High Frequency Acoustic Signal Analysis for Internal Surface Pipe Roughness Classification

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Abstract. This research highlights the method of acoustic emission analysis to distinguish the internal surface roughness of the pipe. Internal roughness of the pipe is referred to the level of corrosion occurring, where normally it is difficult to be monitored online. *Acoustic Emission* (AE) technique can be used as an alternative solution to the corrosion monitoring in pipes, especially for complex pipelines and difficult to achieve by other monitoring devices. This study used the hydraulic bench to provide fluid flow at two different pressures in pipes with different internal surface roughness (rough and smooth). The main source of acoustic emission was from activity in the control valve, coupled with high pressure water flow friction on the surface of the pipe. The signal from these sources was detected by using the *AED-2000V* instrument and assisted by the *Acoustic Emission Detector* (AED) software. The time domain parameter; root mean square, *RMS* amplitude was processed and compared at different pressures for each type of internal pipe roughness at ten different locations. It was observed that a unit less *Bangi number*, AB, derived from RMS values, can be used for discriminating different level of internal surface roughness. Internal surface pipe can still be considered as smooth if AB value is above than 1.0.

Introduction

Pipes are used widely in our domestic and industries. It is one of the most important parts in human life because piping system is a mechanism of delivering or transporting a fluid (liquid or gas), mixture of fluids and others from one location to another. Pipes need to be monitored periodically in order to determine damage to the pipe and its associated equipment, maximize the efficiency and safety of the pipeline, minimize potential accidents, and safeguard company and public interests [1]. Oil and gas industries had suffer lost every year through the pressure drop in their transportation systems due to corrosion. Besides, internal surface corrosion in pipe also can cause the leakage and can be catastrophic for piping system that contains hazardous gases such as ammonia and nitrogen dioxide. It's also had been reported that, one of the root cause of Bukit Antarabangsa landslide tragedy in Selangor, Malaysia was from the improper monitoring of pipeline leakage.

The surface roughness commonly refers to the level of rust or corrosion that occurs inside the pipe. Internal pipe corrosion normally difficult to be detected online especially when it involved a large, complex shape and long piping system. In some of the oil and gas companies, scanning for corrosion need to be done offline, therefore affect the profits. The Acoustic Emission method; one of the most recent nondestructive techniques (NDT), offers a very good alternative of online internal surface pipe monitoring. This high frequency acoustic application was widely used as a tool for condition monitoring in various engineering area [2 – 6]. Although ultrasonic evaluation currently is one the most popular NDT for internal pipe corrosion monitoring, there are still some weakness to the application [7]. Main objective of this research is to enhance the study done by [7] and [8], thus continue to develop an alternative technique to classify internal pipe surface roughness using Acoustic Emission evaluation.

Acoustic Emission Technique

Acoustic Emission (AE) method utilized the knowledge of acoustic emission signals where it can be describe as shock wave that occurs inside a material which is under stress condition due to any impurities or flaws [2, 3 & 5]. The high frequency signal of shock wave is then generated by a rapid release of stress-strain energy from local source within the material and it can be easily sense by the AE sensor. This signal can be detected approximately in frequency range starting from 1 kHz and up to 2 MHz. Fig. 1 shows the AE source propagation and sensor attachment to the material. In addition, Acoustic emission technique can detect any local defect with less noise interruption due its very high frequency shock wave characteristic compared with noises.

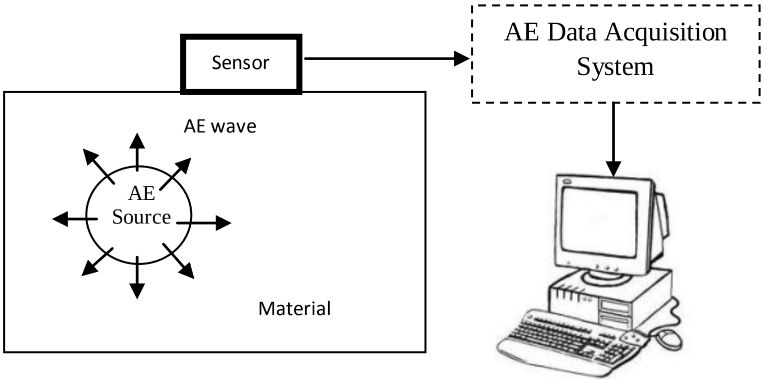

Fig. 1: The source of acoustic signal

One of the good examples of AE source is the crack propagation and initiation that occurred inside a material under cyclic loading. Although it really sensitive in sensing any changes of flaws and defects, however AE wave need a good medium for better propagation and easily sensed by the AE sensor. It was proved that different level of corroded surface will disturb the propagation of AE signal [9].

