DESIGN AND FABRICATION OF LEAD DETECTION TEST RIG

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ABSTRACT

Manufacturing is a process of converting raw material into product. It can be described the transformation of materials into items of greater value by means of one or more processing and/or assembly operations. The study of manufacturing was very important in order to carry out this project to ensure that students understand on what are need to do. This project is about designing and fabricating of lead detection test rig. This project involves the process of designing the piping by consider the type of pipe, and the component that involve to detect the leakage in the pipelines. From the investigated, there have many methods to detect the leak. From the investigated, the design was improved and fabricates the test rig for the analysis. The analysis were run after the fabricate is completed. After all the process had been done, these clotheslines may help us to understand the fabrication and designing process that involved in this project.
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1.1 Project Synopsis.

The purpose of the project is to design and fabricate a lead detection test rig structure for lead detection testing apparatus. This test rig structure should be able to stand the transducer water flow piping that contains several parts which are leakage point, flow meter, valve, and solenoid. In this project, a simple test rig structure has been designed and fabricated. As the Diploma Final Year project allocates the duration of one semester, this project needs a combination of knowledge and skills to handle several problems.

This project involves the fabrication of test rig structure with specification regarding the strength, material, and cost. Tests are required on the new design and fabrication to get a perfect result.
In University Malaysia Pahang (UMP) doesn’t have the test rig structure for leak detection testing apparatus. From this problem, came out an idea to design and fabricate a new test rig structure.
1.2 Project scopes.

i. Design the experimental leakage detection test rig using Solidworks software.

ii. Perform the design with upgrade the piping.

iii. Find the suitable material.

iv. Perform the experimental laboratory for the data measurement.

v. Perform the signal analysis using wavelet transform.

1.3 Project Objective

i. To fabricate the leak detection test rig.

ii. To study the practical implementation signal processing such as wavelet transform method for leakage detection in pipelines.
2.0 Introduction

The test rig structure is the main structure for the leak detects testing apparatus. The leak detect testing apparatus contains of several parts that is a valve, pressure transducer, flow meter, leak, solenoid and variable speed pump. The fluid that produce by the pump will flow through this pipe and the whole component will work. The pump have a variable speed, so to make an experiment about the pressure and flow water, we just change the speed that needed.

The leak detect test rig functions are to study and experiment how the transducer and other component working together. The leak detect test rig is the simple and easiest way to study about the real leakage in the pipe system and encourage the students about the leak detect testing apparatus.
2.1 Causes Of Leakages

There are many causes which contribute to the leakage problems in pipeline system. Among the causes are:

a. Corrosion :

Corrosion is not only contributing to the leakage problem, it also affects the quality of water being transmitted. Corrosion can occur inside or outside and causes the pipe to become weaker in supporting the outer force exerted on it. Corrosion which happen outside of the pipe is mainly due to the environmental effect while water happens quality and corrosion protection layer are the factor affecting corrosion happens in the inside of the pipe.

b. Material defects :

Material of the pipeline used may not comply with the standard requirements. This means that it may not able to sustain the designed water pressure and designed traffic load. Therefore it stands a high potential to get burst and cause leakage problem.

c. Faulty installation :

Every pipe need to be installed properly so that they can take up the water pressure and traffic load designed. Poor workmanship on the pipes installation will greatly reduce the capability of pipes to take up loads exerted on it and eventually causes leakage problem.
d. **Excessive water pressure**:  

Excessive water pressure resulting pipes with small thickness to be easily burst and causes leakage problem.

e. **Ground movement**:  

Ground movement is usually caused by drought or freezing, the arrangement of pipes will differ from its original position either horizontally or vertically after ground movement and this will lead to the non uniform distributed load on the pipes. The pipes will start to crack and eventually resulting in leakage.

f. **Excessive loads and vibration from road traffic**:  

Pipes are often designed to sustain certain amount of traffic loads. Pipes which have been put in used for a very long time may not have ability to sustain excessive increment of the traffic loads and therefore will crack and contribute to leakage problem.

g. **Old and poorly constructed pipelines**:  

This is due to the long term usage of pipelines which is no longer sufficient in providing its service to water supply.

