International Gas Union Research Conference 2014

Limitation of detection range in guided wave testing of buried pipeline

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ABSTRACT

As guided wave test is one of the promising inspection methods for the integrity of plant facility, it could be also a promising tool for inspecting buried pipeline. However, guided wave tends to leak into soil rapidly, and the coating of buried pipe also decreases the signal significantly. There has been ambiguity in detection range limit in buried pipe application. In this work, two types of sensor, magneto-striction sensor and piezoelectric sensor were applied to the buried pipeline test loop. The test loop with standard defects at various lengths was constructed at burial depth of 1.5 m. The results showed that the detection range is of 5~10 m. The magneto-striction sensor showed better S/N ratio at the results. But the lack of circumferential resolution limited the interpretation of signal. The piezoelectric sensor showed lower S/N ratio with circumferential resolution. The results showed the possibility of the method and the limitation together. The method was applied to existing valve station. It reveals several indication of metal loss at the unpiggable sections. The results were shown in this work.

1. INTRODUCTION

The integrity of gas transmission pipes could be maintained by utilizing various inspection tools. The most powerful tool will be inline inspection pigging tool. However many pipes are unpiggable due to the structure of pipe system or other operation issues. The conventional maintenance practice for unpiggable pipe is the direct assessment of the pipelines. The use of RBI (Risk Based Inspection) methods helps to find the most critical parts of a given pipeline network. However many operation want to find more reliable method. The guided wave is regarded as a promising inspection method for the plant. The inspection range of the method reaches around 100m under favorable conditions. However the inspection range of buried pipe is limited by absorption of wave energy by pipeline coating and surrounding soil. Several authors reported the application of the guided wave method to buried pipe (1, 2). There is ambiguity in detection range limit in buried pipe application. The range of detection varied with applied coating and burial depth of pipe. And the detection ranges of the buried pipe were usually estimated by detection capability of girth weld not the real defects.

In this work two types of sensor, magneto-striction sensor and piezoelectric sensor were applied to buried pipe line test loop. The test loop was constructed with defects at various lengths with burial depth of 1.5 m. ln this work it is tried to evaluate detection limit under real construction environment.

The guided wave technology was also applied to unpiggable secton of pipe in existing valve station. The applicability of this technology was estimated.

2. TEST PIPELINE APPLICATION

The test pipes of 8 inch diameter were constructed at sites (figure 1). The artificial defects were machined along the pipe. The defects were designed to have about 5% and10% cross-section area at each pipe (figure 2). The details of the test pipes were shown in table 1.

Table 1. Test pipe details

Pipe Specification	diameter	8 inch
	thickness	Straight 9.5mm Elbow 12.7mm Coating 3.2mm PE
	materials	API 5L x42
Defects	5% Cross-section Straight	DxCxA=5x58x10 mm D: Depth C:Circumferential length A:Axial length

	5% Cross-section Elbow	DxCxA=5x78x10 mm
	10% Cross-section Straight	DxCxA=5x116x10 mm
	10% Cross-section Straight	DxCxA=5x168x10 mm

Figure 1. Test pipe installation and artificial defects

The pipes were inspected with piezoelectric sensor type tool (GUL Co. G3) and magneto-striction type sensor (Digital Ultrasonic Co.) before burial. And the trench was backfilled with soil except for measuring holes (figure 2). Schematic diagram of test loop pipeline with defects relative to measuring points is shown in figure 3.

Figure 2. Test pipes and holes for measurement

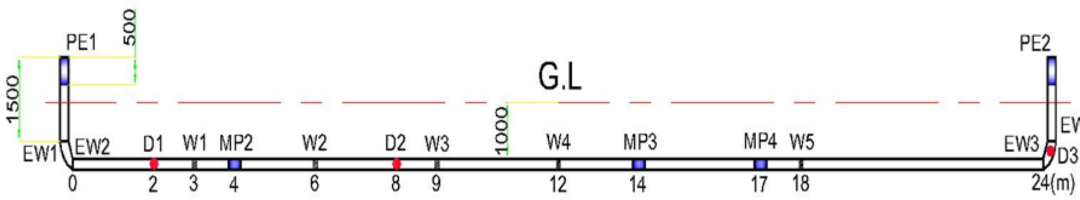

Figure 3. Location of welds and defects at the test pipe

(W: weld, D: defect, MP: measuring point)

Figure 4. Installation of magnetostriction type sensor

Figure 5. Installation of piezoelectric type sensor

The sensors applied to the test pipeline before burial are shown in figure 4 and figure 5. The typical signals taken before burial were shown in following figure 6 ~figure 7 and signals after burials in figure 8 ~figure 9. The signals taken after burial decays faster compared to respective sensor's signal results before burial due to the thick PE coating. Weld and defects signal could be identified up to about 10m range. The signal to noise ratio by magneto-striction sensor is much higher. The piezoelectric sensor showed circumferential resolution which magneto-striction sensor doesn't have and enabled to distinguish between weld signal and local defect. This capability is very useful practically when there is not much information about pipeline weld locations.

