ACOUSTIC REFLECTOMETRY FOR GAS PIPELINES – MONITORING FEATURES IN GAS PIPELINES USING ACOUSTEK®

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Abstract:

This paper will provide an overview of a patented acoustic technique known as Acoustek® that has been developed to detect features, such as blockages and leakages in gas pipelines. The technique involves injecting an acoustic, or pressure pulse into the gas within the pipeline. This acoustic pulse will travel as a plane wave along the pipeline and will be partially reflected wherever there is a change in acoustic impedance. Such an impedance change will occur where there is, for example, a change in the internal cross sectional area of the pipeline. By measuring the reflections produced as the acoustic wave travels along the pipeline, together with knowledge of the speed of sound in the pipeline, the location of features, such as blockages, holes, valves and buckles can be accurately detected and located. The technique is non-invasive and in tests it has been shown to be capable of surveying both small and large diameter pipelines over distances up to approximately 10km. It is hoped that future development will take it considerably further.

This paper will present the results which demonstrate the accuracy of the technique in detecting and locating blockages in gas pipelines. In particular the results of these tests will show how the technique was able to detect pipeline features with background noise.

1. Introduction

With the growth in global energy demand, the lack of shallow-water and onshore opportunities and new technological advances, oil and gas production targets have moved to deepwater environments. The high pressure necessary to overcome deep water flow lines and the cold environment at the sea floor will worsen the hydrate formation scenario [1, 2]. Hydrate plugs can form quickly and completely block the pipeline. This is a major challenge for flow assurance in pipelines and the safety thereof [3]. Of particular concern is that the oil & gas industry spends a significant amount of money and effort in combating the unwanted formation of hydrate blockages in natural gas pipelines, with varying degrees of success. Therefore detection of the formation of hydrate blockages at its early stage is very important and useful for remedial actions before catastrophic effects occur [4].

The steps to be taken in remediating a subsea blockage are to locate, identify and remove the obstruction. The accurate evaluation of the blockage position is a fundamental part of this remediation process. Due to the variety of pipeline layouts and facilities, there is no universal solution for detecting obstructions in all conditions [1]. The conventional methods for blockage detection include flow pressure monitoring detection, diameter expansion measurement and radiographic methods.

Flow pressure monitoring detection uses pressure wave propagation to remotely detect blockages. This method uses a quick-acting valve to generate a water hammer or shock wave inside the pipeline and then records the reflections produced by any blockage [5-7]. This method can detect blockages over long distance, with reports of up to 100 kilometres [8]. However, the speed of sound and noise interference may affect the accuracy and give rise to additional errors [1, 8]. This method has some limitations. It requires the flow line to be shut-down for a short period of time to create the pressure wave. The pressure wave leads to water hammer upstream of the closing valve and cavitational hammer downstream of the valve, which may cause considerable damage to the pipeline and the support structure [9-11]. Because of the potential damage to pipelines, this method is forbidden by some pipeline operators.

Pipeline diameter expansion variation measurement can locate a blockage and evaluate the length of the blockage with very high precision. Pressurising and depressurising the pipeline would cause measurable diameter expansion throughout the pipeline if it were free of blockage. If an expansion is not detected, it means a plug must be located between the source and measuring site. Using this method on both sides of the blockage, it is possible to evaluate the length of the plug [1]. However, this method typically requires the use of a Remotely Operated Vehicle (ROV) and the approximate location

of the plug should be known in advance. A major disadvantage is that this method cannot be used if the pipeline is inaccessible, for example if it is buried underground or inside a concrete structure.
Radiographic detection is a non-destructive testing (NDT) method of inspecting pipeline defects by using the ability of short wavelength electromagnetic radiation to penetrate various materials. It is accurate and used for short distance inspection. Normally this method is implemented on ROVs and the detection ability is affected by the material surrounding pipeline such as concrete structures.

