization and industrialization are imposing rapidly growing demands and pressure on the water recourses. Water supply is subjected to the fluctuations of nature and is therefore largely beyond our control [7].

Water loss occurs in all distribution system, only the volume of loss varies. In the past decades, water loss evaluation has been concentrated on the issues of effective customer metering, categorizing the different elements of water loss and understanding how leakage reacts to different operating modes [8]. There are various techniques to gauge the loss of water. For instances, uncounted water or non-revenues water, water loss index, supervising and testing of meter and also complains from consumer. Among all the techniques, the (NRW) non-revenue water is the famous techniques that used by company of water to measure the water loss. This indicator shows the discrepancy between quantity of water supply and also quantity of used water being recorded by meter [3].

Non-revenue water (NRW) is defined the amount of water put into the systems that brings no revenue to the water supply authority concerned [9]. NRW components consist of physical and commercial losses mean that the water consumed but gives no revenue in the system [10]. Commonly, non-revenue water is expressed in percentage, which is [3];

$$\text{Non Revenue water} = \frac{Production - Metered\ use}{Production} \times 100\% \tag{2.1}$$

The operation cost in pipeline system could be reduced when the physical loss could be solved. However, for commercial reduction, it will only recover back all the unbilled quantity and this will give immediate impact on the revenue pipeline system due to increase on collection from consumers.

The average non –revenue water level recorded nationwide is 36.63% and from Figure 2.2 shows that it is estimated about 21.93% is due to the physical loss and 14.70% is caused by commercial loss. The reasonable non –revenue water level and projected to be accomplished genuinely in 5 years period if special division is approved by government is 26.90% of which 17.00% is projected due to physical loss and 9.90% by commercial loss. From the observations, several states recorded a high NRW level exceeding 40.00%, such as Pahang is 59.9%, Sabah is 49.41%, Negeri Sembilan is 49.16%, Kelantan is 48%, Kedah is 44.97% and Perlis is 44.67%. The others states are also recording high physical loss which is more than 20.00% [10].

STATE	NRW CURRENT (%)	PHYSICAL LOSS		COMMERCIAL LOSS	
		CURRENT	PROJECTION 2015	CURRENT	PROJECTION 2015
		%	%	%	%
Johor	31.95	19.00	17.00	12.95	9.90
Kedah	44.97	28.00	17.00	16.97	9.90
Kelantan	48.32	30.00	17.00	18.32	9.90
Melaka	29.71	20.00	17.00	9.71	9.00
N.Sembilan	49.16	27.00	17.00	22.16	9.90
Pahang	59.90	27.00	17.00	32.90	9.90
Perak	30.68	24.00	17.00	17.68	9.90
Perlis	44.67	22.00	17.00	22.67	9.90
Pulau Pinang	19.08	11.00	10.00	8.08	8.00
Sabah	49.41	30.00	17.00	19.41	9.90
Sarawak	29.52	18.00	17.00	11.52	9.90
Selangor	32.49	23.00	17.00	9.49	9.00
Terengganu	37.85	22.00	17.00	15.85	9.90
NATIONWIDE	36.63	21.93	17.00	14.70	9.90

Figure 2.2: Current and projected NRW level for year 2015 [10]

2.1.1 Source to the NRW Problems

It is commonly known that the Non-Revenue Water (NRW) is separated into two main components, namely physical and commercial losses.

1) Physical loss is due to the following factors:

   a) Pipe burst
   b) Leakage principally the old asbestos cement pipe

The main reason of high physical loss in the whole country is recognised to be caused by leakage of old and broken-down asbestos cement pipes. From Figure 2.3 shows that currently, there is about 127,275km in length of water pipe of several types in the whole country. These pipes are of Asbestos Cement (AC) of 44,282 km is 34.80%, Mild Steel Pipe (MS) of 29,372 km is 23.10%, HDPE pipe of 22,111 km is 17.37% , Unplasticised Polyvinyl Chlorine (uPVC) of 18,683km is 14.70%, Ductile Iron Pipe (DI) /CI of 9,885 km is 7.70% and other types with total length of 2942 km is 2.30% [10].