The signal decay became more significant at the result obtained at buried pipes. The observed decay at buried pipe is around 6dB/m at 25 kHz. The attenuation rate was known to be frequency dependant. At higher frequency the coefficient became higher (3, 4). The detection ranges were identified and are summarized at Table 2, 3.

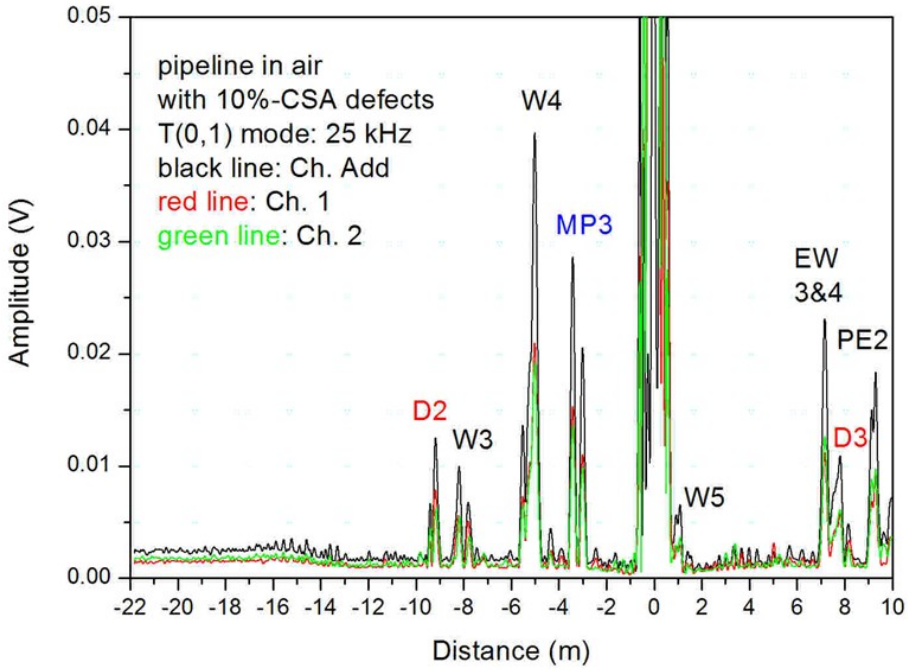

Figure 6. Inspection results with magnetostriction sensor at measuring point 4 before burial

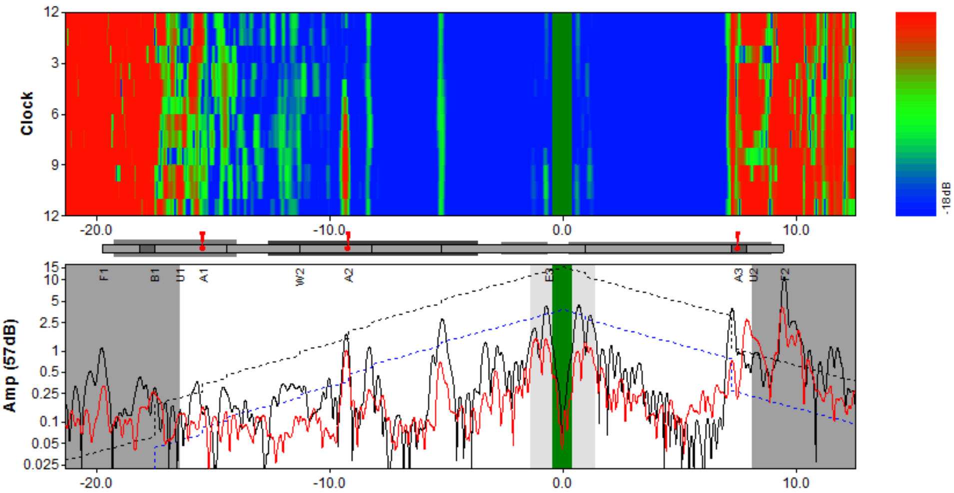

Figure 7. Inspection results with piezoelectric sensor at measuring point 4 before burial

