THE ANALYSIS OF ACOUSTIC WAVE PROPAGATION CHARACTERISTICS IN A BURIED PIPE BY EXTERNAL IMPACT

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Abstract: Occasionally, Pipeline incidents can occur due to third party damage. U.S. Department of Transportation(DOT) pipeline accident statistics indicate that third-party intrusions are often the leading cause of pipeline failure. Some 20 to 40 percent of all pipeline failures in most time periods are attributed to third-party damage. Damage can be directly to acts of man, such as contact with earthmoving equipment, or indirectly, such as subsidence associated with mining. Direct man-made damage, when inflicted by other than the owner of pipeline, is known as third-party damage. Third-party damage tends to be localized to the point of contact, such as by a backhoe or boring tool. These experiments were conducted in the field using a 0.2 km run of abandoned pipeline. The line was cut and not pressurized. In the experiments, the impact signals were generated by backhoe. The impact signals level obtained is much lower than expected from real third-party incident. Distances of accelerometer were 150m, 200m from the impact point. We enforced impact directly to pipe by breaker and bucket. Shape of breaker was hemisphere head and bucket was flat. The objective of the field experiments was to assess the feasibility of using commercially available accelerometers and related signal conditioning. In addition, we wanted to make sure if our system can detect impact loads like those involved with some third-party damage incidents on a buried pipeline.

Keywords: The third-party damage, buried Pipeline, Acoustic wave propagation

1. INTRODUCTION

Gas transmission pipeline systems are long runs of buried "thin-walled" pipe sections typically constructed of steel or plate shaped as a cylinder and welded longitudinally in the mill and thereafter end-to-end in the field. The field experiments were conducted in the field using a 0.2 km run of abandoned pipeline. The objective of the field experiments was to assess the feasibility of using commercially available accelerometer and related signal conditioning and analysis detect impact loads like those involved with some third-party damage incidents on a buried pipeline. The distance between the impact point and the furthest instrumented site was 200m. using pipeline for experiments run along road. Internal pressure of pipe is atmosphere pressure. Impact machine was backhoe. Figures 1 shows the impact machine (backhoe). We enforce impact directly to pipe by breaker and bucket. Shape of breaker head is hemisphere impact head. Bucket head is flat. Two of instrument sites contained accelerometer. Distance of accelerometer is 150m, 200m from the impact point. We make the test site to experiment as figures 2. Total length of test pipeline is 60m. The experiments were conducted in the same way as before. The other hand, The field experiment was conducted. The objective of the field experiments was to assess the feasibility of using commercially available accelerometers and related signal conditioning and analysis to detect impact loads like those involved with some third-party damage incidents on a buried pipeline. The instrumentation selected for the field experiments is listed in Table 1.

Figure 1 **Testing equipment and Scene of field experiments**

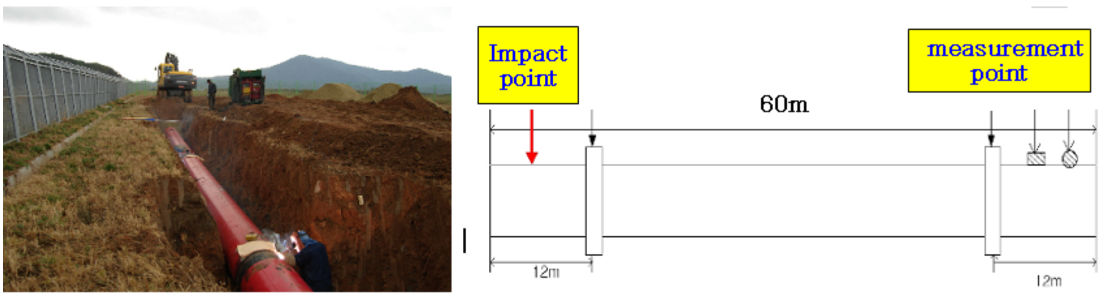

Figure 2 **The site of designed pipeline(60m) for test**

TABLE 1 - Instrumentation used in experiment

Name	Type	Purpose
B&K 4189	Accelerometer	Signal detection
Pulse 3022(B&K)	Measuring instrument	measuring & analysis signal

The acoustics wave propagation process is following, first there is a source, which in the field application could be an excavating tool striking the pipe. The energy from the strike is partitioned into mode, and the total signal level depends on the level of impact. We had experiment that a various type of impact was enforced on the pipe, to evaluate characteristics of acoustic wave propagation. Type of impact is classified into four groups. First, Pipeline is impacted strongly by breaker. Second, pipe is impacted continued by breaker. Third, Pipe is impacted by bucket. For some analyses, the signals were filtered from 10 to 1,600 Hz. Because significant components above 1,000 Hz are not expected due to attenuate.

