

DETECTION OF PIPING DEFECTS IN NUCLEAR PLANTS BY ULTRASONIC PULSE-PHASE THERMOGRAPHY

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ABSTRACT

In this study, the applicability of ultrasonic pulse-phase infrared imaging method for real time crack detection is described. As vision technique, an ultrasound wave passing through a material with mechanical discontinuity, such as a disbanding crack, causes temperature raise of that due to internal friction or thermo-mechanical effect. And the elastic wave with vibration energy is converted to the heat in the vicinity of the crack of the defect. its local heat emitted in the crack of the defect is monitored as the hot spot area via the thermal infrared camera. From the experimental works, the test material was austenitic STS 304, which was used as pipelines in the reactor coolant system of a nuclear power plants. As conclusions, Internal crack in a pipe using ultrasonic infrared thermography imaging to detect defects were. Also, at the end of the crack was able to identify hot spots using NDT.

Keywords : Nuclear Plants, Ultrasonic, Pulse Phase, NDT, Thermography

1. Introduction

From past several decades, there have been lots of nondestructive inspection technologies widely. On the other hand, thermography method in these nondestructive testing(NDT) has recently expanded its application range gradually with the development of vision techonology. Ultrasound Infrared Thermography(UIRT) among thermographic techniques is one of active thermography technologies. When a ultrasound horn injects the ultrasonic frequency ranging 20 kHz to 40 kHz into the test material, thermo-mechanical dissipation is abnormally generated in the crack part and this increased heat source can be detected by the infrared thermography system to monitor the condition of defects.^[1]

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This technology may have different effect owing to the difference of sound impedance caused by the difference of materials. However, as the elastic wave with high energy excitement is delivered to the structure, heat-generation phenomenon takes place only on the defected part locally, causing the temperature difference to detect defects fast with thermography.

Since the test technique of UIRT can examine wide areas at the same time and detect defects such as crack and delamination at real-time, it can be applied as a defect detection technology in the industries of automobile and aerospace engineering.^[2,3] This study is to carry out an experiment to find out whether inner crack defects in the austenite STS304 Pipe, used for nuclear power plants, can be detected by using the test technique of UIRT.

2. Ultrasound Infrared Thermography Technique

Thermography technique using high energy ultrasound excitement causes heat locally in the defected part by impressing short ultrasound pulse to the test specimen with the pulse width ranging 50 ms ~ 200 ms and frequency ranging of 20 kHz~40 kHz. The infrared thermography camera records and stored the process of heat-generation phenomenon in the defected part according to the time progress, before and after the impression of ultrasound pulse, while converting it into images to detect the defects of test specimen.^[1] Since injecting the vibration energy to the structure in the case of the ultrasound excited, hot spots within several dozens of ms are observed by the thermography camera.

Fig. 1 shows the schematic diagram for the experiments set in this study. Ultrasound with frequency ranging 20 kHz has several pairs of cm in the wavelength band width. In addition, in the case that it is

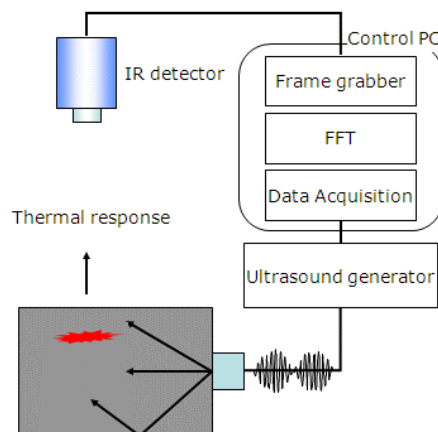


Fig. 1 Schematic diagram of experimental set-up

proceeded to propagate its intensity much farther distance than the wavelength, ultrasound can spread, having sufficient amplitude energy, which means that when there is no loss in the material, ultrasound can spread to the distance of several wavelengths. The sonic speed of solid matter is up to several km/s. Those characteristics of ultrasound indicate that the sound field completely includes the test domain of materials used for this experiment. The decrease of sound amplitude in solid matter is proportion to the square of the frequency of sound wave.^[4] The higher the frequency is, the vibration wavelength gets lower due to the ultrasound vibration. Accordingly, in order for heat-generation to be effectively excited in the defected part of structure, frequency ranging 20 kHz is widely used by using frequency ranging 15 kHz to 40 kHz.

