**Internal SCC Detection of Pipe Using Ultrasonic Infrared Thermography**

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**Abstract**

This study detected internal PWSCC of DMW (STS304 Pipe and SA106 Gr. b) pipes using the ultrasound infrared thermography Method and the lock-In image process method among infrared thermography method. An ultrasonic wave generator of 20 kHz oscillation frequency was made utilizing this characteristic and the experiment was conducted with 250 Watt output. According to the experiment result, By using the Lock in Ultrasound Infrared Thermography Method, the internal PWSCC defects of DMW pipes used at nuclear power plants could get detected, and the locations of detects could get determined. But, It was difficult to detect the defects when the closed cracks had large openings.

**Keywords:** Ultrasound, Lock in, Infrared, Thermography (IRT), Dissimilar weld metal (DMW)

1. **Introduction**

PWSCC generates by mutual reactions of three factors such as material sensibility, weld joint residual tensile stress and in-service load while using and corrosion environment [1]. Necessary condition for the generation of SSC (Stress Corrosion Crack) is when the major three factors (tensile stress, sensitive material, corrosion environment) are satisfied. Safety examination of weld joints of the pipes that are the most fundamental structure to constitute these nuclear development facilities is especially a vital part to consider. The residual stress generated upon welding generates by mutual reactions of various parameters such as local temperature gradient, mismatch of material properties, constrained boundary condition, etc. The weld joints of a nuclear power plant are mostly consisted of pipe butt weld joints, and if considering the fact that recently PWSCC is generating at the Dissimilar Metal Weld Joints of PWR (Pressurized Water Reactor), an examination method to detect SCC at the Dissimilar Metal Weld Joints is necessary.

IRT (Infrared thermography nondestructive method: IRT) is a method to detect the infrared energy emitted by all objects above absolute temperature 0 K, create an image that is visible to the test and examine it, which has a merit in examining a broad range within a short time being without making a contact. By utilizing the IRT and attempting the defect detection of weld joints, the IRT's potential possibilities are examined. This study is to carry out an experiment to find out whether inner crack defects in the DMW (STS304 Pipe and SA106 Gr. b) pipes, used for nuclear power plants, can be detected by using the test technique of UIRT (Ultrasonic Infrared Thermography).

2. **Specific instructions**

2.1 **Preparation of DMW piping PWSCC test specimen**

The piping is made of STS 304 stainless steel and SA106 B Grade carbon steel. The specimen used in this experiment was the specimen prepared by the dissimilar butt weld process (Figure 2(a)). The welded parts were in the same shape and same materials being used in actual nuclear power plants and the PWSCCs were created in the pipe internal. Figure 2(b) is the DMW piping actually fabricated. Chemical components, and mechanical and physical properties are shown in Table 1 DMW piping simulating actual nuclear power plant piping and made of same DMW material mainly used in nuclear power plants had been fabricated. The creation of PWSCC defects on the fabricated DMW piping had been asked to the team of Professor Lee Bo-Yeong of Korea
Aerospace University. In general, most of defect test specimens are fabricated by applying mechanical fatigue or heat impact because it is difficult to fabricate actual test specimens simulating nuclear power plant PWSCC. However, the test specimens used in these tests had been fabricated of their PWSCCs using actual pressure, temperature and strong chemical solutions the pipe internal. The fabrication process of test specimens is shown in Figure 1. Figure 1(b) is the PWSCC structure created on the welded part of STS 304 and SA106. Figure 1(a) shows the location of defects on the cross-section of welded test specimens. The results of structure test enabled the confirmation of IGSCCs actually existing in the PWSCCs.

<table>
<thead>
<tr>
<th>Materials</th>
<th>S</th>
<th>Si</th>
<th>Mn</th>
<th>C</th>
<th>Ni</th>
<th>Cr</th>
<th>P</th>
<th>Cu</th>
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<tbody>
<tr>
<td>SA 106Gr. b</td>
<td>&lt;0.058</td>
<td>&gt;0.10</td>
<td>0.29-1.06</td>
<td>&lt;0.30</td>
<td>&lt;0.4</td>
<td>&lt;0.4</td>
<td>&lt;0.035</td>
<td>&lt;0.4</td>
<td>Balance</td>
</tr>
<tr>
<td>STS 304</td>
<td>0.02</td>
<td>0.9</td>
<td>1.8</td>
<td>0.08</td>
<td>8.00</td>
<td>18.00</td>
<td>0.04</td>
<td>-</td>
<td>Balance</td>
</tr>
</tbody>
</table>