2. ANALYSIS OF EXPERIMENT RESULTS

One of the features of the acoustic impact detection scheme is that the acoustic wave is observable from the outside wall with accelerometer. As the acoustic pressure propagates down the pipe, it imposes a dynamic hoop stress in the pipe wall. That stress causes a radial displacement/strain of the wall that can be detected by accelerometers mounted on the outside wall of the pipe. Therefore, we need to conform that detected signal is imposed by acoustic wave. There is a 0.142 second difference between first point(150m far away from impact point) and second point(200m far away from impact point). This performance was deemed acceptable. Because normally, we think of the speed of sound in air is 340 meters per second at 20 ℃. Frequency of the circumference vibration (Background noise) is only a 60 Hz as an electric noise.

2.1 Breaker impact

When pipe line is impacted by a breaker. Acceleration of first point(150m away from impact) is shown in Figure 2. And acceleration of second point(200m away from impact) is shown in Figure 2. An analysis of frequency is shown figure 3. As seen Figure 3, An Important frequencies of two point(150m, 200m) are 330, 520, 712, 912 Hz.

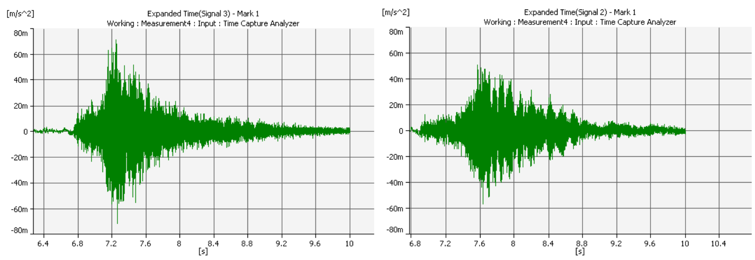

Figure 2 Acceleration by breaker impact

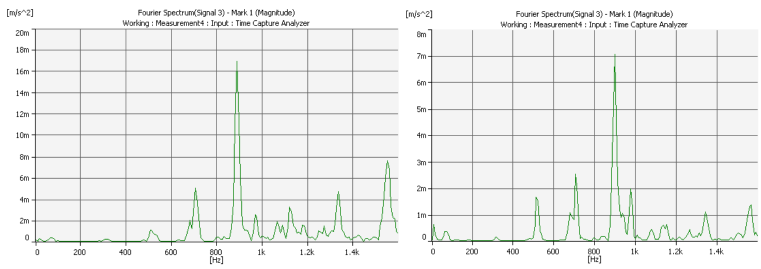

Figure 3 Spectra of breaker impact

2.2 Continuous impact

In case of continuous impact, as figure 5. There is overlap signal. We need to confirm the frequency character from when the shock and shock are repeated. Frequency analysis which is not piled one upon another(blue box in figures 5) is shown figures 5 Frequency is similar to frequency to be is enforced by single impact. Frequency which is piled one upon another is shown in figures 5 we can know that it is different in frequency characteristic from figure 3. Important frequencies are 290, 480, 520, 660, 712, 912 Hz. .

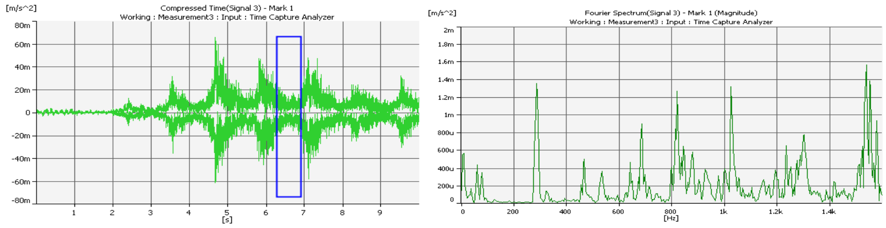

Figure 5 Acceleration and spectra by continuous impact

2.3 Other breaker impact

We want to know what is different between breaker and other breaker as figure 5; An Important frequencies are 320, 506, 710, 800 Hz. There is no big difference from the result of 2.1 breaker impact.