h. **Poorly maintained valves and mechanical damage**:  

Mechanical damage usually will cause the pipelines system to not function in its optimum level which the quality of water pressure. In serious cases, it will result in the occurrence of leakage.
2.2 Impacts of Leakages

According to a research, water loss due to leakage water distribution system is generating more than just financial loss. Some leakage is generating more than just financial loss. Some of the potential impacts of uncontrolled leakages in water distribution system are:

a. **Loss of revenue.** Every state in the country spent an immense amount of cash in treating raw water and to deliver the treated water to its final consumer, which are community and the industry. Wherever leak presents is distribution system, the money spent will be lost and it is not recoverable. Observing the current leakages problem across the country, a state’s government is anticipated to be able to cut its operating cost to half or double its revenue should there is an efficient water detection survey.

b. **Optimum energy consumption cannot be achieved.** Pressure need to be increased in a water distribution system in order to deliver the water in the supply network system whenever leak occurs. This is because leakages will usually cause a significant plunge in pressure and thus the delivery of this energy will not be efficient.

c. **Risk of contamination.** Water pipelines are normally laid several feet underneath the massively developed and densely populated cities. These cities are usually exposed to numerous forms of pollution. Leakages in water
network system will increase the risk of contamination to treated water supply through seepage of pollutants from environment into the piping network.

d. **Damage to infrastructure.** As in the aforementioned impact, leakages tend to overflow from underground to road surface. Water is famously known for its destructive behaviors such as damaging the road structure and also causes skidding effect of vehicle which is definitely an effect that could endanger the lives of road users.

e. **Inefficient fire-fighting capabilities.** Due to the failure to maintain optimum pressure in the water distribution system servicing hydrants, fire-fighting capabilities may be reduced and becomes inefficient. This situation is certainly going to increase the number of lives and properties lost due to the presence of leaks in water distribution systems.

f. **Jeopardizing public confidence.** Complaints from the public which is more accurately to be addressed as consumers, is inevitable whenever there is a disruption in water supply. State water authorities are expected to be bombarded with numerous complaints from end consumers. This will not only increase the work loads of state water authorities, it will also jeopardize the public relations between consumers, this will not only increase the work loads of state water authorities, it will also jeopardize the public relations
between consumers and the authorities and generate unnecessary negative image among public.

g. **Delayed capacity expansion.** Leakage problem will increase the operating cost of state water authorities to treat more water as to meet the demand, increase the amount spent in network maintenance, and reduced revenue from inefficient water supply system. The decrease in revenue will prevent the state water authorities to expend its network capacity to serve more people.

### 2.3 Methods Of Leaks Detection;

Various methods have been developed in order to detect pipeline leakage in a more effective way. Among all the methods being developed, acoustic method is the one gaining much popularity compared to other methods such as tracer gas, ground-penetrating radar, infrared imaging and also thermography method. The acoustic methods is popular because it is easy to adopt and effective in detecting leakage. Other than aforementioned methods, pressure point analysis, wave alert, SCADA-based system, radioactive tracing and many more techniques are also common practices. These practices are described in the following paragraphs.
1 **Acoustic Methods**;

Acoustic device are the principle equipments used by the water industry to locate leaks in the distribution system nowadays. The adoption of acoustic-related devices is not uncommon since 1980s. In fact, the simple to understand, easy to operate, and most importantly high accuracy nature of this method has actually accelerated the technology development and advancement of acoustic devices. Today other than simple listening device such as listening rods, sounding stick and aquaphones, sophisticated equipments that utilizing acoustic theory to locate leaks at more diversified water distribution network, for example, leak noise correlator and Sahara leak detection system, had also been developed and are tested to be able to locate leaks efficiently.

The theory used behind the acoustic methods is sound will be induced by water as it escapes from pipes under pressure. Leak sounds are transmitted through the pipe itself over significant distance(depending on the pipe size and type), and through the surrounding soil into the immediate area of leak. By utilizing simple devices to listen for this sound, leaks can be detected easily. Although acoustic methods are widely practiced by the water industry, the detection and location of leaks are not always fruitful due to the several factors that may influence the listening process.

