Improved Corrosion NDT Measurements Using Phased Array Ultrasonic Technology

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1. Introduction

When corrective measures are not taken, corrosion can lead to the reduction in capacity of structural members and early failure. Corrosion progresses unevenly, therefore it is important to reliably detect and monitor the corrosion of structural elements, including on difficult to access surfaces of the elements. Ultrasonic technology (UT) could measure precisely the thickness of the steel elements even when only one surface of the element is accessible. Standard UT method based on single probe technique has difficulties to measure corroded surfaces as the reflected waves falling on surfaces which are non-orthogonal to the incident wave are reflected away from the ultrasonic single probe. To address this limitation, we propose determining 3D shape of corroded elements and measuring remaining thickness using phased array probes. A practical corrosion inspection method using ultrasonic phased array technology and multi-angle steered waves is proposed for the onsite inspection of steel structural elements.

2. Corrosion Specimen and Experimental Methods

In this study, we analyze the applicability of the linear and planar phased arrays UT for the inspection of corrosion in steel plates with one surface inaccessible for visual inspection. A corroded plate specimen retrieved from the Benoki Bridge (Okinawa) which had collapsed due to advanced corrosion was examined nondestructively by pulse-echo UT, and then, plate was cut along scanning planes and plate thickness measured with the vernier caliper.

3. Corrosion Detection by UT Phased Array

The phased array (PA) probe consists of a group of small transceivers. Phased array can focus and steer resulting wave by adjusting the individual timing of each of the elementary waves it generates. Focusing the waves concentrates the wave energy at the desired spot, and mitigates the wave spreading which would occur with single probe transceiver. In addition, wave steering allows transmitting and receiving waves at an inclined angle, improving reception of waves reflected on inclined corroded surfaces, non-parallel with the surface ultrasonic probe is placed. Ultrasonic wave could be steered at up to 70degree, for angles above 45degree reflected wave intensity decreases.

4. Experimental Results

Corrosion measurements by linear phased array are shown in Fig. 4. For each measurement a group of 16 out of 64 transceivers are used, and then the active transceivers group is shifted by one, obtaining 48 sets of scans at each location, as shown in Fig.1. Optimal number of transceivers used in a group was determined to be 16 for current scan depth. Data are acquired with the wave focusing at 5 to 9mm deep, where 9mm is the original thickness of the plate. The probe is then shifted by 28mm (the probe active scanning aperture) for the next set of measurements. The reflection from corroded surface is weak when reflected surface is not orthogonal to the vertical wave. We proposed a multi-angle steered wave scanning law, extending the software capabilities of the UT test instrument,

[Fig 1.a] Vertical scan by linear phased array

[Fig 1.b] Inclined wave scan by linear phased array.

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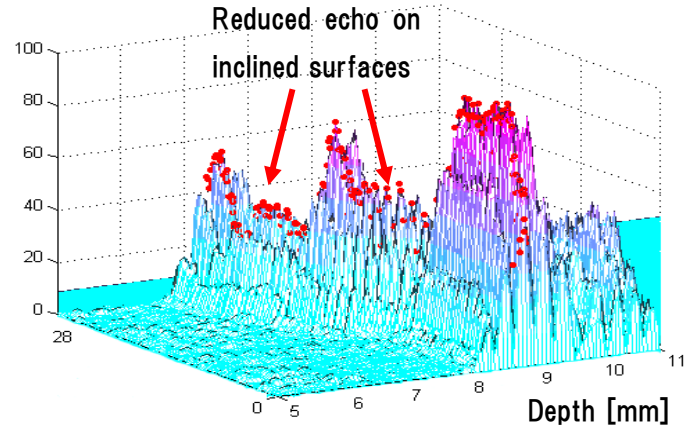
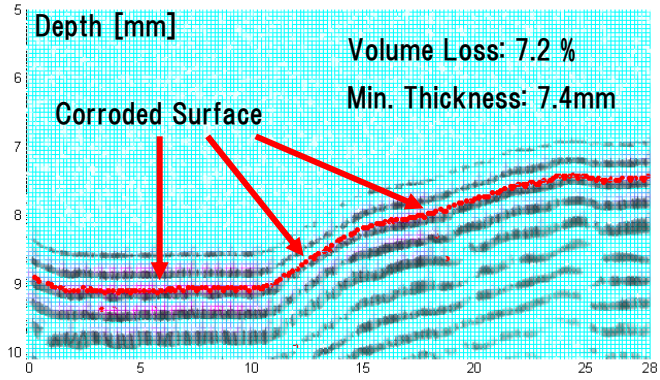
by generating for each measurement linear scanning waves inclined at +/-15, +/-5 and 0 degree. Reflections on inclined surfaces are improved, while scanning time remains the same. SAFT (Synthetic Aperture Focusing Technique) combines multiple scans into a higher resolution reconstructed image of the surface.

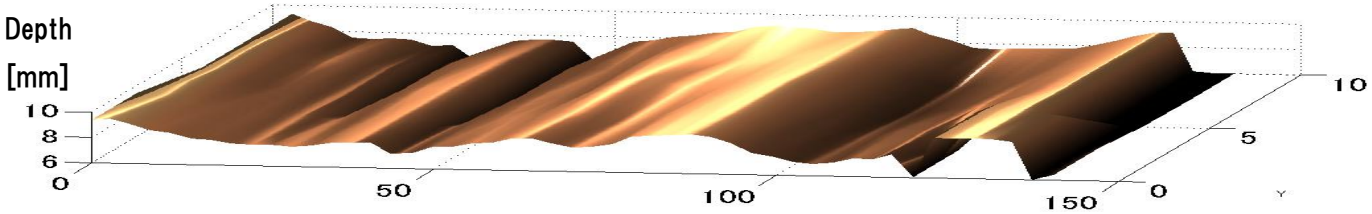
Corrosion measurement by planar array probe consisting of 8x8 transceiver elements was also evaluated. Planar array could steer the waves in any direction, this is advantageous compared to linear array scanning which could receive only the waves reflected in the scanning plane. The drawback is an increase in volume of scan data.



[Fig.2] Corroded surface back-echo reflection's intensity



[Fig.3] Corroded surface scan by multi-angle linear PA



[Fig.4] Corroded surface 3D plot by linear phased array

[Fig.5] Photo of the corroded specimen (section)

Scanning Section	UT Linear Ph. Array Measurements [mm]	Vernier Caliper Measurements [mm]	Error
A	8.12	8.15	0.40%
B	8.05	7.95	1.20%
C	8	8.02	0.10%
Average	8.06	8.04	0.57%

[Table.1] Comparison of thickness measurements

After the UT measurements were completed, the plate was cut along the scanning planes and the thickness of the material was measured with the vernier caliper. The average thickness from UT and caliper measurements is shown in Table 1. The differences between measurements by the two methods are partially attributed to positioning error, as both caliper measurements and UT probe positioning are made manually, with mm precision.

5. Summary

- Phased Array UT was evaluated for detection of corrosion on the inaccessible face of the structural elements.
- A practical method is proposed for measuring element thickness even for surfaces with advanced corrosion. Phased Array UT improves detectability of the surface shape and accuracy of the corrosion measurements by using waves focusing and multi-angle wave steering. Detailed 3D shape of the surface is obtained by SAFT.
- Data processing software helps to identify the spots with advanced corrosion and calculate loss of material. Automatic scanning and data processing are recommended for handling the increased volume of data.