Fig. 1 PWSCC DMW pipes specimen (STS304+SA106 Gr. b)

2.2 Experiment method of ultrasound infrared thermography

For this experiments specifically, the Ultrasonic Infrared Test, which is an easy method for fine crack detection was used. The procedure of Ultrasonic Infrared Test is shown in Fig. 2(a). UIRT(Ultrasonic Infrared Thermography) is one of the active thermography technologies, and when it injects ultrasound wave ranging 15 to 100 kHz into the test material, heat is generated in the crack part and the heat source is measured by the infrared thermography camera to detect defects. To detect the defects of weld joints of dissimilar metal pipes, it was set up as shown in Fig. 2 and a vibration was induced. The frequency was 50 mHz, 20 kHz ultrasonic wave and 250 Watt acoustic energy were used. while Silver 480 m Model (NEDT: 25 mK) made in French Cedip was used for the infrared camera. As for the material of specimen, pipes with 3 inch in outside diameter (OD), 7.6 mm in thickness and 250mm in length. For the sensitiveness of thermography images, the surface of pipes was applied with black flat paint so that such a complete condition might be satisfied as black body with 1 of emissivity.
Test set up is shown in Figure 2(a), in which the contact with piping was made only by the self-weight of the ultrasound generating device. As shown in Figure 2(b), the piping had been rotated to 4 directions with 90° interval during the test. The most important cause for small heat generation of the ultrasonic infrared thermography generates by frictions mainly caused by vibrations and ultrasonic waves.[2] This study detected internal defects of pipes using the Ultrasonic Infrared Thermography Method and the Lock-In Image process Method among infrared thermography method. Infrared thermography methods offer a big merit when detecting fine defect in micro units and testing the target object generating a heat under the environment to maximize the friction heat caused by vibrations and ultrasonic waves.[3]

2.3 Defect detection using optical microscope and ultrasound infrared thermography

It was possible to observe that SA106 steel had more corrosion than STS304 on the piping surface when they had been used under same conditions. In the piping internal, there were partial wall-thinning. In order to confirm the cracks occurred inside, an ultrasound test had been tried; however, there were many noises during ultrasound test because of the material wall-thinning caused by welded beads corrosion on the internal welded parts and the surface conditions. Therefore, optical microscope had been used in the internal cracks observation as shown in Figure 3. It was possible to observe 3 bigger defects, which can be seen by bare eye, out of the image observed by the optical microscope. Figure 3 shows (a) and (b), where the cracks had been confirmed, and (c), where the crack had been suspected.
Figure 4 is the actual image obtained by the infrared thermography test using ultrasound on the DMW piping. It was possible to identify the defect locations through the hot spots obtained at each angle. Most of the hot spots indicated that the defects are generated at the welded parts where STS 304 and Alloy 182 had been welded. It is believed that these defects had been caused at the locations where the material properties are not constant, or, the welding stress had not been uniform, rather than the defects had been caused by the basic material.

The actual defects found in nuclear power plant piping do not occur on specific locations but they occur on various locations; therefore, the fact that the PWSCC defect detection is possible by ultrasound infrared thermography is more significant than the locations of the defects.

![Figure 4. Lock in Infrared thermography of stainless steel 3 inch specimen](image)

Figure 5 shows the defects found by optical microscope and the defects found by ultrasound infrared thermography. The OM1 and OM2 look like they are located with distance in the figure; however, they are located quite near. Considering that they can be shown as a single defect in the thermography which is expressed in the two-dimension plane image, it is possible to judge that the HOT 3 defect detected by ultrasound infrared thermography may be the single hot spot created by OM1 defect and OM2 defect. In order to observe the internal defect clearer, the piping had been cut in two and PT had been done. It was possible to confirm the defects at the locations detected by the ultrasound infrared thermography.
When the ultrasound infrared thermography had been used and the cracks were micro-cracks created by the high-frequency and vibration of ultrasound, heat is generated when there would be friction at the defect locations. Therefore, the heat transfer mechanism at the heated part is more important than the acoustic impedance and properties of the metal material. In addition, there is an issue that the defect may not be detected, though there are defects, when the defects have large openings with less friction at the defect locations. However, the ultrasound infrared thermography has an advantage that it can detect micro-cracks with scores of μm sizes. Therefore, it is possible to detect earlier cracks when this advantage would be utilized.

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References