I. **Factors influencing the effectiveness of acoustic method**;

Factors that are influencing the effectiveness of acoustic methods are pipe size, type and depth; soil type and water table level; leak type and size; system pressure; interfering noise; and sensitivity and frequency range of the equipment. All this factors are actually dealing with the fundamental of acoustic methods, which
is the sound or noise generated from leak in a pipeline. The significance of each factor is discussed as follows:

a. **Pipe size, type and depth.** The attenuation of leak signals in a pipe depends greatly on the pipe materials and also the pipe diameter. For instance, leak signal is travelling farther in metal pipe than in plastic ones. The greater the diameter of the pipe, the greater the attenuation, which means the harder it is to detect the leak. Besides, the pipe material and diameter also effect the predominant frequencies of leak signals. Leak signals are more susceptible to interference from low-frequency vibration, such as from pumps and road traffic, if the diameter of the pipe is large and the pipe is less rigid, due to the lower predominant frequencies.

b. **Soil type and water table level.** In general, leak sounds are more audible on sandy soils than on clayey ones; and on asphalt or concrete surface that on grass. Besides, leak signals become weaker when the pipe is below the water table level.

c. **Location and size of leak.** Leaks occur at different part of a pipe will generate different frequency of noise. Splits and corrosion pits in pipe walls usually induce stronger leak signals and higher frequencies than leaks in joints or valves. Leaks which are to small may be too hard to induce leak signal significant enough to detected. Therefore, the larger the leak, the stronger the leak signals. But this may not true for every large leaks.
d. **Pipe pressure.** The higher the pipe pressure, the stronger the leak signals and thus the easier to locate a leak. However, increase pressure in pipe may reduce the efficiency of distribution network. The sudden increment of pipe pressure may also cause damage to piping system.

e. **Sensitivity and frequency range of equipment.**

   Indeed, the more sensitive the leak sensors, the higher the signal-to-noise ratio of the equipment, which means the smaller the leaks, can be detected. Filters and amplifiers may be incorporated to make leak signals more significant.

II. **Ground Surface Listening Devices;**

   There is several ground service listening devices as mentioned by Hunaidi (2000), which have been put in use for quite sometimes. These include listening rods, aquaphones, and geophones or ground microphones. To detect leaks in pipeline system, leak detection crew first roughly bracket leaks in the system by listening on all accessible contact points in the distribution system by listening on all accessible contact points in the distribution system such as fire hydrants and valves. Whenever suspected leaks are identified, the leak detection crew will start to pinpoint the leaks by listening on the ground surface at very close intervals (usually about 1 m) with the aforementioned devices. Although the operation of listening device usually straightforward, their effectiveness depends greatly on the experience of the user. If the crew was inexperienced, then it is very likely that he will miss out the possible leak location.
Besides, the noise generated is louder only when the leak is closer to the listening device. Thus, the crew may miss out a leak if he is further away from the leak.

III. Leak Noise Correlators;

Alternatively, suspected leaks can be pinpointed automatically by adopting the use of modern leak noise correlators which have become popular in recent years. Normally, leak noise correlators are the state-of-art portable computer based devices that can pinpoint leaks automatically, but it is not based on listening to the noise transmitted through the ground to the surface, like the principle adopted by listening devices. The operation of the leak noise correlator is by measuring vibration or sound at two points that bracket the location of a suspected leak. Figure shows how leak noise correlators is put into operation. In this method, acoustic leak signal are measured with vibration sensors or hydrophones are placed at two pipe contact points that bracket the location of a suspected leak. Vibration or sound signals are transmitted wirelessly from the sensors to the correlators.

The leak is in most cases located asymmetrically between measurement points and consequently there is a time lag between the measured leak signals. As to pinpoint a suspected leak, a correlator first determines the time lag between measures leak signals by calculating cross-correlation function. The location of the leak is calculated based on a algebraic relationship between the time lag, the sensor-to-sensor distance, and the propagation velocity of sound waves in the pipe. Normally, the distance
between sensors is measured on site or read from distribution system maps. Propagation velocities for various pipe types and size are usually available in most commercial devices or they can be measured easily on site.

