Long Range Inspection of City Gas Pipeline Using Ultrasonic Guided waves

Ji Yoon Kim[1], Dong Hoon Lee[1], Kyo Shik Park[1], Young Do Jo[1], Song Chun Choi[1]
Chang Hun Lee[1], Sung Jin Song[2], Yong Moo Cheong[3]

[1]Institute of Gas Safety Technology, Korea Gas Safety Corporation, Shiheung, South Korea,
[2]School of Mechanical Engineering, Sungkyunkwan University, Suwon, South Korea
[3]Korea 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 modlate 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.

In this paper, we used the ultrasonic guided waves for flaw detection in the Korea city gas pipelines. And also we found the optimized condition using the Magnetostrictive Level Sensors.

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 notices that Flexural modes have similar patterns of dispersion with the longitudinal modes and congregated according to the mode number[3]

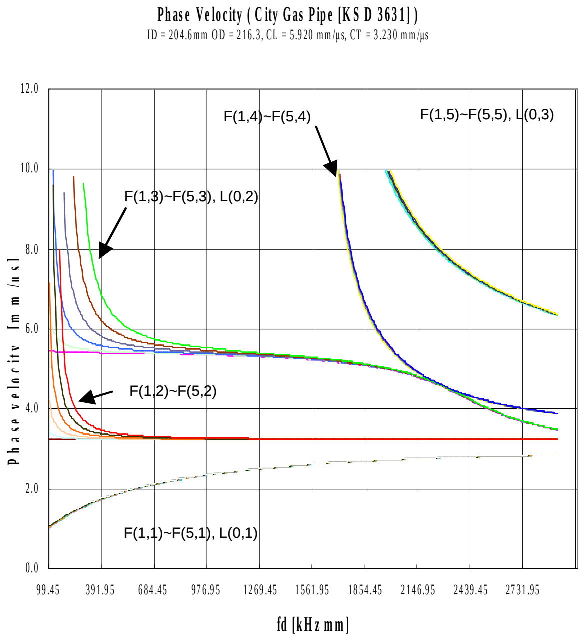


Figure 1 : *Phase velocity dispersion curves in city gas pipes[KS D 3631]*

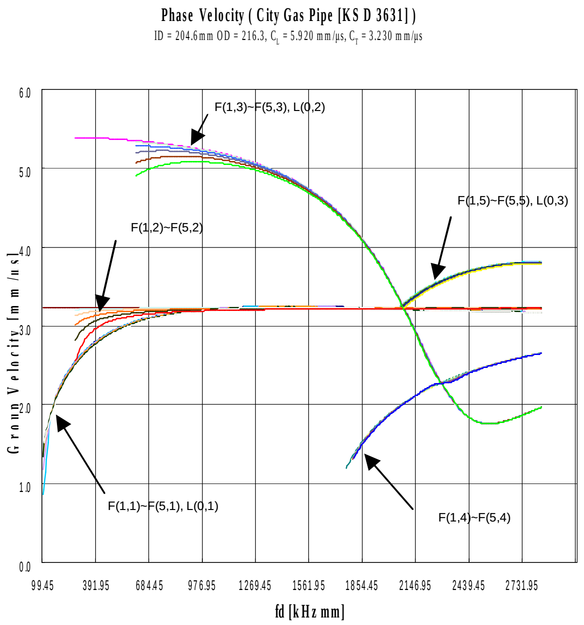


Figure 2 : *Group velocity dispersion curves in city gas pipe[KS D 3631]*

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 1 : geometric and velocity of city gas pipes (KS D 3631)

Material	KS D 3631
Inside Diameter	204.6 mm
Outside Diameter	216.3 mm
thickness	5.85 mm
Longitudinal wave Velocity	5,920 m/s
Shear wave Velocity	3,230 m/s

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.

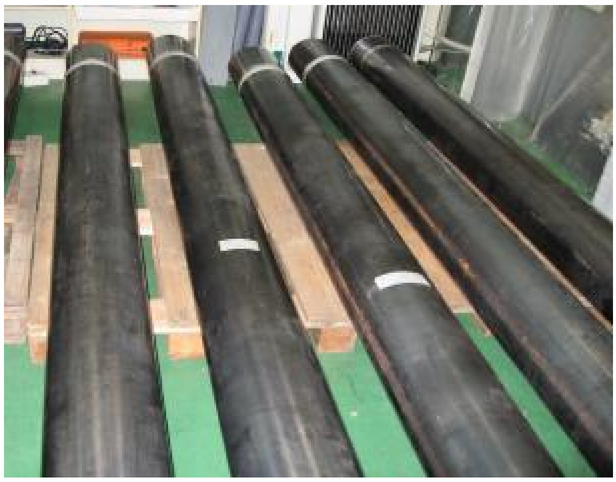


Figure 3 : *City gas pipe for the investigation*

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.

