Study on the Thermal Image with the Defect Detection Using Ultrasonic

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***Abstract*—The purpose of this study was to confirm the soundness of parts and materials considering the productivity and quality of Nondestructive Testing (NDT) technology by overcoming the limitations of this technology. For this purpose, thermal conversion technology based on ultrasonic energy was combined with infrared thermography to develop a hybrid NDT system. Thermal conversion technology was based on the control variables of ultrasonic excitation time (or frequency), ultrasonic intensity and the design of ultrasonic horns. Accordingly, optimum values were determined and an ultrasonic excitation controller with two control variables—ultrasonic excitation time (or frequency) and ultrasonic intensity—was developed. This controller can be applied to various objects, regardless of their size and thickness. In other words, if blinking is detected for an object with a defect, it should be tested again by infrared thermography. This is the core technology proposed in the present study. With regard to the inspection process of parts and materials in many industries, existing poor working conditions and environmental friendliness should be improved and productivity should be increased.**

***Index Terms*—ultrasonic, defect detection, nondestructive testing, horns**

I. Introduction

In many industries, the detection of flaws in different parts and materials is very important to ensure stable operation. NDT (Nondestructive Testing) is a localized techniques use to evaluate the integrity of component, material or measure some characteristic of an object. However, NDT technology has several drawbacks.

Especially, in magnetic particle tests and penetrant tests, worker productivity and working environment must be improved and eco-friendly technology must be developed continuously [1].

For this purpose, thermal conversion technology based on ultrasonic energy has been combined with infrared thermography to develop a hybrid NDT system. Thermal conversion technology is based on the control variables of ultrasonic excitation time (or frequency), ultrasonic intensity and the design of ultrasonic horns.

Accordingly, optimum values are determined and an ultrasonic excitation controller with two control variables—ultrasonic excitation time (or frequency) and ultrasonic intensity—is developed. This controller can be applied to various objects, regardless of their size and thickness. In other words, if blinking is detected for an object with a defect, it should be tested again by infrared thermography.

This is the core technology proposed in the present study. The purpose of this study is to confirm the soundness of parts and materials considering the productivity and quality of NDT technology by overcoming the limitations of this technology. With regard to the inspection process of parts and materials in many industries, existing poor working conditions and environmental friendliness should be improved and productivity should be increased [2]-[4].

II. NDT Technology

NDT is a very broad, interdisciplinary field that plays a critical role in ensuring that system performance function and structural elements to be stable and efficient. NDT is used in flaw detection, leak detection and estimation of mechanical and physical properties to assist in product development, to screen or sort in coming material and to verify proper process. Without this technology there might be problems which could cause reactors to fail, pipelines to burst and a variety of less visible. NDT is performed in measuring test and the result showed that

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NDT does not affect, harm or damage the parts or material which simplified that NDT provides an excellent balance between quality control and cost-effectiveness. The technologies used in NDT are similar to those used in the medical industry, but nonliving objects are the subjects of the inspections. The number of inspection methods seems to be growing daily, but a quick summary of the most commonly used methods is provided below [2].

A. Radiography Test (RT)

A radiography test, shown in Fig. 1, is a NDT method used in higher energy version of the electromagnetic waves in order to look for defect or examine hidden features on material and product. The radiation can come from gamma or X-ray or a radioactive source. A radioactive isotope or an X-ray is the source for radiation. The part is placed between the radiation source and a piece of film or detector. The film darkness will verify the amount of radiation reaching the film through the test part [5].

Figure 1. Radiography test(RT)

B. Megnetic Particle Test(MT)

Magnetic particle inspection, shown in Fig. 2, is a NDT method used to detect both production discontinuities and in-service damage. A ferromagnetic material is magnetized with strong magnetic field and if the specimen has the discontinuity, it will interrupt the magnetic field flowing. When the flux leakages occur, it showed that there is a discontinuity. This produces visible indication and it can be visually detected. The image below shows the magnetic particle test.

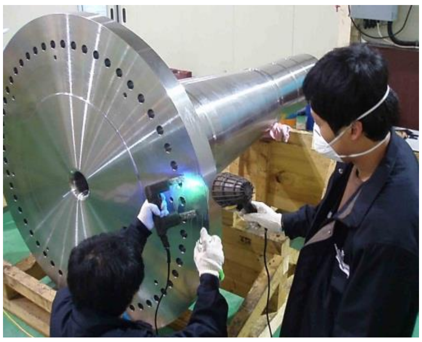


Figure 2. Magnetic particle test (MT)

C. Penetrant Test (PT)

As shown in Fig. 3, the Penetrant test is used to locate surface-breaking defect in the specimens. In this test method, a solution with a fluorescent or visible dye is applied to the surface object. The penetrant is often used with fluorescent dyes and the ultraviolet light is used to inspect and increase test sensitivity. The red indications in Fig. 3 represent a defect in the component.

