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# Evaluation of metal weld-zone by using Poisson's ratio distribution

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## 1. Introduction

Heat affected zone (HAZ) is one of fracture sensitive area which is weaker than both the base metal and weld zone. Therefore welded joints are very sensitive to fracture and it should be inspected for structural integrity. Typical material characterization of weldment involves microscopic analysis of material texture and micro-hardness test. In nondestructive testing (NDT), ultrasonic wave speeds and attenuation of the sample are measured. Poisson's ratio, the ratio of lateral contraction to longitudinal extension, has not received much attention because of its narrow range of value and difficult measurement. However, It has been reported that Poisson's ratio is closely related to the bonding forces and ultrasonic wave speeds in the material [1]. It means Poisson's ratio can also be one of characterizing factor.

In previous work, genuine nondestructive evaluation method of characterizing weld-zone using Poisson's ratio distribution was proposed. By immersion ultrasonic testing, longitudinal and transverse wave speeds were measured simultaneously. Having no couplants makes free scan possible over large surface area. Moreover, velocity ratio can be obtained without prior knowledge of specimen thickness. Poisson's ratio can be calculated by using the relationship below.

$$\mu = \frac{1-2\alpha^2}{2-2\alpha^2} = \frac{\tau_t^2 - 2\tau_l^2}{2\tau_t^2 - 2\tau_l^2} \qquad (1)$$

where $\alpha = c_t / c_l$ is the ratio of transverse and longitudinal wave velocity, and $\tau_t$ and $\tau_l$ are the transit times of transverse and longitudinal wave respectively [2-4].

In the present work, weld specimen SM490 steel was provided. Ultrasonic pulse-echo signals were acquired in the immersion testing and the mode converted signals were identified. Focused transducer as well as normal one was employed for ultrasonic testing. Micro-hardness was measured by Vickers Hardness testing and compared with the Poisson's ratio distribution.

## 2. Experiment

Double V-groove welded steel plates were fabricated by CO2 welding method. As a welding bar, Dual shield 7100 was used. The specimen is of 20 mm thickness and of 75 mm width. Specimen was cut out from the weldment with water cooling to avoid thermal effects during cutting the specimen. Two samples are prepared.

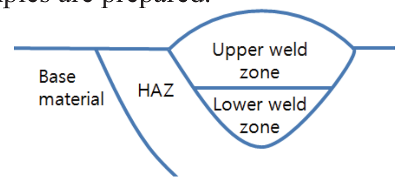


Fig. 1 Diagram of Welded Zone

For measuring the hardness of the sample, samples are processed to show HAZ and Weld zones. After that, Vickers Testing was performed 5 times in each area including base material, HAZ, upper welding zone and lower welding zone. Load used in the testing was 10kg and duration was 10 s. Vickers hardness data, which is directly related to yield strength of material, was obtained.

Moreover, microstructure photos are taken by microscope. (Fig. 2) The grain size and grain pattern can be observed in these pictures. Each photo has 150μm width. Fracture like structure is identified in HAZ.

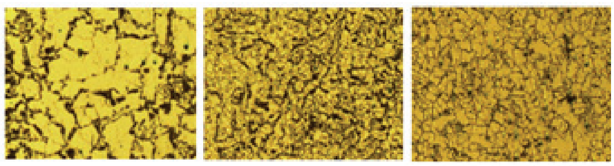

Fig. 2 Micro-structure of base metal, HAZ and weld zone

The echo signals were captured using the normal beam transducer of which diameter and a center frequency were 9.5 mm and 10 MHz and focused transducer of which diameter and a center frequency were 12.7 mm and 10 MHz, respectively. Focused transducer has maximum focal length 50.8mm. Ultrasonic pulser/receiver (Panametrics 5800) and A/D converter module (NI PXI-5124) were used for generation, reception and acquisition of signals. Sampling rate was 200MHz/s, so that the time resolution was 5 ns. Cross-section of specimen was scanned in water tank. Scan area was 35 mm x 25 mm with 1.0 mm step in both width and length.