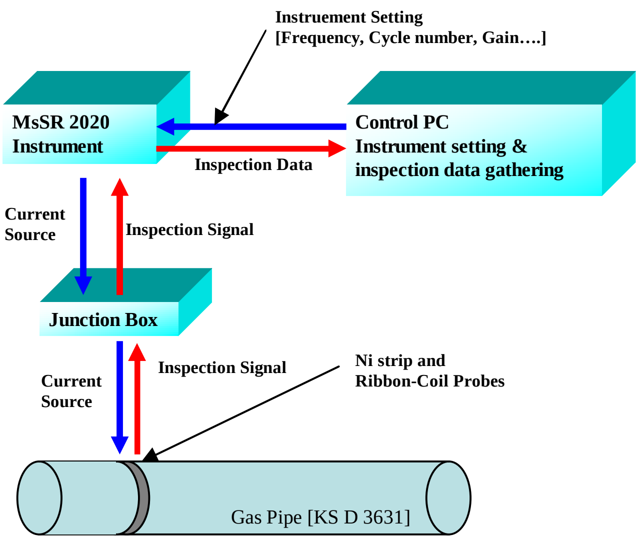


Figure 4 : *Schematic diagram of experimental setup for ultrasonic guided waves in city gas pipes*

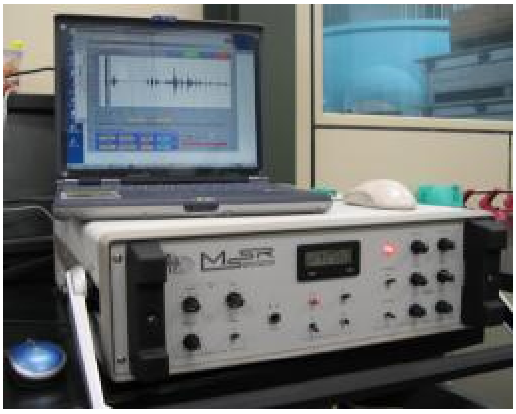


Figure 5 : *Experimental setup using MsSR 2020*

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.

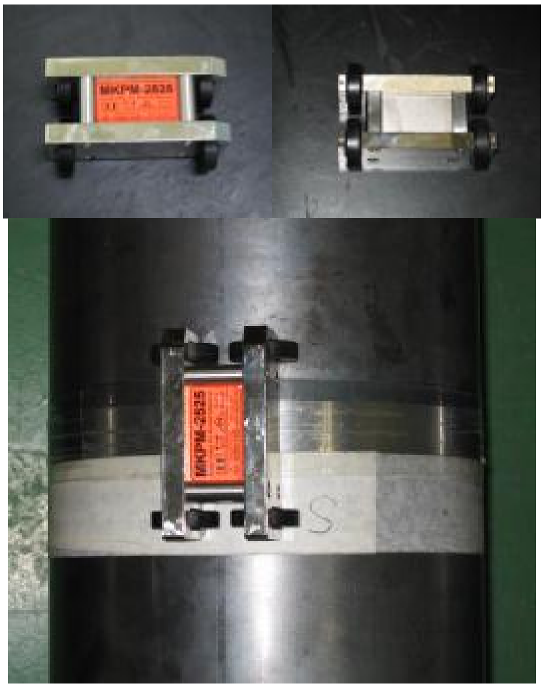


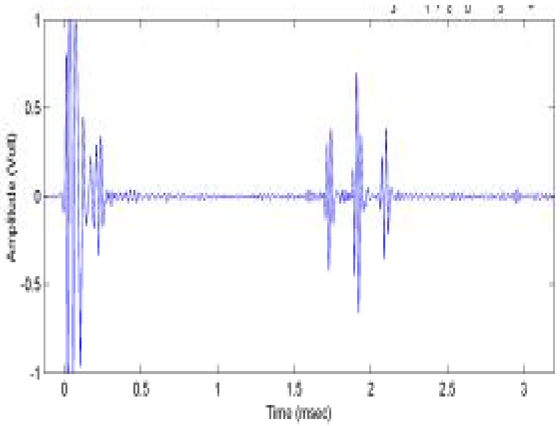
Figure 6 : *Magnet for inducing residual magnetization in a nickel strip*