AE Parameters

Usually, AE parameters that measured for the analysis are frequency, amplitude, energy, root mean square (*RMS*) amplitude, kurtosis, counts, rise time, peak amplitude, even and signal duration [8]. Fig. 2 shows the example of AE transient wave signal. The signal is unique for different nature of source.

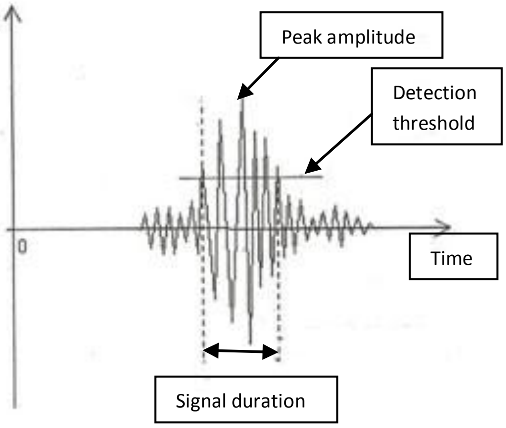

Fig. 2: Acoustic emission transient wave

For this study, the time domain parameter, RMS amplitude values were calculated from AE wave. It was selected since the value actually represented the intensity of the AE signals obtained from experiments. For discrete time or digital signal, the RMS value can be estimated as [10],

$$y_{R.M.S.} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}({y_i}^2)} \qquad \text{eq. (1)}$$

Bangi number, AB, need to be used for further analysis, and it's defined as

$$AB = \frac{A_{low}}{A_{high}} \qquad \text{eq. (2)}$$

where, A_{high} is referred to the selected AE parameter value (*RMS*) at high flow rate (or low pressure) and A_{low} is the AE parameter value (*RMS*) at low flow rate (high pressure) [7].

Methodology

The experiments involved the measurement tools which were acoustic emission system device (*AED-2000V*), hydraulic bench, simple pipeline with pressure gauge, and personal computer (PC) with *Acoustic Emission Detector* (AED) software. The schematic diagram in Fig. 3 shows the data measurement set up that was used during the test.