STATE	Pipe Length (km)	Pipe Length (Based on Pipe Type (km))					
		AC	MS	uPVC	HDPE	DI/CI	Others
Johor	18,781	7,861	3,427	4,942	849	1,681	21
Kedah	14,644	5,816	2,104	1,958	3,798	964	3
Kelantan	4,982	3,632	194	276	401	175	305
Melaka	5,687	1,826	976	810	1,724	131	219
N Sembilan	7,480	4,710	1,522	159	423	301	364
Pahang	8,853	3,450	1,622	780	1,957	200	844
Perak	10,659	2,764	1,306	1,707	4,322	556	3
Perlis	1,806	948	219	3	628	8	0
Pulau Pinang	3,916	1,402	736	94	998	674	11
Selangor	24,893	5,652	12,875	3,527	1,195	845	799
Terengganu	7,138	1,531	1,421	2,804	596	760	25
Sabah	8,376	2,345	2,622	1,620	796	687	306
Sarawak	9,590	2,121	311	1	4,253	2,861	43
Labuan	471	225	37	0	170	39	0
NATIONAL	**127,275**	**44,282**	**29,372**	**18,683**	**22,111**	**9,885**	**2,942**

Figure 2.3: Pipe length and type [10]

2) Commercial Loss factors:

a) Inaccurate meter reading is the quantity showed the old meters is less than the actual
b) Water theft illegitimate tapping
c) Maintenance of water supply system through pipe flushing after leakage repair works, reservoir cleaning and fire brigade use.

From commercial aspect, most of the states recorded a high level refer to Figure 2.2 of loss except Selangor, Pulau Pinang and Malacca where these states recorded a commercial loss of less that 12.00% and other states such as Pahang, Perlis, Negeri Sembilan, Sabah, Kelantan and Kedah recorded high level of commercial loss of more than 16.00% [10].

2.2 LEAKAGE DETECTION METHODS

The leak detection techniques may be classified into two categories; external and internal methods. The external methods can detect the leak by looking from eyes for signs of it external the pipelines and for the example of this external method by using visual inspection and appreciate equipment. For the internal methods, such as internal inspection is try to find the leak and blockages impurity from inside the pipes and for the example in this category are included a panoply of mathematical, computation and signal processing methods such as the volume balance and some of these signal processing methods are based on pressure transient and use of some form of measuring instrument for data capture [4].

2.2.1 Leak Detection Technique based on external methods

The detection technique based on external methods can detect the leak by looking from eyes for signs of it external the pipelines and for the example of this external method by using visual inspection and appreciate equipment. However, most of these methods have been used to detect and locate the leaks, but most of these methods can’t determine the quantity of the leakage. Examples of this method are visual observation, tracer gas method, infra-red thermography, ground penetrating radar (GPR), video inspection and acoustic leak detection.

2.2.1.1 Visual Observation

Leakage detection for external method using visual observation is a traditional and also the simplest method to detect leaks. This can be done by experienced person who can detect and locate the leaks either by flying, driving or walking along the pipeline, searching for abnormal activity near the pipeline or listening to the noises and vibration generated by product escaping from a hole [8]. Over the decades, leaks from the pipelines were detected by visual observation of fluid. Since these detection methods for historic leaks are so limited in resolution and effectiveness, it is likely that a significant number of pipeline leaks have not been detected. Therefore, a technology was needed to detect the specific location of unknown pipeline leaks so that characterization technologies can be used to identify any risks to groundwater caused by waste released into the vadose zone [11]. The unsaturated zone, sometimes called the vadose zone or zone of aeration [12].

2.2.1.2 Tracer injection

The definition of this technique is that a non-toxic, water in soluble and lighter than air gas such as helium or hydrogen is injected into the pipe system that have isolated segment of water pipe. Then the operation of this technique, gas escapes at a leak opening and then, being lighter than air, permeates to the surface through the soil and pavement. For the result, the leak is located by scanning the ground surface directly above the pipe with a highly sensitive gas detector [13]. In addition, it can be used in any containment pipe networks (water, gas, etc.), and also it can be used to detect leaks at any stage in the life of the landfill. On the other hand, tracer gas methodology is widely used for the machinery testing; however the high time consumption and high cost and give this method cannot be used for everyday leak inspections motoring in the pipeline. Furthermore, this method does not usually find the location and size quantity of the leak cannot be accuracy [8].