Ideally, any blockage detection method should be fast, accurate and cheap to employ and it should not interfere with the normal pipeline operation. A new economical patented method, named Acoustek®, of detecting and locating a blockage in an operating gas pipeline has recently been developed by the authors [12]. The basic concept of the technique is to inject a pulse of sound into a pipeline and then measure the reflections produced as this signal travels along the length of the pipe. Wherever the cross sectional area of the pipeline changes then there will be a reflection produced. With knowledge of the speed of sound in the gas, the time of flight can be determined and the location of the change in cross sectional area can be identified. The technique is non-invasive and can be used to accurately detect many pipeline features, such as holes, blockages and other objects including valves and even welding joints. The proposed method has the advantage that it is fast and accurate, requires relatively low cost instrumentation and unlike many existing blockage detection methods, does not require interruption of pipeline operations. .

This presents the results from the testing carried out to date.

2. Experimental method

Laboratory tests were conducted on a 16m rigid PVC pipe (Figure.1) with an internal diameter of 63mm. This pipe consisted of several sections, which were connected by bends. The bend connections were not sealed airtight. The schematic of the solid pipe is presented in Figure.1.

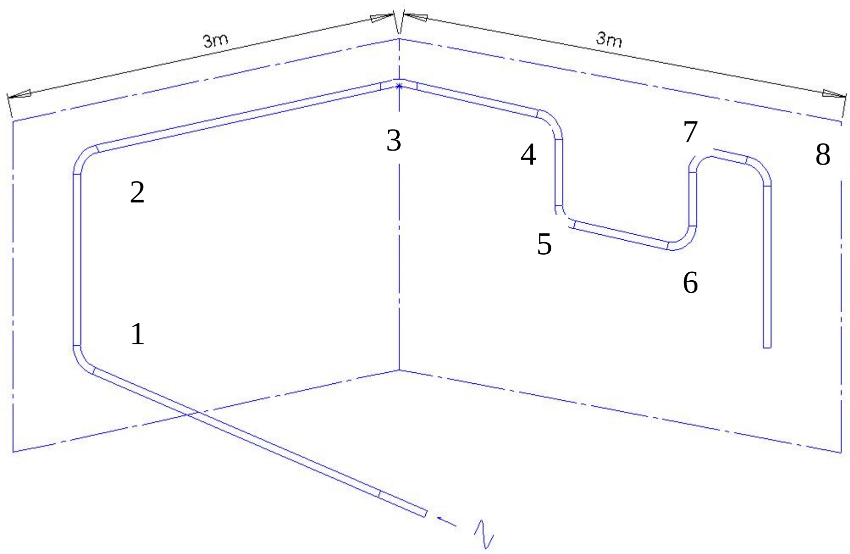

Figure 1 Schematic of 16m rigid PVC pipe

In the experimental tests, the signal generated by an acoustic pulse generator was passed through an amplifier to drive a loudspeaker, which transmitted the signal into a pipe. A microphone, which was installed at the same end as the loudspeaker, was then used to measure the transmission and reflection of this wave through the pipe. The sampling frequency of the data acquisition was 10kHz. The recorded data was analysed using matched filters. The output from the matched filtering was a series of peaks, each of which indicated a cross sectional area change resulting from a blockage, hole or other pipeline feature.

3. Results and discussion

800Hz waves were injected into the pipe. A centrifugal fan was used to generate air flow in the pipe. The reflections are presented in Figure. 2. It is difficult to identify the location of the pipe end from this figure because of the high level of noise. The matched filtering analysis of the reflection is presented in Figure. 3. The location of the pipe end is now clearly displayed. However, there is no significant reflection from the bends. This is because the fan generated turbulence in the pipe and small reflections from the bends were difficult to detect after the matched filtering process.