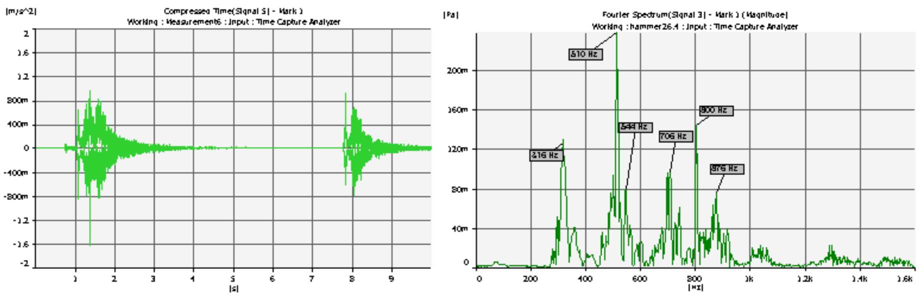

Figure 6 Acceleration and spectra by other break impact

2.4 The field experiments

In the experiments, sensors were placed on a pressurized, 30-inch diameter pipeline to detect impacts on the line. The distance between the impact point and the sensing point was 5.5km. The sensors were commercially available accelerometers. 20 kg weight was dropped from 200 cm provide the impact. The two signals plotted in figures 7 are the actual signal, magnification signal and spectra. An Important frequency is 230 Hz.

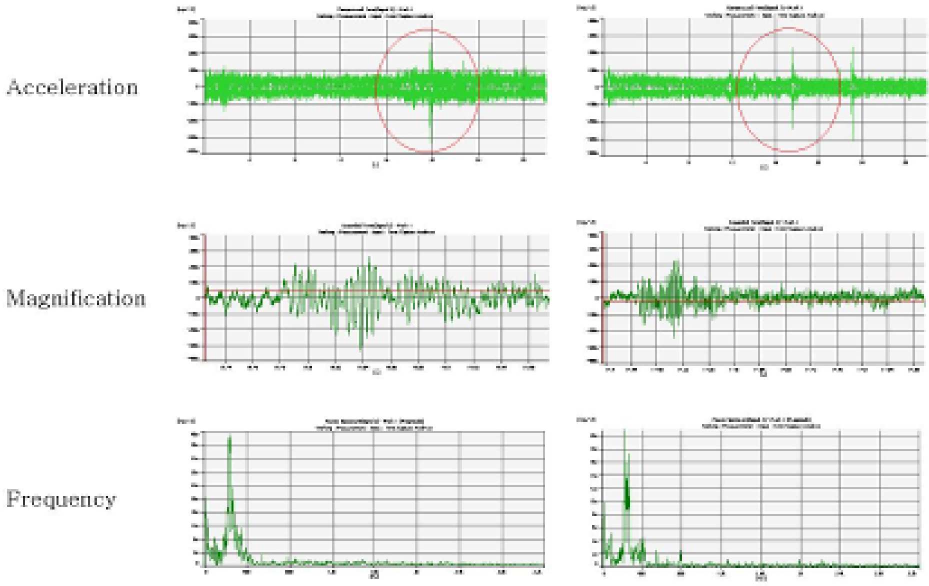

Figure 7 Results of the field experiments

2.5 Theoretical analysis

Theoretical cut -off frequency in underground pipes is also described. From inside pipe which has a static pressure, the acoustic pressure propagation is decided by cut-off frequency. Cut-off frequency is decided by the geometric quality of pipe section, also the Dispersive wave occurs. Each mode is determ ined by cut-off frequency, the frequency which is lower than cut-off frequency becomes Non-Dispersive wave. The frequency which is higher cutoff frequency becomes the Dispersive wave. There are 260, 430, 540, 590, 750 Hz from below 1,000 hertz. Which may be given as

$$f_{n,l} = \frac{c}{2\pi a}\alpha_{n,l} \qquad n, l = 0, 1, 2, .. \qquad (1)$$

Here c is speed of sound, is The Extrema of the First Kind of the Bessel Function's, a is radius of pipe

3. DISCUSSION AND CONCLUSION

Frequency of each experiment is shown in table 2. We know that there is no great frequency difference between breaker impact, continuous impact, difference between breaker and bucket. This result come from that pipe geometry determine wave transmission in pipe. Namely, cut-off frequency plays a decisive role. But the frequency of the field experiments is 230 Hz. Attenuation is the most important factor affecting the viability of this technology for impact detection.

TABLE 2 – Type of impact and Frequency

Type of impact	Important frequency(Hz)
breaker impact	330, 520, 712, 912
Continuous impact	290, 480, 520, 660, 712, 810,

	843, 907
Other breaker impact	320, 506, 710, 800
The field experiments	230
theoretical analysis	260, 430, 540, 590, 750, 905

Reference list

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