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

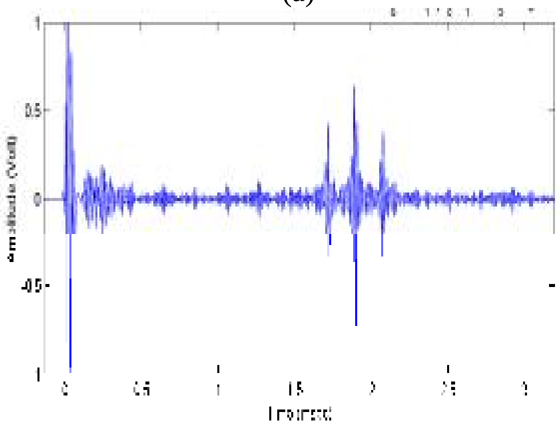
Figure 7 : *Coil adapter and 8 inch ribbon coil*

4.2. Frequency optimizations for guided wave inspections

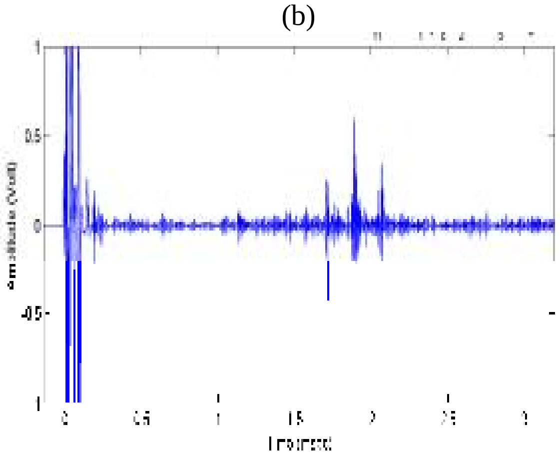
In order to determine an ideal inspection frequency for detecting various flaws in the city gas pipes, we analyzed signals acquired in each frequencies(32 kHz, 64 kHz, 128 kHz, and 256 kHz). Figure 8 showed the signals received on the end of city gas pipe.



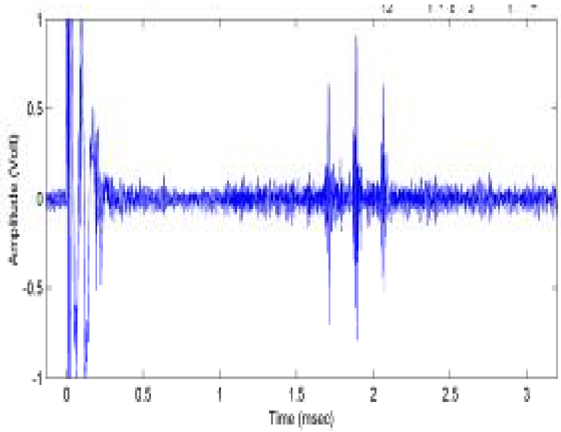
(a)



(b)



(c)



(d)

Figure 8 : *Signal of 3m long pipe without defect*
(a) 32 kHz (b) 64 kHz (c) 128 kHz (d) 256 kHz

4.3. Flaw detection in city gas pipe

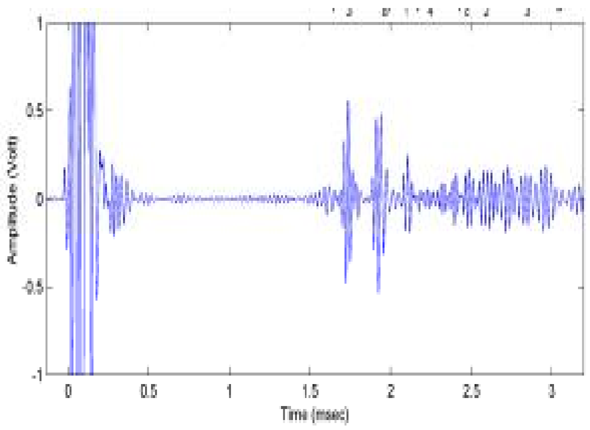
one artificial notches were fabricated on the city gas pipes, shown in Figure 9 and the dimensions are Table 2.