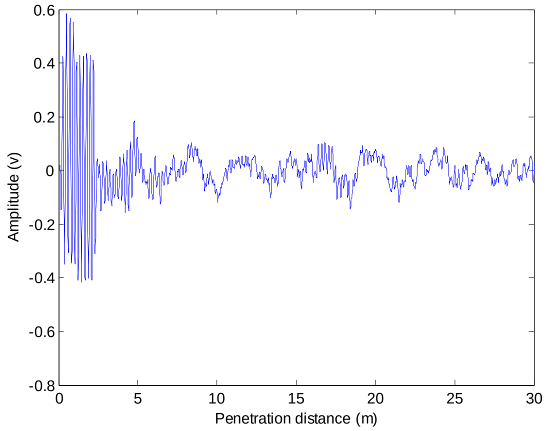

Figure 2 Reflections of 800Hz waves

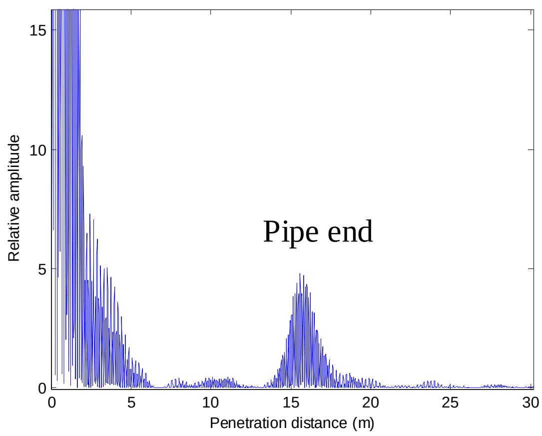

Figure 3 Matched filtering analysis of the reflections of 800Hz waves

A piece of wood was placed into the pipe at a location of 11m. The wood occupied half of the cross section area. The processed reflected signal is presented in Figure. 4. The locations of the pipe end and the blockage can be identified from this figure.

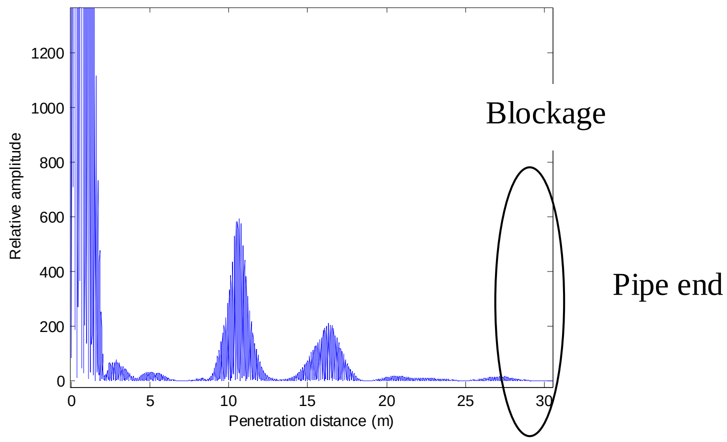

Figure 4 Detection of a blockage in the pipe

Under stagnant air conditions, a chirp signal with a frequency band of 0-800Hz was injected into the pipe. The resulting reflections are presented in Figure. 5, which shows it is difficult to obtain any useful information from the raw data. The matched filtering analysis of the reflections (Figure. 6) shows the locations of bends and pipe end. Since the time duration of the chirp signal was 0.02 seconds and some bends were very close to each other, it is not possible to identify all the bends. The wood blockage was placed into the pipe again and the location can be clearly detected (Figure. 7).