Figure 3. Penetrant test(PT)

D. Ultrasonic Test (UT)

Ultrasonic testing is a type of non-destructive testing technique where high frequency sound waves are used to receive the reflected sound back from the surfaces or flaw. The amount of reflected and sound travel time can be detected and provide information about the size and distance. Fig. 4 shows an example of shear wave weld inspection. Note the indication extending to the upper areas of the image [4]-[5].

Figure 4. Ultrasonic test (UT)

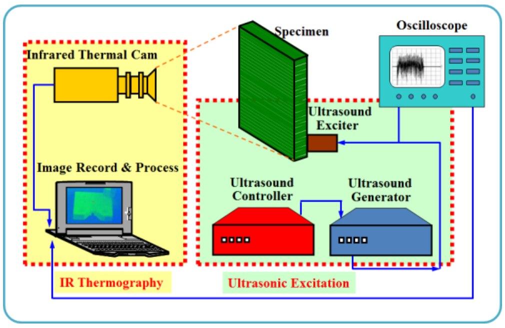


Figure 5. Configuration of hybrid NDT System with ultrasonic

III. Hybrid NDT System

Fig. 5 and Fig. 6 show a hybrid NDT system with ultrasonic. A sound wave passing through a material with a mechanical discontinuity such as a crack or disbanded area with facing surfaces will ordinarily cause heating of those surfaces. The heating results from friction caused by the rubbing of the surfaces or from plastic deformation when the surfaces “clap.” The effect appears to begin on a timescale of milliseconds or less after the initiation of a sound pulse in the sample. In addition, if blinking is detected for an object with a defect, it should be tested again by infrared thermography [6].

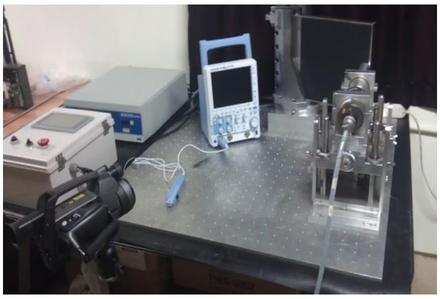


Figure 6. Test using hybrid NDT system

A. *Ultrasonic Excitation Unit [7]*

The modulation of the ultrasonic wave frequency and amplitude results in periodical heat generation. In Fig. 7and Fig. 8, the Ultrasonic emission is detected via the temperature modulation at the surface, which is analyzed by tuning the blinking phenomenon to the frequency and amplitude modulation. An ultrasonic transducer is attached to a fixed spot and face; from this spot, the acoustic waves are launched into the entire volume of the specimen where they are reflected several times until they most likely disappear into a defect and generate heat. The results are shown in Fig. 9, Fig. 10 and Fig. 11. These modulations are very efficient in heating because many hysteresis cycles are performed by the ultrasound controller.

Figure 7. Ultrasonic excitation unit and controller

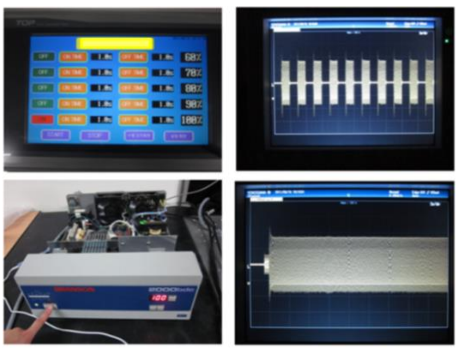


Figure 8. Comparison of burst and control waves

In Fig. 8, the burst wave causes a rise in the temperature of the specimen. Therefore, in this study, a control wave is applied to detect flaws. Then, if blinking is detected for an object with a defect, it should be tested again by infrared thermography.