Table 2. Dimension of artificial notches on city gas pipe

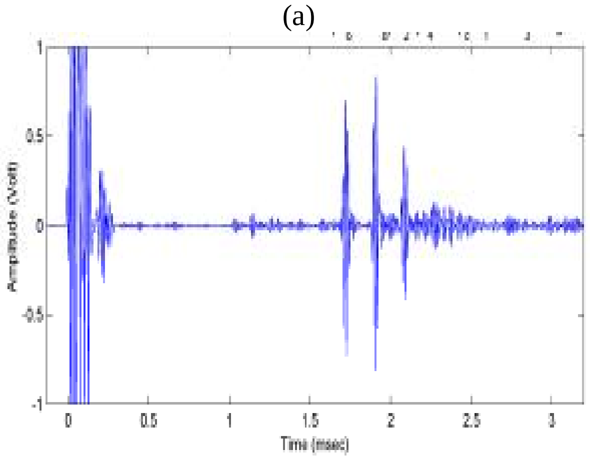
Length	5 mm
Width	1 mm
Depth	2 mm (≒30% t)
Location (from sensor)	1.7 m

Figure 9 : *photos of artificial notche in city gas pipe.*

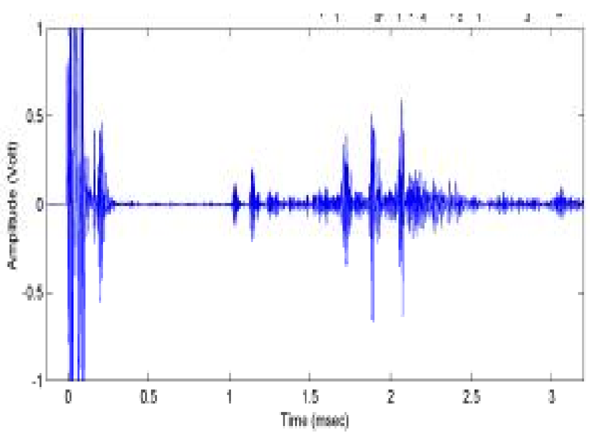
Figure 10 shows an acquired guided wave signal from the artificial notch on the city gas pipe.



(a)



(b)



(c)

Figure *10 Guided wave signal from city gas pipe(#2) with 2mm of depth notch (a) 32kHz, (b) 64kHz, (c) 128 kHz*

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 64kHz and 128 kHz.

6. Reference

[1] D. C. Gazis, "Three dimensional investigation of propagation of waves in hollow circular cylinders. I. Analytical foundation", J. Acoust. Soc. Am., Vol. 31 (5), pp.568-573, (1959)

[2] D.H Lee, "A study on scale detection in water piping using guided waves", MS. Thesis, Sungkyunkwan University, (2002)

[3] D.H Lee, "Application of Guided Waves for Detection of Scale Inside Water Supply Pipes", Key Engineering Materials Vols. 270-273(2004)

[4] Sensor System and NDE Technology Department "Operating and Technical Instruction Manual for Magnetostrictive Sensor(MsS) Instrumentation System", SwRI (2002)

[5] Sang Y. Kim, "Guided Wave Inspection of Gas Transmission Line", GTI Conference, (2005)

[6] Y.M Cheong, "Optimization of the ultrasonic guided wave parameters for crack detection in a feeder pipe of the PHWR power plants", Ultrasonic International`03 (2003)

[7] J. L. Rose, Ultrasonic Waves in Solid Media, pp.96, Cambridge University Press, (1999)

[8] J. J. Ditri and J. L. Rose, "Excitation of guided elastic wave modes in hollow cylinders by applied surface tractions", J. Appl. Phys. Vol. 72 (7), pp.2589-2597, (1992)

[9] J. J. Ditri, "Utilization of guided elastic waves for the characterization of circumferential cracks in hollow cylinders", J. Acoust. Soc. Am., Vol. 96, pp.3769-3755, (1994)

[10] H. Kwun and K. A. Bartels, "Experimental observation of elastic-wave dispersion in bounded solids of various configurations", J. Acoust. Soc. Am., Vol. 99 (2) pp.962-968, (1996)

[11] H. J. Shin and J. L. Rose, "Guided wave tuning principles for defect detection in tubing", J. NDE, Vol. 17 (1), pp.27-36, (1998)

[12] Y. M. Cheong, D. H. Lee and H. K. Jung,"Ultrasonic guided wave parameters for detection of axial cracks in feeder pipes of PHWR nuclear power plants", Ultrasonics, Vol. 42, pp.883-888 (2004)