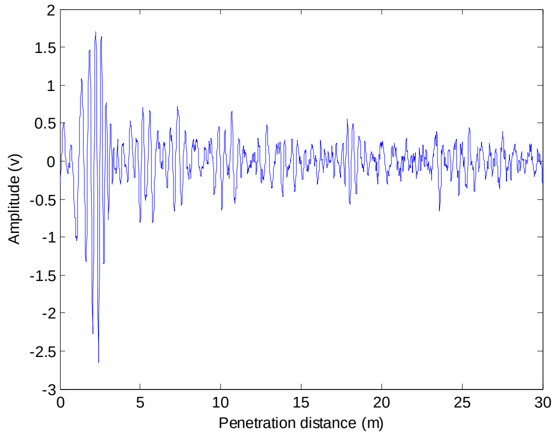

Figure 5 Reflections of 0-800Hz chirp signal

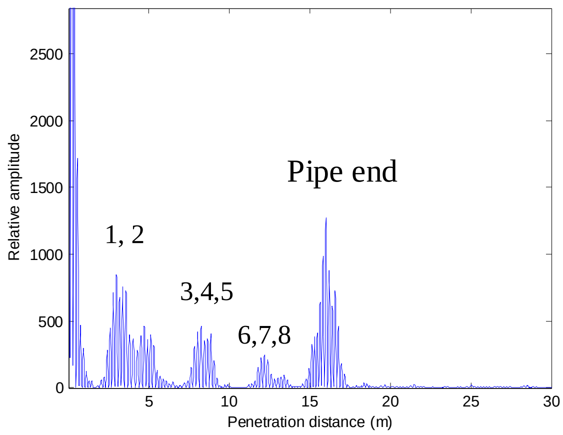

Figure 6 Matched filtering analysis of the reflections of the chirp signal

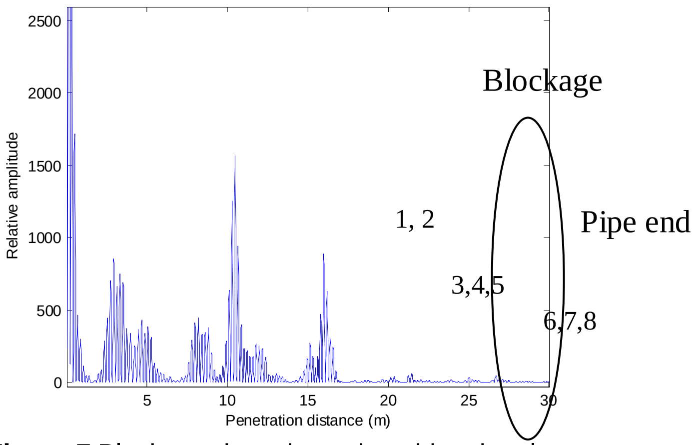

Figure 7 Blockage detection using chirp signal

The laboratory experiments show that the matched filtering technique is a promising method for detecting pipe defects in a noisy environment. It is worth noting that the durations of the injected signals were more than 0.01 seconds in the laboratory experiments, and as such certain features in the pipe could not be detected. For example, there were several bends that are located close to each other, the reflections from these could not be differentiated. To detect and isolate reflection from features which are close to each other, higher frequency or shorter time duration signals should be employed. However, high frequency signals will attenuates quicker in a pipe[13] and will therefore not transmit over long distances. In the oil and gas industry, this technology will normally be required to survey long lengths of pipeline and therefore low frequency signals will be required. The specific signal that is used should be selected according to the pipe configuration with a compromise on survey length and accuracy.

4. Field trials

Following field trials and further development of the technique, Acoustek® has now been used on a number of occasions in the field, mainly offshore. Field trials and live applications have been conducted which have shown the accuracy of the technique in detecting and locating blockages in gas pipelines containing both static air and flowing, high pressure natural gas. In particular, the results of these tests show that the technique is able to detect both full and partial blockages in large scale steel pipelines with lengths exceeding 10km.

One of the field trail results is presented in Figure 8. The testing pipe loop contained two pig traps (T1 and T2), located at either end of the pipe, two motorized valves (M1 and M2) which were able to isolate the pig traps, and two drainage valves, located at the end of two short 2" T-sections (shown as locations X and Y in figure 9). The pipeline also crossed a small access road at the point marked Pipe Bridge in figure 9.