Figure 2.1: Schematic illustration of the cross-correlation method for pinpointing leaks in water pipes.

The technology of leak noise correlators is no stranger to most of the water industry around the globe. As early 1980s, the water industry in the United Kingdom had purchased correlator and in the first week of operation, they had found a leak which they suspected and had investigated for a year. The success of the operation saved the water industry 270,000 gallons of water per day. Five years later, another United Kingdom water authority operated a microprocessor correlator over a period of six weeks with a total of 48 correlation attempts, found a total of 48 leaks successfully (Halliday, 1985).
In the late 1980s, water authority of Nagoya city occupied a series of water leak detection works in the city which also incorporated leak noise correlator in their operation, had successfully increased the efficiency of water supply in the city (Teruo Sanobe, 1989). After years of operations, the Nagoya City water authority had summarized its operation as having less number of leakage repairs and an increased of the effective rate and accountable water rate. The overall effectiveness of water supply in the city was reported to be nearly 100%. The water authority also concluded that measures for leak prevention by mean of ‘sound’ should be developed more rigorously. Thus we can conclude that the utilization of leak noise correlator is capable in locating pipeline leaks and increase efficiency of water distribution.

Although leak noise correlator is capable in locating leaks in pipeline, it is not always providing accurate results, especially while being tested on plastic pipes, to the water industry for subsequent excavation and repair works. Hunaidi et al. (2000) had performed a test to determine the best testing methods to detect leaks in plastic pipeline. The test concluded that leaks in plastic pipe are able to be located by leak noise correlators. But several difficulties had been giving the method challenges. Professional leak detection teams in this test found out that when operated in automatic and manual mode, leak noise correlator was rarely succeed in locating leak signals as the range of frequency selected was usually too high for plastic pipe which has frequency range of mostly below 50Hz. The teams concluded that the leak noise correlators may yield a better result if the
automatic mode algorithms are revised are revised. In the test, it was found the non-acoustic methods appeared to be more promising.

IV. Leak Detection In Large Water Transmission Mains;

   a. Limitations of previously discussed devices;

   When utilizing listening devices, the distance from the leak location to the listening sensor is a critical factor deciding the accuracy of leak’s location. In general, the deeper in the ground that the leak occurs, the harder it is to detect. The type of soil and soil conditions can also be a factor, as sound attenuation or the reduction in intensity of a sound is greater in clay soils versus sandy soils. To effectively detect a leak, listening devices need to be placed almost directly over a leak location. Thus, ground surface listening device, or even ground penetrating rods, which are historically proven to be effective in detecting leaks on distribution pipelines that are buried relatively shallow are unsuitable for the detection of large diameter pipelines, due to the long distance of these pipelines and also the various uncertainties as to where the pipelines actually run underground.

   Another leak detection device, the leak noise correlator, which is also widely used in leak detection, is not suitable for the leak detection carried out at large diameter transmission mains. The availability of
accessible appurtenances on which to attach the accelerometer becomes a limiting factor to the use of the noise correlator, which required accelerometers to be attached to a relatively close space. Besides, identification of leaks can be limited by the physics of acoustic attenuation and propagation of the acoustic activity in large diameter pipeline.

b. In-line acoustic based leak detection system (Sahara);

In-line acoustic based leak detection system, which also known as the Sahara system, is one of the newer non-destructive technologies developed with the aim to detect leaks in pipeline system. Sahara system not only pinpoints the location of leak, it also estimates the magnitude of leaks. The system of leak detection is used in water transmission mains. The Sahara systems uses a highly sensitive acoustic detector unit (known as drogue), which is inserted into the main at any tap point of two-inch or greater in diameter while the pipeline remains under pressure (between 3 and 200 psi or 0.3 and 13.8 bar) (Larsen et al., 2005). Other than the acoustic detector unit, the operating unit also consists of cable which incorporates with a retractable guide which protects the cable from damage as it passes into the pipe, a winch which forces the umbilical into the pipe against water pressure and withdraws the umbilical from the pipe upon completion of the survey, and cable drum which control the development and retrieval of the umbilical.