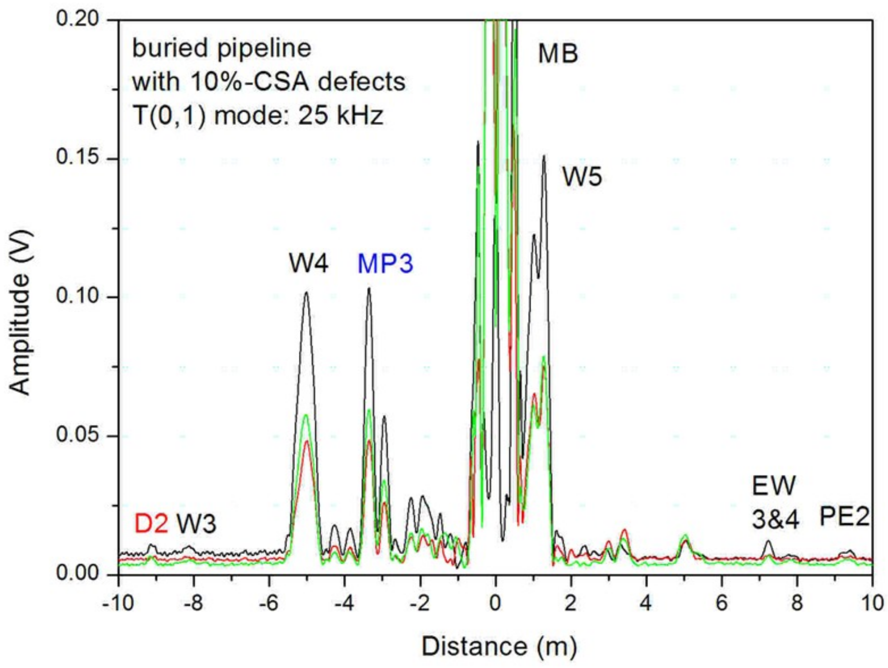

Figure 8. Inspection results with magnetostriction sensor at measuring point 4 after burial

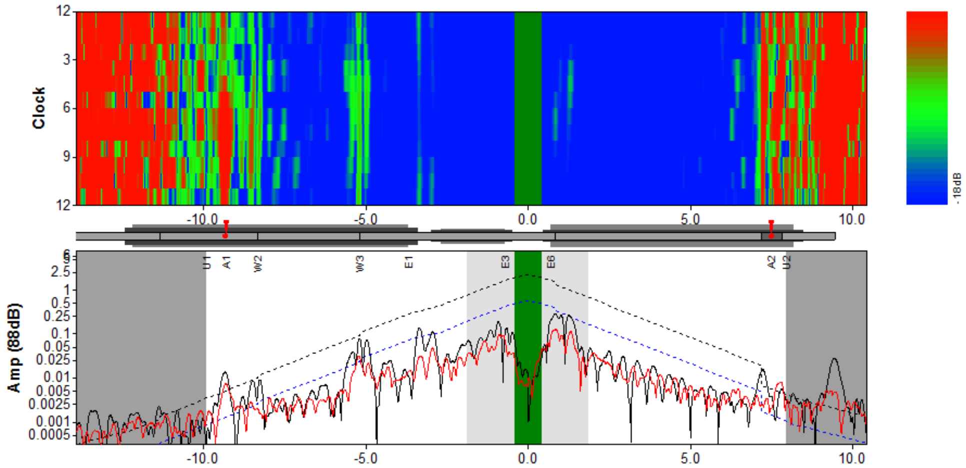

Figure 9. Inspection results with piezoelectric sensor at measuring point 4 after burial

Table 2. Detection range with magnetostriction type sensor (white shade: detectable, gray shade: semi-detectable, dark gray shade: undetectable)

Test # %Cross-section/measuring point No	*Defect No. (before burial)*			*Defect No. (after burial)*		
	D1	*D2*	*D3*	*D1*	*D2*	*D3*
5-2	*2.0*	*4.0*	*20.3*	*2.0*	*4.0*	*20.3*
5-3	*12.0*	*6.0*	*10.3*	*12.0*	*6.0*	*10.3*
5-4	*15.0*	*9.0*	*7.3*	*15.0*	*9.0*	*7.3*
10-2	*2.0*	*4.0*	*20.3*	*2.0*	*4.0*	*20.3*
10-3	*12.0*	*6.0*	*10.3*	*12.0*	*6.0*	*10.3*
10-4	*15.0*	*9.0*	*7.3*	*15.0*	*9.0*	*7.3*