Figure 8 shows the reflected signal when the equipment was connected to T2. This figure provides several peaks in the measured reflections: these are labelled in the figure for convenience in the subsequent analysis.

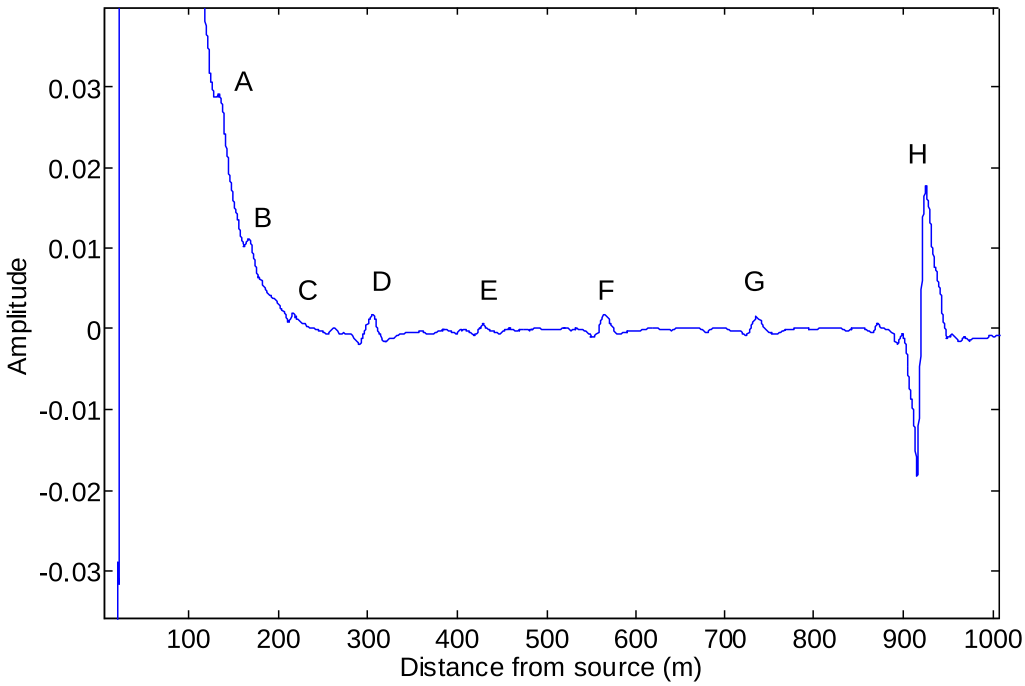

Figure 8: Location of multiple features in the pipeline

The locations of the peaks in figure 18 are approximately: 133m (A), 162m (B), 210 (C), 280m (D), 414m (E), 545m (F) and 721m (G) away from pig trap T2. These points are marked on the pipeline layout displayed in figure 9. Each of the reflections, labelled A to H, is believed to have been created by features within the pipeline. Thus, the results confirm that very minor features in the pipeline will result in significant reflections. Here, it is believed that the reflections measured in this pipeline were small deposits of water that remained in the pipe after it had been evacuated. The evidence for this was that, during the tests, it was observed that the pipe sections were not absolutely horizontal, and several dips could be identified. Consequently, if any water remained in the pipeline after the evacuation procedures, these would have been the most likely locations for the water to accumulate.

Previous experiments in the laboratory have shown that the length of the reflected signal can provide a reasonable estimate of the extent of any partial blockage. Similarly, analysis of the acoustic reflections produced at locations D and F suggest that the length of these partial blockages is approximately 15-20m. Furthermore, the amplitude of the reflection peaks suggests that these particular blockages were small and probably occupied only a small percentage of the pipeline cross-sectional area.

The locations of each of the features displayed in figure 9 were confirmed from the independent set of measurements made when the equipment was connected to valves X and Y.

