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Application of ultrasonic NDT technique for butt fusion joints of plastic pipes

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1. Introduction

Plastic pipes such PE(Poly-ethylene), PVC (Polyvinyl chloride) and PA(Polyamide) are an important player in the construction of domestic and overseas infrastructure for conveyance of fluids, such as in gas and water systems for many years. The long term-durability and the soundness of the plastic pipe have been sufficiently verified through use of the plastic pipe during the past several decades. Recently, as the pipe material have been constantly developed, the application of the plastic pipe is expanded to various industrial fields, such as an increase of a use pressure, the bigger diameter of the pipe, etc. In a nuclear power plant where a carbon steel pipe and a stainless steel pipe are mainly used as a safety class III buried pipe, safety in an operation is seriously threatened by abrasion, heat deterioration or the like, frequently generated in a metal pipe. Therefore, in order to provide an alternate to this problem there is a rising interest on using high-density polyethylene (HDPE) pipes which are known to provide much enhanced corrosion, abrasion and impact resistant properties. With polyethylene piping, one of the issue that is being looked into is the integrity of butt-fusion joint. At the present time the Referencing Code and Standard for the NDT technology of for butt fusion joint of the plastic pipe have not yet established. Therefore, it is a current situation that securing a non-destructive inspection standard technique is much urgently required. As a global interest on the HDPE pipe has been raising as increased demand for new construction of nuclear plants and replacement of old pipes, investigations are underway in countries that are leading the nuclear plant technology in order to procure inspection technologies for the purpose of ensuring the integrity of butt fusion joints in buried polyethylene pipe. [1- 5] This study is to develop a non-constructive inspection technology to ensure the integrity of butt fusion joints of a nuclear plant safety class III HDPE pipe. To achieve this, two kinds of ultrasonic techniques, phased array ultrasonic testing (PAUT) and time of flight-diffraction (TOFD), were investigated.

2. Properties and Applications

2.1 Properties of ultrasonic wave for HDPE pipe

An HDPE material has properties of high attenuation to ultrasonic waves and low propagation velocity in comparison ultrasonic waves in metallic materials. Therefore, it is required to develop an additional study for the application in field inspection. For this, the selection of proper ultrasonic probes and the establishment of inspection techniques are necessary.

2.2 PAUT(Phased Array UT)

A PAUT technique simultaneously obtains inspection data by generating beams at various angles and in various shapes in such a manner to apply electric time delays to each vibration element using a probe consisting of several elements and combine it. Particularly, there is an advantage in that the interior of an inspected object can be observed at various angles through sectorial scan (Fig.1).

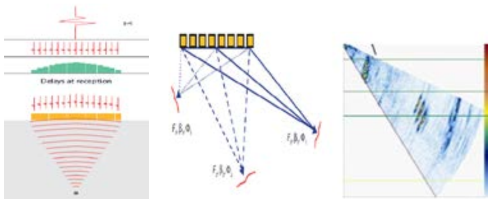

Fig. 1. Obtaining data through transmission & receiving

2.3 TOFD(Time Of Flight Diffraction)

A TOFD technique is an inspection method using a diffraction phenomenon of a sound wave and a technique to inspect a surface and an interior of a butt joint through high speed scanning by two probes for transmission and receiving, that face each other at a predetermined interval (Fig.2). Basically, TOFD relies on diffraction of ultrasonic energies from 'corners' and 'ends' of internal structures (primarily defects) in a component being tested.

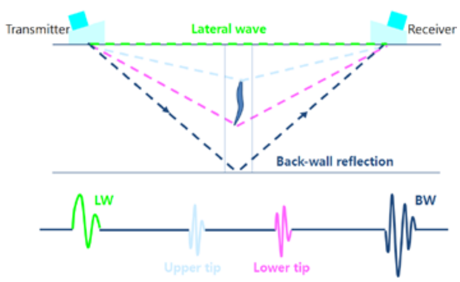

Fig. 2. Probe arrangement for TOFD technique

3. Experiments and Results

There are various diameters and wall thickness of HDPE pipes and their use depends on applications.

To select suitable test frequency and secure flaw detectability with the thickness of pipe, this study exhibits results from reference blocks made from different thickness HDPE piping materials as well as in butt fusion joint containing flaws, using both PAUT and TOFD methods.