Echo signals from the scanning were post

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processed. Ratio of the two ultrasonic speeds is calculated by 2P, 4P, 1P1S and 3P1S signals' transit times. Poisson's ratios were obtained by eqn. (1).

## 3. Result and Discussion

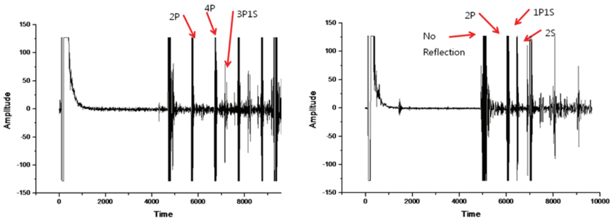


Fig. 3 Pulse-Echo Signals of Normal (Left) and Focused (Right) Transducers

Fig. 2 and Fig. 3 represent the measured pulse-echo signals by normal and focused transducer. In focused transducer, the mode converted signals are much more powerful and easily detected (2S signals can be distinguished). In each case, signal detecting algorithm was different. In normal transducer, 2P, 4P and 3P1S signals are used for calculating Poisson's Ratio while first signal, 2P and 1P1S signals are used in focused one. Because focused transducer show much stronger mode-conversion signal, in automatic process, data from focused one produced better and clearer image (Fig. 4).

Table 1 Vickers hardness and Poisson's ratio (Sample1)

| Average Values | Upper Weld zone | Lower Weld zone | Heat Affected Zone | Base Metal |
|---|---|---|---|---|
| Vickers Hardness | 187.4 | 175.8 | 173.6 | 198.8 |
| Poisson's Ratio | 0.288 | 0.287 | 0.285 | 0.297 |

Table 1 shows the measured Vickers Hardness and average Poisson's ratio of each area. It is shown that the HAZ has smaller Vickers Hardness, which means it has lower yield-strength than Base Metal. Table 1 and Fig. 4 shows that HAZ has lower Poisson's ratio than Base Metal. In previous work, lower Poisson's ratio was analyzed as the proof of hardened structure [5]. However, that analysis is contradicted to Vickers hardness data in Table 1, which shows weakened structure of HAZ.

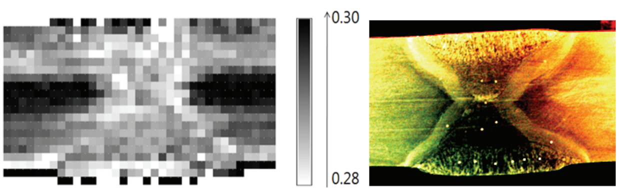


Fig. 2 Poisson's ratio distribution scanning (left). Darker color means larger Poisson's ratio.

Fig. 3 Picture of specimen (etching is processed)

For this, following idea is suggested.

1) When base metal is heated by welding process, structure is disorganized (Fig. 6) but it can't be organized again because of fast-cooling process after weldment.
2) Loose structure cause low Poisson's ratio because when structure is pressed in one direction, it will not expand in another direction due to empty space in the structure.
3) Because of loose structure, interaction between atoms in HAZ is weaker than interaction in base metal. Therefore HAZ has lower yield-strength and it results in low Vickers hardness.

## 4. Conclusion

In this work, HAZ of welded steel specimen was characterized by Poisson's ratio distribution owing to micro-structural variation during the welding process. Instead of normal transducer, focused transducer was used and different characteristics are indentified. It is shown that focused transducers have the advantage of strong mode-conversion signals, but focusing length of transducer and distance between transducer and specimen should be matched for its usage. Micro-hardness was measured by Vickers hardness test. It was confirmed that HAZ has lower Poisson's ratio but weaker structure, and mechanism is proposed. For further investigation, Vickers hardness test for each point in weld-zone will be performed.

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