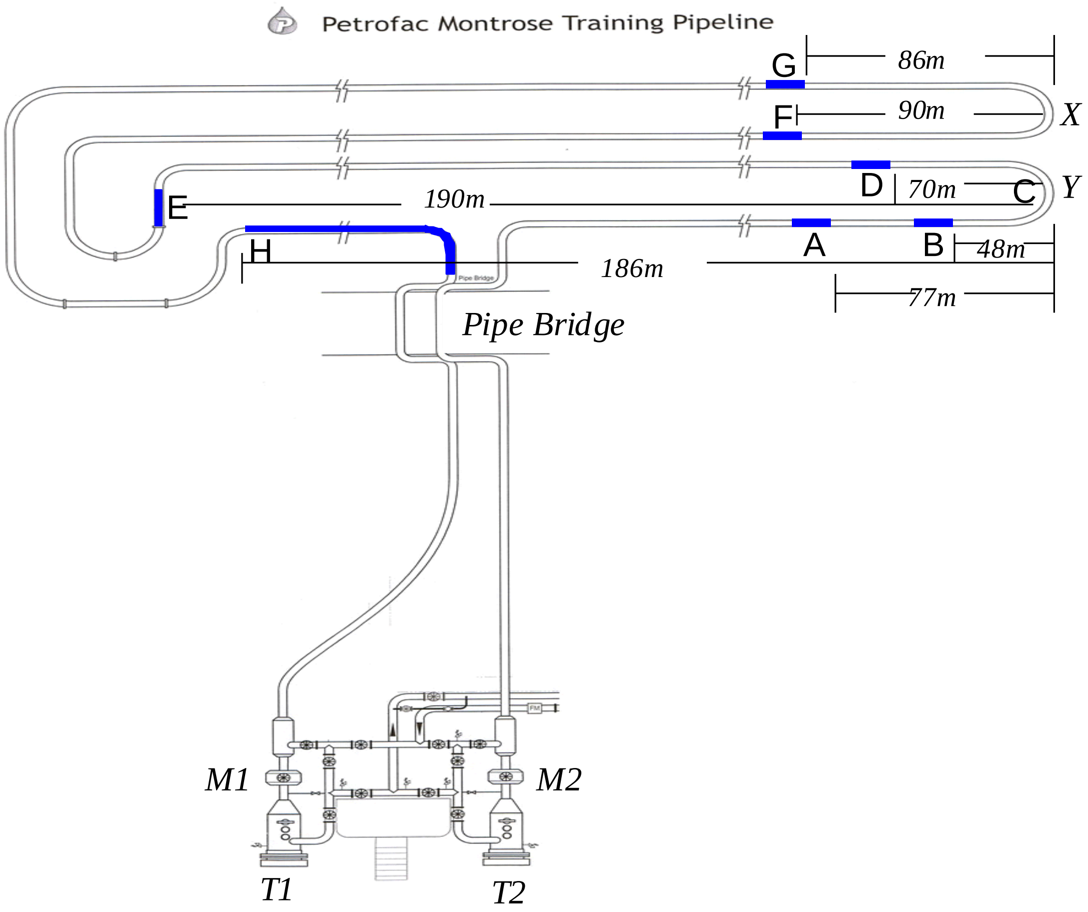

Figure 9: Location of the blockage features identified located in the pipeline

5. Conclusions

In this paper, a patented acoustic reflectometry technique for detecting defects in gas filled pipelines has been described. The work described here has show that, by using signal processing techniques, acoustic reflectometry can be used to identify features even on complicated pipeline arrangements with strong noise interference. Work is continuing, including testing on longer lengths of live gas pipeline. The technique is non-invasive and in both tests and live field trials it has been shown to be capable of surveying both small and large diameter pipelines with lengths of up to approximately 10km. Although development work continues to improve Acoustek®, it is now offered in its current form by Pipeline Engineering & Supply Co Ltd as a commercial service and has been used successfully to locate blockages in operational lines.

6. References

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