3. Experimental Equipment

In this study, when ultrasound vibration pulse is impressed, the ultra infrared thermography equipment consists of ultrasound excitement equipment and an infrared thermography camera, and in order to minimize the heat exchange between test specimen and outer heat source during the test, experimental equipment is installed inside the insulation chamber as shown in Fig. 2.

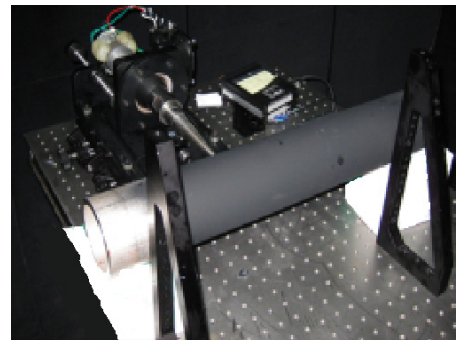
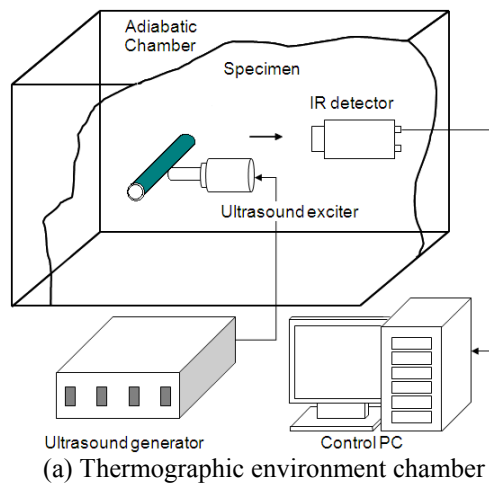


Fig. 2. Experimental apparatus in the experiments

The infrared excitement equipment has 400 Watt of output and 20 kHz of frequency, while Silver 480 m Model (NEDT: 25 mK) made in French Cedip was used for the infrared camera. As for the material of specimen, seamless pipes of STS 304 in the austenite category was used, and pipes with 89 mm in outside diameter (OD), 11t in thickness and 89mm in length were repetitively given heat impact for fatigue test to produce defect specimen similar to natural cracks. 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. Besides, the ultrasound exciting horn and the exciting area of pipes are excited in a state of being properly pressed with the power of 30 kgf.

4. Results of the Experiment

In Fig. 3, in order to make the same form of cracks as natural ones, chemical notches with 0.2 mm in depth were provided inside the specimen toward the circumference, and the specimen made by giving heat fatigue repetitively was placed horizontally and excited with ultrasound.

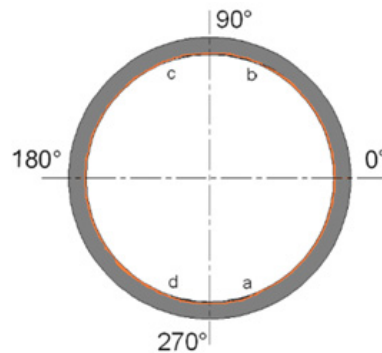
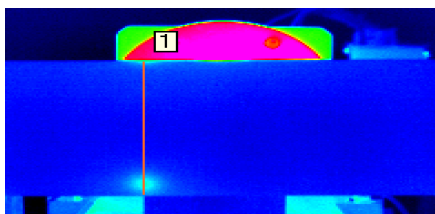


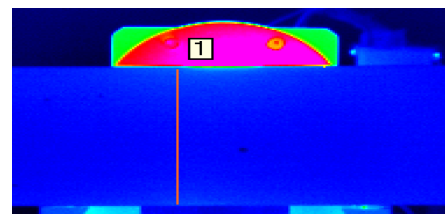
Fig. 3 The Inside of the Pipe Cracks in STS 304

The test direction was processed at $0^\circ \sim 270^\circ$ for testing. According to the approximate location of specimen at the experimental condition varied, for instance, the angle of 0 up to 270° was rotated by 90° respectively to detect defect forms appearing during the experiment.