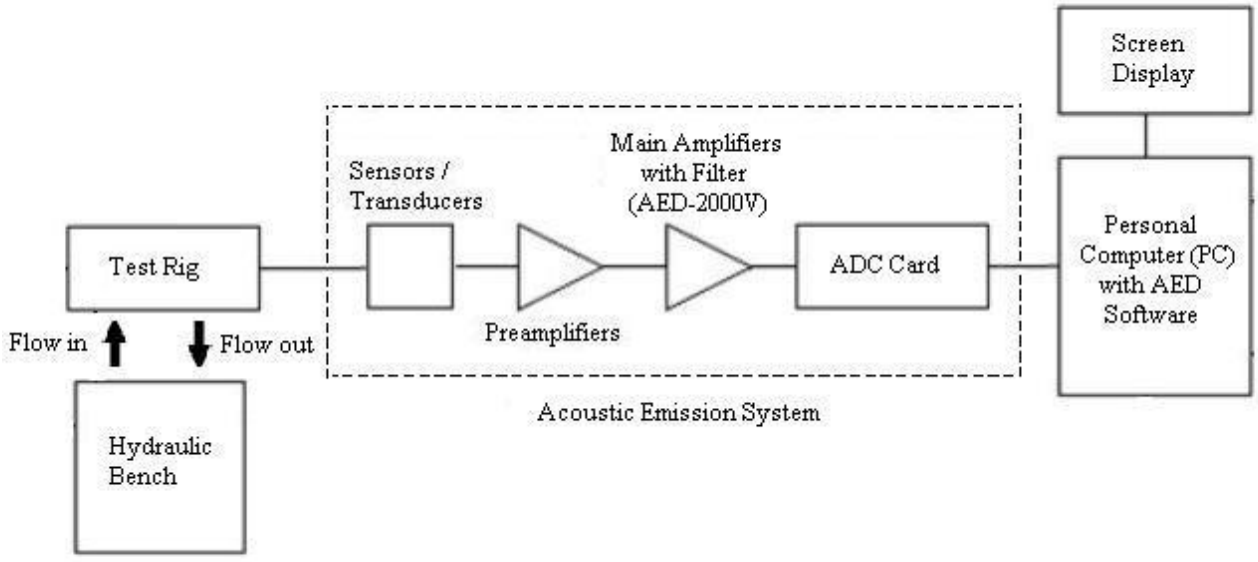

Fig. 3: Experimental architecture

The tests were done to obtain acoustic emission signal from pipe line with different internal surface type (rough and smooth) and different pressure of water flow at ten different locations on pipe. The flow rate can be determined by using volume water indicator at hydraulic bench and pressure setting was done by varying the valve opening. The valve was positioned at the end of the pipe line so that the smaller the flow rate, the pressure increase.

Two types of pipes were used where, each one represented smooth and rough internal surface pipe (Fig. 7). They were galvanized iron type with length of 2 meters each, inner diameter of 3.81 centimeters (1.5 inches) and 3 millimeters thickness. The internal roughness depth of the pipe at every measured point was then measured using *perthometer* for further analysis. The test rig set up was as shown in Fig. 4 where the white arrows show the flow of water. The AE sensor was attached directly on the pipe line as in Fig 5. There were two pressure gauges, which located at the inlet and the outlet flow (Fig. 6). However, only the gauge reading from inlet flow was referred and used as pressure flow indicator.

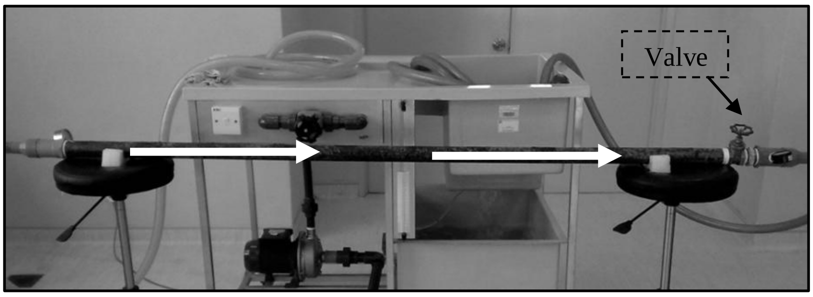

Fig. 4: Test rig set up

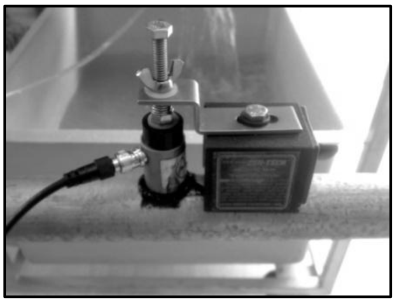

Fig. 5: Sensor attachment on pipe

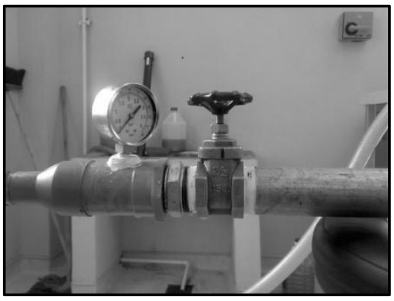

Fig. 6: Pressure gauge

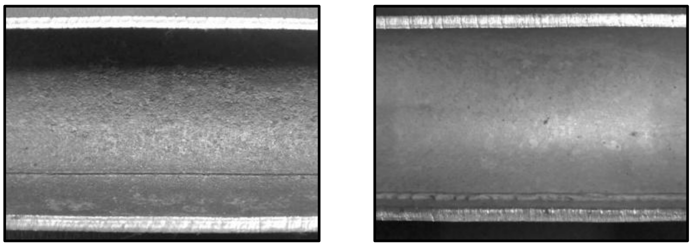

Fig. 7: Rough surface (left) and smooth surface (right)

Results

Fig. 8 shows the *RMS* values for smooth and rough surface pipe at two different pressures of water flow. Both flows were in the range of turbulent flow (Table 1). The figures reveal that the main AE signal source was from the activity in valve where RMS values decrease steadily with the increase of distance from valve.