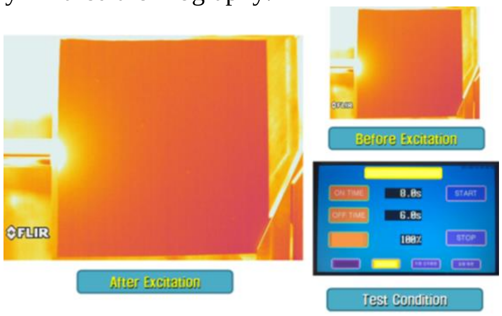


Figure 9. Test result obtained by using control wave

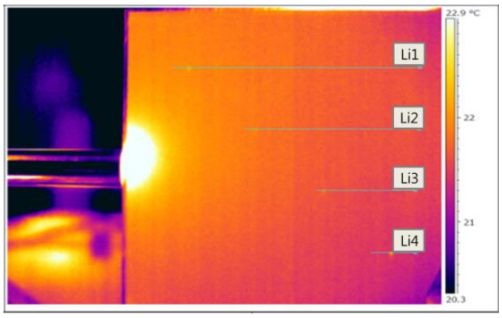


Figure 10. Check with the temperature analysis line

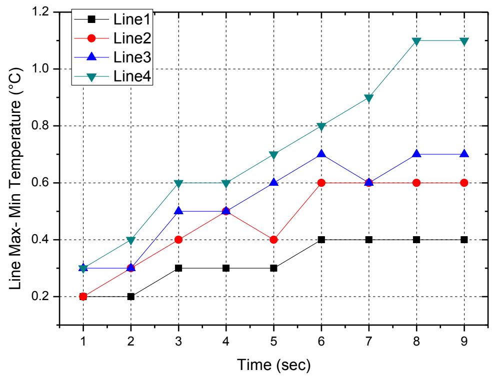


Figure 11. Check with the optimal excitation time

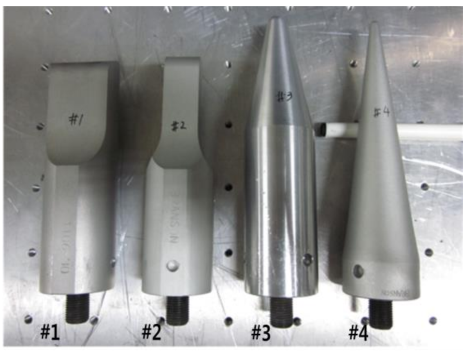
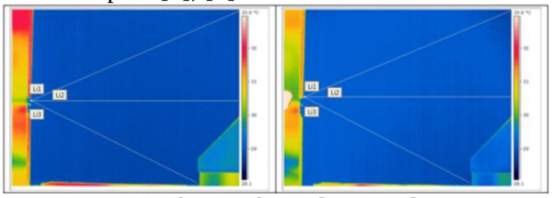


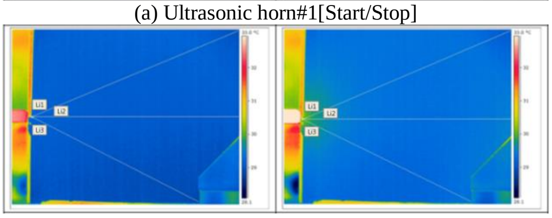
Figure 12. Designed ultrasonic horns

B. *Ultrasonic Horn*

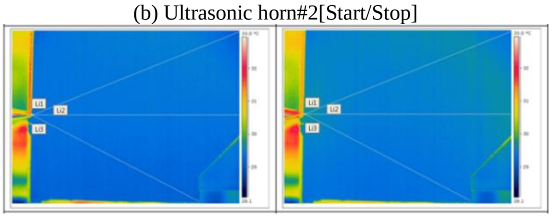
To increase the amount of ultrasonic incidence, ultrasonic horns were designed (see Fig. 12). In the process of confirmation, the greater the amount of incidence, the larger was the contact area. In addition, correlations were found on the area of the ultrasonic transmission path [8], [9].



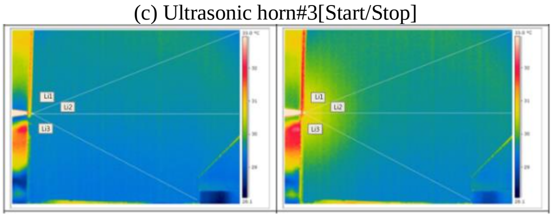
(a) Ultrasonic horn#1[Start/Stop]



(b) Ultrasonic horn#2[Start/Stop]

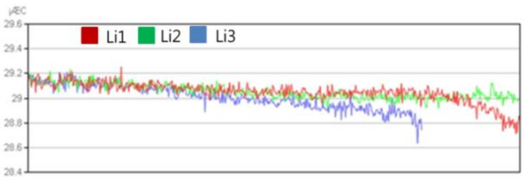


(c) Ultrasonic horn#3[Start/Stop]

