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Improvement of Visualization Efficiency for the Nondestructive Inspection Image of Internal Defects in Plate-Type Nuclear Fuel

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1. Introduction

Plate-type nuclear fuel has been adopted in most research reactors. The production quality of the fuel is a key part for an efficient and stable generation of thermal energy in research reactors. Thus, a nondestructive quality inspection for the internal defects of plate-type nuclear fuel is a key process during the production of nuclear fuel for safety insurance. Nondestructive quality inspections based on X-rays and ultrasounds have been widely used for the defect detection of plate-type nuclear fuel.

X-ray testing is a simple and fast inspection method, and provides an image in real-time as the inspection results [1]. Thus, the testing can be carried out by a non-expert field worker. However, it is hard to detect closed-type defects that should be detected during the production of plate-type nuclear fuel.

Ultrasonic testing is a powerful tool to detect internal defects including open-type and closed-type defects in plate-type nuclear fuel [2]. However, the inspection process is complicated because an immersion test should be carried out in a water tank. It is also a time-consuming inspection method because area testing to acquire image is based on the scanning of the point-by-point inspections.

Among nondestructive inspection techniques, the techniques based on laser interferometry and infrared thermography have been widely used in the detection of internal defects of plate-type composite materials, such as aircraft, automotive etc. While infrared thermography technique (IRT) analyses the thermal behavior of the specimen surface, laser interferometry technique (LIT) analyses the deformation field. Both techniques are useful tools for detection and evaluation of internal defects in composite materials. Especially, the laser interferometry technique can provide the depth information of internal defects [3].

Laser interferometry technique (LIT) is a non-contact inspection method faster than thermography. Also, this technique requires less energy than thermography and the signal processing is almost instantaneous. As a disadvantage, LIT is more sensitive to mechanic vibrations. So, in order to properly detect internal defects, several inspection parameters, such as acquisition time, processing methods, external stimulation, vibration environment etc., must be optimized when the assessment procedure is developed.

If a current inspection image showing the information of internal defects is displayed on the monitor in real-time, it will be helpful for the practical field application of nondestructive evaluations. For this purpose, a real-time visualization technique for the detection of internal defects was developed in this paper. An active laser speckle interferometer with periodic thermal power was adopted to detect the defects. The laser speckle interferometer is sensitive to very small displacement at a resolution of nanometers by superposing the speckle patterns of two different object states. Amplitude and phase differences in deformation among intact and defective areas have been widely used for the detection of internal defects in plate specimens [4].

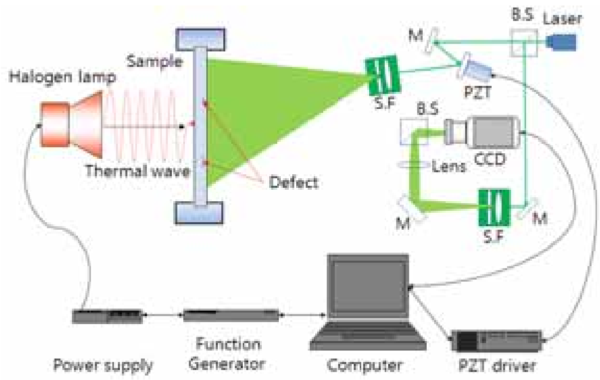

Fig. 1. Configuration of a developed optical nondestructive inspection system.

2. Configured Optical Nondestructive Inspection System and Experiments

A configuration of the developed visualization system to detect internal defects using an active laser interferometer with a thermal wave is shown in Fig. 1. The noncontact real-time visualization system was configured using a halogen lamp with a driver (DDS 5600, LEVITON MFG. co) controlled by a function generator, a testing specimen held by a grabbing holder, a digital speckle pattern laser interferometer (CW laser: 532 nm, 100 mW, Cobolt Samba™ 150) with a phase control driver (E-665.XR, LVPZT-AMP, PI) and a main control computer.

The deformation shape of the specimen surface will vary according to the applied thermal power at the back side of the specimen. The intensity of the thermal wave is a periodic sinusoidal pattern controlled by a signal generator. The laser interferometer acquires a deformation interference image for the front surface of the specimen. The deformation interference image is an interference image between a reference laser beam and signal laser beam. Internal defect information is contained in the acquired interference image because the deformation difference is caused by the reflection of the thermal wave at the internal defects. A current inspecting image will be displayed in real-time through accumulation of inspection images after extraction defect information by using an efficient high-pass filtering.