3.1 Butt fusion

A butt fusion process using an automatic/manual type-butt fusion welding machine (Fig. 3a) is as follows: bring both ends of pipes together (Fig. 3b) → machine surfaces and check the alignment (Fig. 3c) → press and fuse contact surfaces and apply heat (Fig. 3d) → cooling under pressure (Fig.3e) → complete fusion (Fig. 3f). Essential variables in the butt fusion are heater surface temperature, interfacial pressure and time.

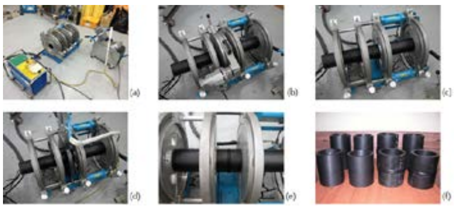

Fig. 3 Butt fusion process. (a) butt fusion welding machine, (b) bring surfaces together and (c) machine surfaces and check the alignment, (d) apply pressure/temperature for butt fusion (e) cooling under pressure, (f) butt fused specimens.

3.2 Reference blocks

As a reference block, HDPE flat plates with each thickness of 10 mm, 30 mm, 60 mm and 100 mm were used. Side drilled holes (SDHs), and surfaces notches were used as reflecting objects as shown in Fig. 4. It was intended to obtain an optimum inspection condition value through the evaluation ultrasonic wave attenuation, the size of defect detecting signal with respect to each reference block [6- 8].

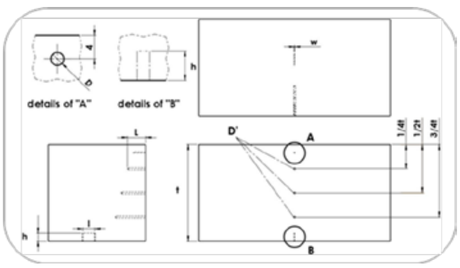

Fig. 4. Diagram of a single reference block containing SDHs (1/4t, 1/2t, 3/4t) and a bottom surface notch

3.2.1 Inspection image (reference block)

Reference blocks with thickness range of 10 mm to 100 mm were inspected. An example of an inspection result, in the form of images from a 60 mm thick reference block are shown in Fig 5 and 6. The optimum inspection condition was confirmed by checking the maximum reflecting signal, resolution and diffracted signals with respect to the reflecting object in each technique. Meanwhile, considering material characteristics such as a low speed, various specific tools such as a water wedge or the like were designed, manufactured, and applied to the inspection.

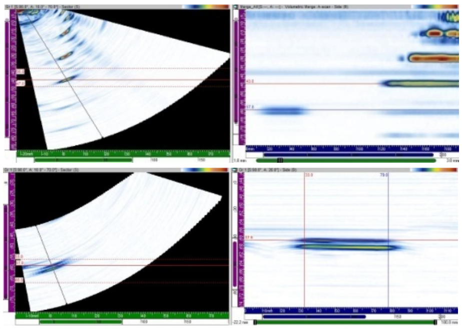
(a)
(b)

Fig. 5. Frequency 2.25 MHz inspection (thickness : 60 mm)
(a) SDH signal, (b) bottom surface notch tip and corner signal

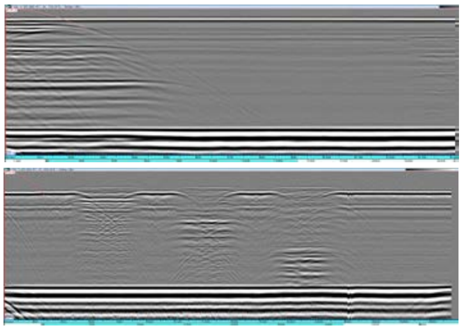
(a)
(b)

Fig. 6. Frequency 5.0 MHz inspection (thickness : 60 mm)
(a) SDH signal, (b) surface notch signal

3.3 Butt fusion joints with simulated flaws

A butt fusion joint of a 450 SDR 7 pipe containing artificial flaws at the joint interface is manufactured and inspection performed. Flaws include particulates, lack of fusion (LOF), and voids.

3.3.1 Inspection image (butt fusion joints)

Fig 7 shows a test result from PAUT. In case of particulate defects, the signal can be seen as not clear and also indicates particulate are not well distributed.