Table 3. Detection range with piezoelectric type sensor (white shade: detectable, gray shade: semi-detectable, dark gray shade: undetectable)

Test # %Cross-section/measuring point No	Defect No. (before burial)			Defect No. (after burial)		
	D1	D2	D3	D1	D2	D3
5-2	2.0	4.0	20.3	2.0	4.0	20.3
5-3	12.0	6.0	10.3	12.0	6.0	10.3
5-4	15.0	9.0	7.3	15.0	9.0	7.3
10-2	2.0	4.0	20.3	2.0	4.0	20.3
10-3	12.0	6.0	10.3	12.0	6.0	10.3
10-4	15.0	9.0	7.3	15.0	9.0	7.3

3. FIELD APPLICATION

The field applications of piezoelectric sensor were conducted at sites (figure 10). The following results show that suspected defects was identified successfully as shown in figure 11. The detection range at the field is slightly shorter than the test pipe. It is believed that uneven soil condition and coating degradation induces higher noise level than that of the test pipe. The detection range is also limited by elbows. In the valve station there are too many elbows in short distance which limit detection range. None the less the guided wave technology enables inspection of the pipe which could not be examined without this technology.

Figure 10. Inspection with piezoelectric sensor at valve station

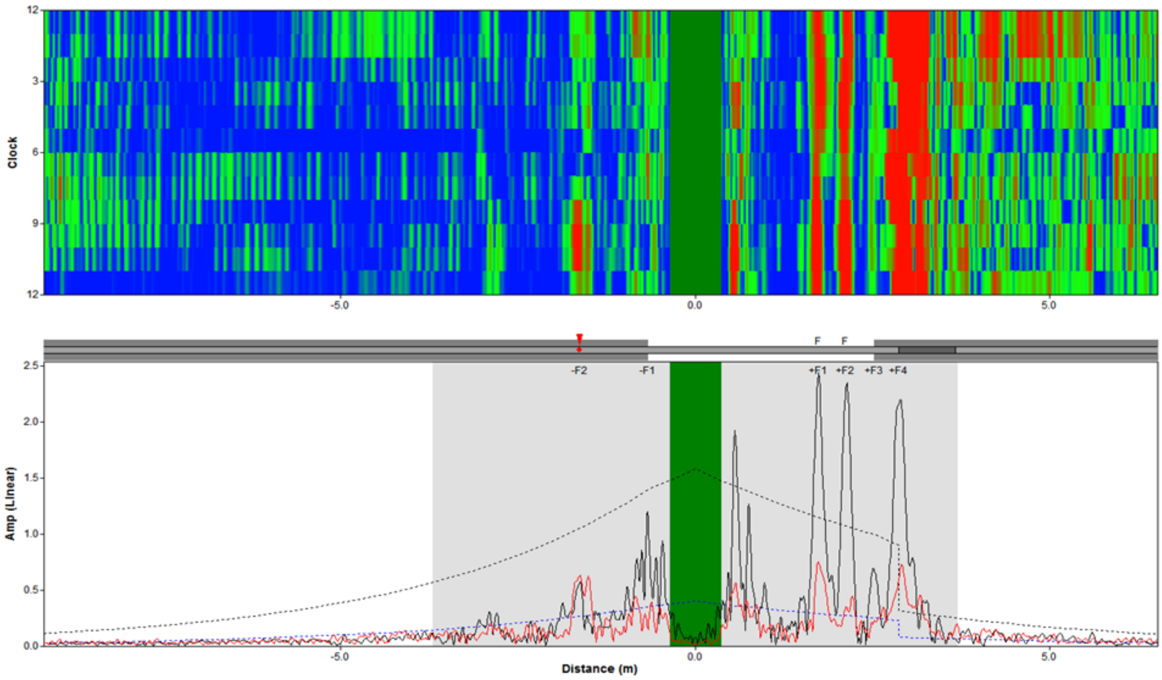

Figure 11. Inspection results with piezoelectric sensor at valve station

(suspected defects at -2m from the measuring point)

4. SUMMARY

In this work two types of sensor, magneto-striction sensor and piezoelectric sensor were applied to buried pipeline test loop. The results showed that detection range is of 5~10 m. The magneto-striction sensor showed better S/N ratio at the results. But the lack of circumferential resolution limited the interpretation of signal. The piezoelectric sensor showed lower S/N ratio with circumferential resolution.

The method was applied to existing valve stations and reveals several indication of metal loss at the unpiggable sections. The results showed the possiblility of the method and the limitation for the inspection of buried pipeline integrity together.

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