By virtue of the real-time display, the inspection can be carried out by a non-expert field worker. Here, the surface deformation is induced by a heater supplying thermal wave with the periodic sinusoidal intensities.

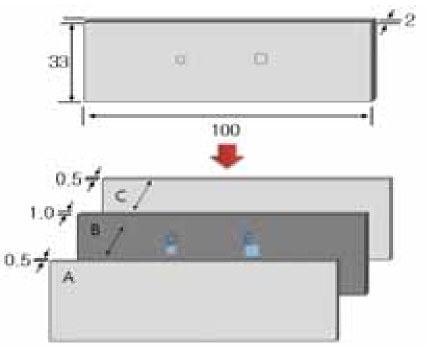

Fig. 2. Dimension of the testing specimen for plate-type nuclear fuel

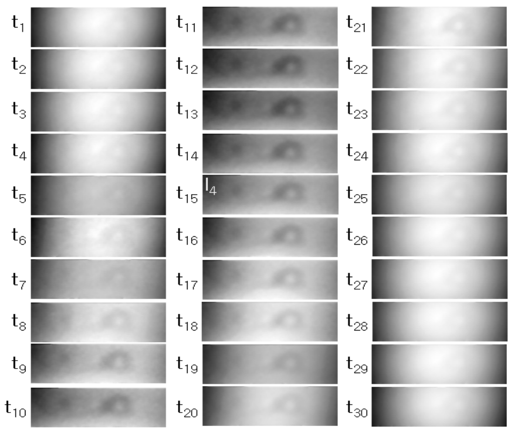

Fig. 3. Inspecting images during one period of sinusoidal heating intensities.

As shown in Fig. 2, a testing specimen was prepared for the experiments using noncontact optical imaging inspection for plate-type nuclear fuel. A tungsten plate (B) with a similar density was used instead of uranium nuclear fuel. In a common structure of plate-type nuclear fuel, a plate-type uranium core is placed at the center of an aluminum alloy plate. The thickness of the used tungsten plate (B) was 1.0 mm, and the thicknesses of the aluminum alloy at the front and back side were 0.5 mm, respectively. Three plates were bonded by metal paste except two delmaination-type defect areas of D and E, as shown in Fig. 2. The sizes of the two delamination-type internal defects were 3.0 mm x 3.0 mm and 5.0 mm x 5.0 mm, respectively.

The inspected images during one period of the 4th are shown in Fig. 3. Here, we can't visually discriminate defects because it is varied according to heating intensities. The notation of t_{15} is the acquisition time of a reference image.

Thus, the inspection system extracted and accumulated defect information from each image by applying efficient high-pass filter and displayed it on the monitor in real-time as shown in Fig. 4. Here, we can visually see and discriminate the crack information in real-time.

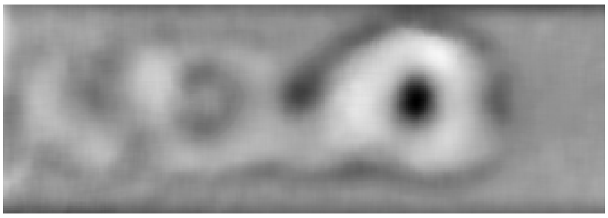

Fig. 4. Real-time displayed accumulation image showing internal defects information.

3. Conclusions

A non-contact real-time visualization technique for internal defects was developed for nondestructive inspection of a plate-type nuclear fuel specimen by using an active optical interferometer. Internal defect images were efficiently visualized on a monitor in real-time by accumulating defect information through extraction of high frequency components. As a nondestructive inspection system, the developed visualization system was proven to be a valuable tool to detect the internal defects of plate-type nuclear fuel.

REFERENCES

[1] J. K. Ghosh, S. Muralidhar, K. N. Chandrasekharan, Nondestructive Evaluation of Plate Type Nuclear Fuel Elements for PURNIMA-III and KAMINI Research Reactors, Advanced Materials, Manufacturing, and Testing Information Analysis Center, 1992.

[2] Mucio Jose Drumond de Brito, Wilmar Barbosa Ferraz et al, Nondestructive evaluation of plate type nuclear fuel elements during manufacturing stage using ultrasonic test method, 2009 INAC, Roi de Janeiro, Sept., 2009

[3] Y. K. Zhu, G. Y. Tian et al, A Review of Optical NDT Technologies, Sensors 11, 2011.

[4] J. P. Ferreira, F. Lopez et al, Comparison of infrared thermography and shearography for non-destructive evaluation of composites materials, 5th Pan American Conference for NDT, Cancun, 2011.