In case of a thin plate simulated as LOF, a size of the plate can be estimated through a depth different between an upper end and a lower end of a defect. In case of void, the void could be distinguished using characteristic signal from the end. Fig. 8 shows an image from the TOFD inspection. A defect was evaluated while paying attention to a change in an ultrasonic signal phase value. A highly accurate size information value regarding the defect could be secured through the TOFD inspection.

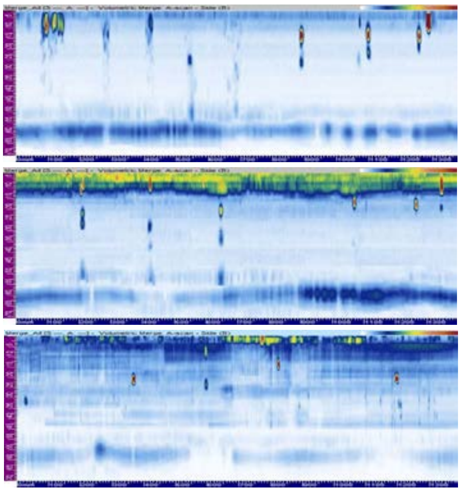

Fig. 7. PAUT data. (a) Particulates (b) LOF (c) void

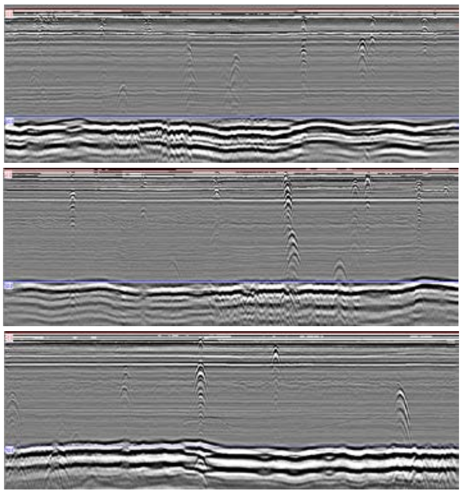

Fig. 8. TOFD data. (a) Particulates (b) LOF (c) void

4. Conclusions

An optimum inspection parameters were determined according to the thickness of the HDPE pipe. It was also confirmed that most of the detection results of two techniques have matched with each other. In the PAUT, it is easy to distinguish signals with from the flaws made by the thin plate and the void. Also the resolving power of PAUT on the detection in the depth direction has been demonstrated to be satisfactory. In the TOFD inspection, it is shown that particulates are distinguished and distribution is checked. Particularly, it can be checked that the size of the defect is accurately measured. In order to improve the reliability of inspection, PAUT and TOFD techniques are required to be complementarily performed in a volumetric examination of fused joints of HDPE pipes. This study demonstrated that PAUT and TOFD are viable methods for non-destructive inspection to be utilized for the establishment of a standard technique for the integrity of the butt fusion joints.

ACKNOWLEDGMENT

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REFERENCES

[1] PNNL Technical Letter Report 2008 "Preliminary Assessment of NDE Methods on Inspection of HDPE Butt Fusion Piping Joints for Lack of Fusion"

[2] Hagglund F, Spicer M and Troughton M: “Phased array ultrasonic testing of welded joints in plastics (PE) pipes”, 6th Middle East NDT Conference and Exhibition, Bahrain, 7-10 October 2012.

[3] Troughton M, Spicer M and Hagglund F: “Development and assessment of a phased array ultrasonic inspection system for polyethylene pipe joints”, ANTEC Conference, Las Vegas, USA, 28-30 April 2014

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[4] Byungho park, Wonnyung Heo and Hyunsang cho: "An Application of Phased Array and Time of Flight Diffraction Methods for Inspection of HDPE Butt Fusion for Nuclear Power Plants", KSNT Conference, Seoul, Korea, 23-24 October 2014.

[5] Hyungtaik Lim and Taegyung Kim: "Recent Trends of NDE Technique & Associated R&D in HDPE Pipe Joints", KPVP Conference, Busan, Korea, 4-5 December 2014.

[6] ISO 13588, "Non-destructive testing of welds – Ultrasonic testing- Use of automated phased array technology"

[7] ISO 10863, " Non-destructive testing of welds — Ultrasonic testing — Use of time-of-flight diffraction technique"

[8] ASTM E2373, " Standard Practice for Use of the Ultrasonic Time of Flight Diffraction Technique"