Table 1: Flow’s pressure and Reynolds number

Pressure	Reynolds number, Re
1.6 bar	22703.61
1.8 bar	16359.96

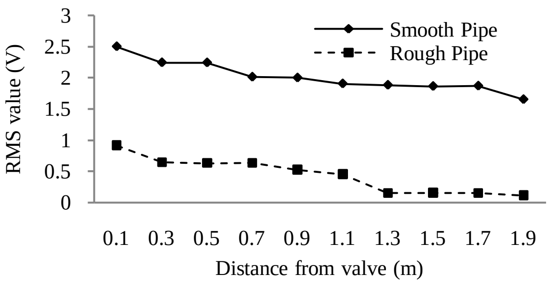

Fig. 8 (a): Pressure 1.8 bar

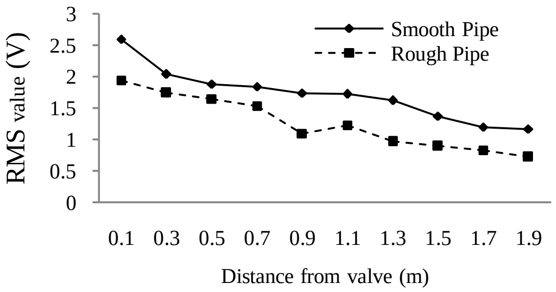

Fig. 8 (b): Pressure 1.6 bar

Fig. 9 shows the *Bangi number*, AB, plot combine with mean roughness depth. AB values were calculated using eq. (2). It can be seen that, the surface still smooth if *Bangi number, AB* value is above than 1.0.

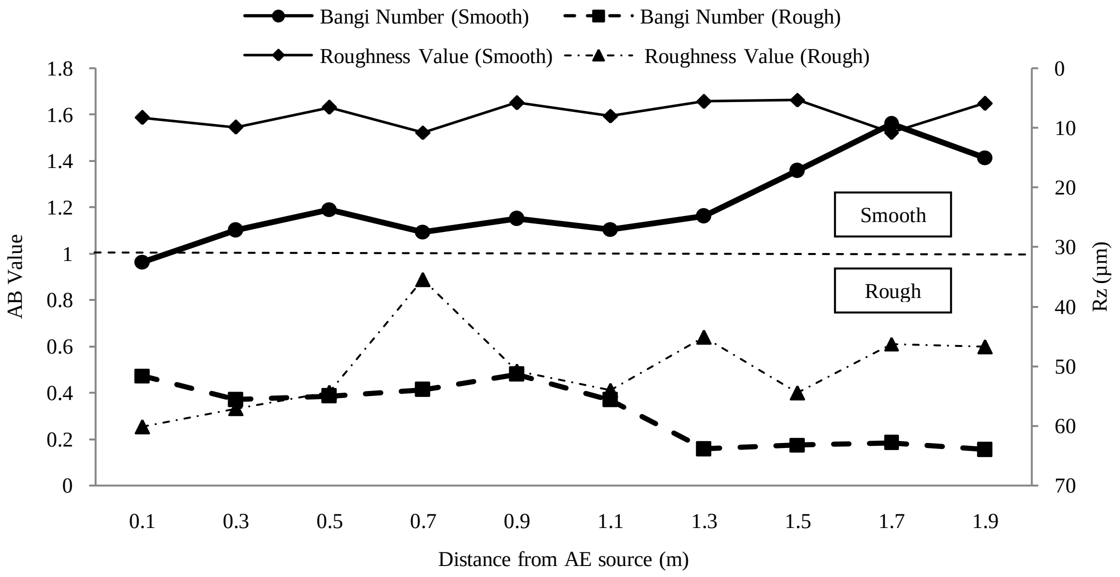

Fig. 9: Bangi number and roughness level plot

Summary

The results shown give a potential usage of Acoustic Emission method for internal pipe corrosion monitoring system. It also confirmed the study done by [7] and [8]. Note that the higher number for sampled signal will indicate more accurate result. It is therefore concluded that the objective of this research has been achieved. Future enhancement in this research includes the inclusion of more data to show better relation between *Bangi numbers*, *AB* with the AE parameters. Besides, AE source also needs to be studied to reveals more understanding of its mechanism therefore any unwanted signal can be eliminated.

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