Fig. 4 shows images obtained when cracks were excited with square-wave at each angle at intervals of 50mHz, showing hot spots in a, b, c and d in Fig. 3. At similar parts approximately between 0° and 180° and between 90° and 270° at each angle, hot spots were detected, and a, b, c and d were the parts where inside defects were completed. Since as shown in the existing studies, such a phenomenon took place due to the lack of heat-generation caused by friction at the too wide or narrow opening below $3 \mu\text{m}$, it was not

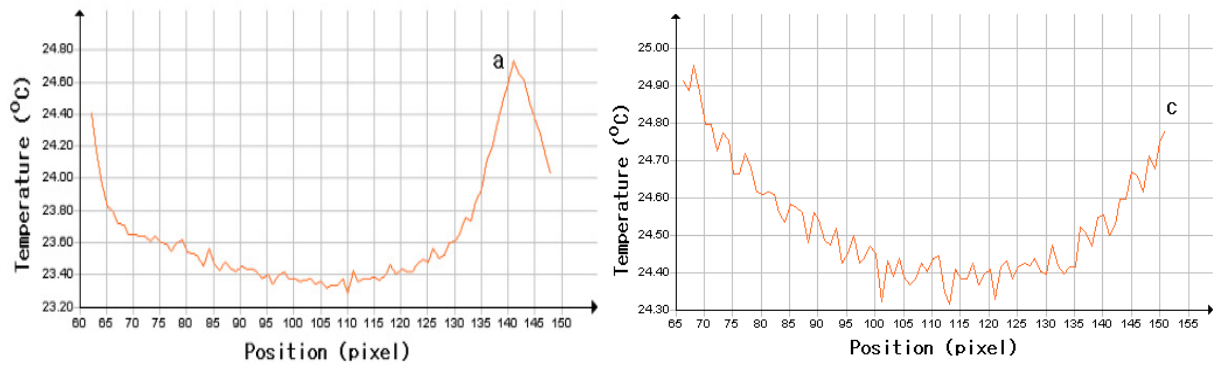


(a) spot image at angle 0 degree



(b) spot image at angle 270 degree

Fig. 4 Inspection of Piping Got Spot Image Due to the Angle



(a) temperatures at anle 0 degree

(b) temperatures at angle 270 degree

Fig. 4 Piping temperaturesat spot image per each Angle

easy to detect defects. Therefore, in the defected part of 5~10 □ in width, where friction was likely to occur more frequently, heat was generated well, and it was judged that in a, b, c and d where the defect of hot spots was completed, images in the form of hot spots were detected.^[5]

Fig. 5 shows the temperature distribution around the circular pipie, when hot spots occurred, through the analysis of the data of thermography images detected from each angle as shown in Fig. 4. It shows the temperature of the part when hot spots occurred was generally higher than the average temperature. Especially, it was found that the temperature difference between a and b sections was about 1.2□, showing a high temperature, compared to the temperature difference, 0.5□, occurring between c and d sections. As a result of examining the ultrasound, while the cracks between a and b sections were deep enough to be penetrated around 0°, the middle part of the section, the depth of cracks between c and d sections was 5.7mm, resulting in the difference of the heat quantity. It seemed to be because the size of defects between c and d sections was small, compared to that between a and b sections.

While in the section where defects took place most, the thickness of cracks included thickness through which heat was generated most due to the friction, in the section where the size of defects was small, it was judged that such a condition was not fully established. With the thermography images obtained through this experiment, it was supposed that spots including parts actually having defects should be referred to when carrying out an ultrasound thermography test in the future. However, it was still possible to detect defects inside the pipe through the ultrasound thermography technique.

5. Conclusion

This study is to detect defects with the infrared thermography test technique when defects actually exist inside STS304 seamless pipes in the austenite category, which simulates heat-fatigue cracks occurring inside the pipe used for nuclear power plants. Through this technique, not only could cracks be detected after providing artificial notches. With specimen whose defects were developed by heat impact, it was found that hot spots judged to be defects took place in the part where cracks were completed. However,

despite the existence of large defects, it was found there were still some parts where they were not properly detected. Therefore, when this technique is supplemented with other undestructive test methods, it is expected that this method will contribute to measuring defects inside the pipe.

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