Long Range Inspection of City Gas Pipeline Using Ultrasonic Guided waves

Ji Yoon Kim¹, Dong Hoon Lee¹, Kyo Shik Park¹, Young Do Jo¹, Song Chun Choi¹
Chang Hun Lee¹, Sung Jin Song², Yong Moo Cheong³

¹Institute of Gas Safety Technology, Korea Gas Safety Corporation, Shiheung, South Korea,
²School of Mechanical Engineering, Sungkyunkwan University, Suwon, South Korea
³Korea Atomic Energy Research Institute, Daejon, South Korea

Abstract

In order to develop a long range nondestructive testing technology to detect flaws in city gas pipelines, the dispersion curves for the pipe were calculated by Matlab program. Ultrasonic guided waves were generated in city gas pipeline using MsSR 2020 equipment. The magnetostrictive sensor (MsS) technology was developed by Southwest Research Institute for generation ultrasonic guided waves. In this paper, the field test data from straight city gas pipeline. We modulate a frequency to search for the optimal frequency (32 kHz ~ 256 kHz) and defect detection sensitivity. This technique is relatively simple and easy to detect the defect, but its application would be limited due to the small axial crack.

1. Introduction

In the recent year, the city gas pipelines from Korea about 25,000 km is to in the process of using the many portion is laid in underground. The city gas pipelines which is established initially 20 years in present time elapse as the corrosion due to the deterioration of pipelines and underground laying which it follows in the urbanization which is receiving the effect of interference.

Initial Nondestructive Testing methods (Ultrasonic Testing (UT), Radiographic Testing (RT), Eddy Current Testing (ECT), Magnetic Flux Leakage (MFL) can be point by point inspection. It has the problem of time restriction and expense. To overcome these problems, the develop of effective testing method has been needed. Ultrasonic guided waves follows the geometric structure and it propagates with length direction. It consist of a longitudinal wave and a transverse wave.

The ultrasonic guided waves with the general ultrasonic waves has a very different characteristics. Specially, It has Infinite wave mode exist in widely frequency spectrum and the propagated speed is changed according to the frequency and the thickness. Therefore, the dispersion curve with dispersion characteristics is very important.

Research of the ultrasonic guided waves in tubes has been basic research in the 1960[1]. And the research for the heat exchanger tubes and pipes is advanced actively after 1990[2-12]. Recently, The SwRI develop the MsSR 2020 instrument using the Magnetostrictive Level Sensors, and it applies in field.

2. Dispersion characteristic of the city gas pipe.

Guided wave modes and their dispersive characteristics can be revealed by solving a wave equation with proper boundary condition[1]. In piping, there are infinite number of modes that are named longitudinal modes(L(0,n)), torsional modes(T(0,n)), and flexural modes(F(M,n)), where M is the circumferential order and n is the mode number. In most cases, longitudinal and torsional modes are used for the inspection because they are axisymmetric modes. Flexural modes are non-axisymmetric modes and often propagate together with longitudinal modes.

Figure 1 and Fig 2 shows the phase and group velocity dispersion curves for longitudinal, torsional and flexural modes in the city gas pipe with the outside diameter of 216.3 mm and the wall thickness of 5.85 mm. The axes of ordinates represent the phase and group velocities, while the horizontal one the frequency(f) times thickness(d) of pipe(fd). For the investigation of the dispersion characteristics, we have used a computer code
implemented by Lee[2] that can calculate the phase and group velocities in elastic hollow cylinders. It is noticed that Flexural modes have similar patterns of dispersion with the longitudinal modes and congregated according to the mode number[3].

Table 1. shows inside diameter, outside diameter, thickness, longitudinal wave velocity and shear wave velocity of city gas pipes in Korea(KS D 3631).

<table>
<thead>
<tr>
<th>Material</th>
<th>KS D 3631</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside Diameter</td>
<td>204.6 mm</td>
</tr>
<tr>
<td>Outside Diameter</td>
<td>216.3 mm</td>
</tr>
<tr>
<td>thickness</td>
<td>5.85 mm</td>
</tr>
<tr>
<td>Longitudinal wave Velocity</td>
<td>5,920 m/s</td>
</tr>
<tr>
<td>Shear wave Velocity</td>
<td>3,230 m/s</td>
</tr>
</tbody>
</table>

3. Specimens

The specimens used in this study are shown in Figure 3, which are city gas pipes(KS D 3631) without polyethylene coating that are used for the distribution of fuel gas.

Figure 3 : City gas pipe for the investigation

4. Guided wave inspection on city gas pipes using MsSR 2020 Instrument

4.1. Instrument set-up

A schematic diagram of the MsS and associated instrument for generation and detection of guided
waves is illustrated in Figure 4. And, Figure 5 shows MsSR 2020 instrument.

In practical inspection applications, the guided waves is controlled to transmit and receive in one direction with two or more channels of transmitter and receiver so that the either side of the MsS probe can be separately inspected. The direction control is achieved by applying the phased array principle using two sets of transmitters and receivers that are built into the MsS instrument and two or more transmitting and receiving coils in MsS probes.[4,5] In this paper, the guided wave generated at a location of city gas pipe propagates in both directions.

Induce residual magnetization along the lengthwise direction of the strip by moving a permanent magnet for pipes (such as the one shown in Figure 6) over the strip.

The ribbon-coil probe is for use on pipes, tubes, cables, wires, and rods of any cross-sectional shape (such as circular, square, rectangular, hexagon, etc.)[4]. The probe consists of two components, coil adapter and ribbon cable, as shown in photos in Figure 7.
4.2. Frequency optimizations for guided wave inspections

In order to determine an ideal inspection frequency for detecting various flaws in the city gas pipes, we analyzed signals acquired in each frequencies (32 kHz, 64 kHz, 128 kHz, and 256 kHz). Figure 8 showed the signals received on the end of city gas pipe.

![Figure 8: Signal of 3m long pipe without defect](image)

(a) 32 kHz (b) 64 kHz (c) 128 kHz (d) 256 kHz

4.3. Flaw detection in city gas pipe

One artificial notches were fabricated on the city gas pipes, shown in Figure 9 and the dimensions are Table 2.

<table>
<thead>
<tr>
<th>Dimension of artificial notches on city gas pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
</tr>
<tr>
<td>Width</td>
</tr>
<tr>
<td>Depth</td>
</tr>
<tr>
<td>Location (from sensor)</td>
</tr>
</tbody>
</table>

![Figure 9: photos of artificial notch in city gas pipe](image)
Figure 10 shows an acquired guided wave signal from the artificial notch on the city gas pipe.

5. Conclusions.

In this study, we investigated suitability for long range inspection of city gas pipes in Korea[KS D 3631] using MsS guided waves technique. The dispersion curves obtained from the method were calculated by Matlab program. In order to determine an ideal inspection frequency for detecting various flaws in the city gas pipes, we analyzed signals acquired in each frequencies(32 kHz, 64 kHz, 128 kHz, and 256 kHz) at the end of them. From the results, it was identified that the circumferential flaw in them could suitably be detected at 64 kHz and 128 kHz.

6. Reference