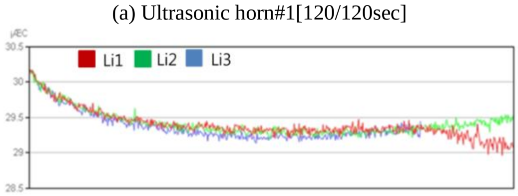


(d) Ultrasonic horn#4[Start/Stop]

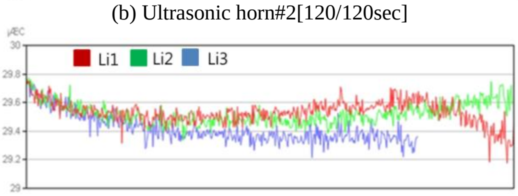
Figure 13. Test results for designed ultrasonic horns



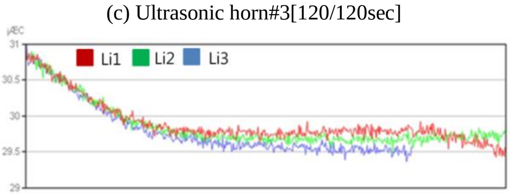
(a) Ultrasonic horn#1[120/120sec]



(b) Ultrasonic horn#2[120/120sec]



(c) Ultrasonic horn#3[120/120sec]



(d) Ultrasonic horn#4[120/120sec]

Figure 14. Temperature distribution of specimen

Test results, shown in Fig. 13 and Fig. 14, for the amount of ultrasonic incidence are based on three important variables, which were confirmed experimentally: contact area of the ultrasonic horn, and the area and shape of the ultrasonic transmission path.

Comparing horns #2 and #3, the ultrasonic transmission path, rather than the horn contact area, is found to be a priority.

In practice, the temperature of the horn contact area is confirmed to be higher for horn #2 than for horn #3[10].

C. *Test Jig and Specimen [11]*

As shown in Fig. 15 and Fig. 16, a test jig was designed while focusing on improving the contact efficiency of the ultrasonic horn. To ensure part clearance, a separate lock was added.

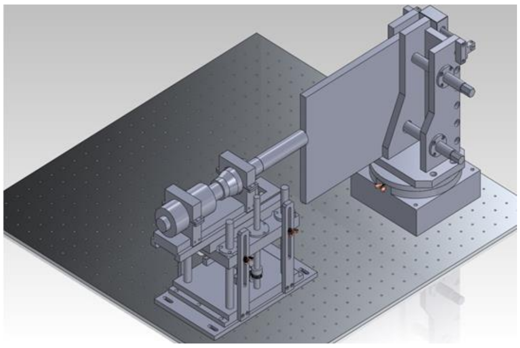


Figure 15. Test jig modeling

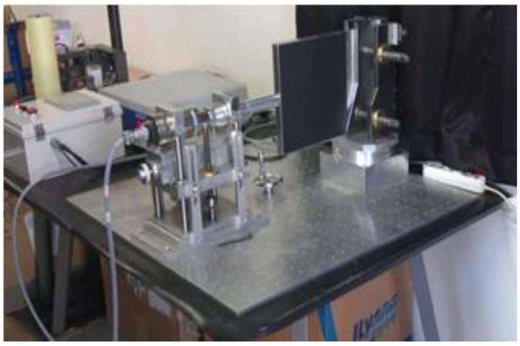
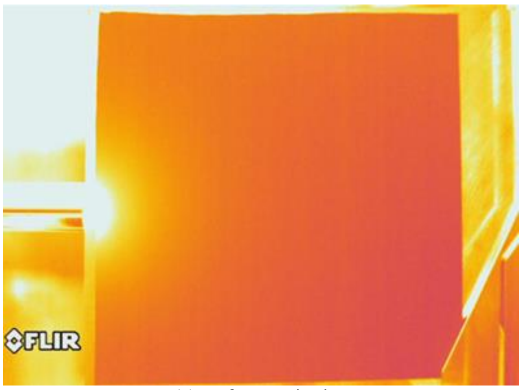


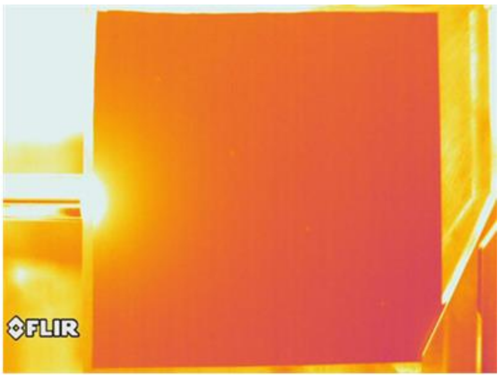
Figure 16. Test jig modeling

D. *Test Results*

By performing a series of steps using the completed hybrid NDT system, the following test results, shown in Fig. 17, are obtained.



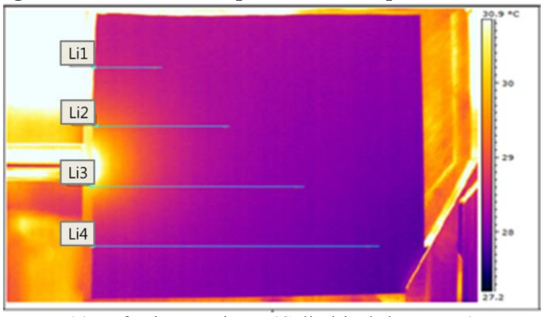
(a) Before excitation



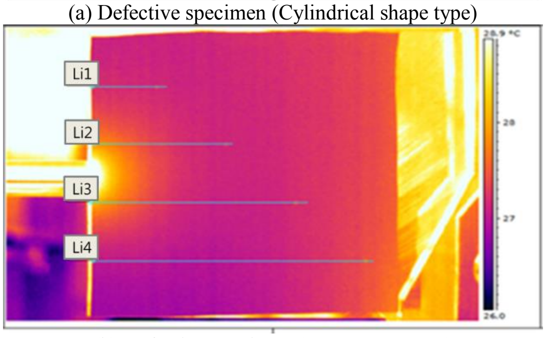
(b) After excitation

Figure 17. Test images obtained by using hybrid NDT system

Fig. 18 and Fig. 19 show the test images obtained by using the hybrid NDT system. The defect detection ability can be seen from the difference in the images taken before and after ultrasound excitation. To analyze heat distribution, an infrared thermal camera was used to obtain the profile function by the thermal analysis method. Fig. 18 shows the hot spots, which represent defects.



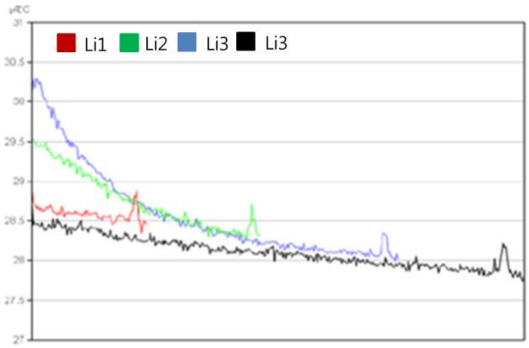
(a) Defective specimen (Cylindrical shape type)



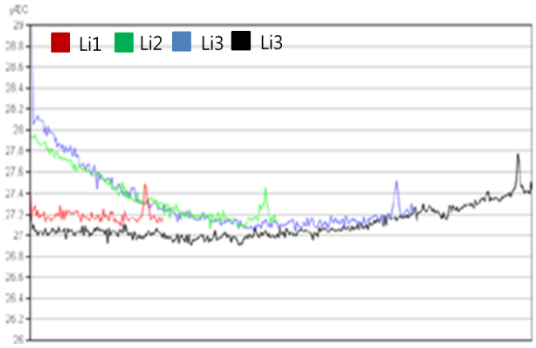
(b) Defective specimen (Square post type)

Figure 18. Detective hot size and position

Fig. 19 shows the analysis of the heat distribution along each line. For each line, a peak indicates the existence of a defect.



(a) Temperature graph (Cylindrical shape type)



(b) Temperature graph (Square post type)

Figure 19. Analyzed thermal distribution

IV. Conclusions

The proposed hybrid NDT system has clear advantages over the conventional burst-wave thermography system. If blinking is detected for an object with a defect, it is tested again by infrared thermography. Ultrasonic emission is detected via the temperature modulation at the surface, which is analyzed by tuning the blinking phenomenon to the frequency and amplitude modulation.

The probability of defect identification is thus improved while reducing the measurement time and with no cooling time. Especially, in MTs and PTs, worker productivity and working environment can be improved and eco-friendly technology can be developed continuously.

Acknowledgment

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