# 3P2-3

# Imaging Inspection for Delamination Using Energy Variations of Flexural Vibrations Generated by Laser
レーザにより励振した屈曲振動のエネルギ変化を利用した剥離の画像化検査

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## 1. Introduction

Delamination is often generated by external impact and aiging in carbon fiber reinforced plastics, painting coating on a steel plate, and concrete structures, and leads to extreme degradations in the structures. However, it usually cannot be detected by visual inspection and requires other non-destructive inspection techniques to secure the soundness.

This study discusses the inspection of delaminations by using Scanning Laser Source technique (SLS). The SLS is the measurement technique in which a laser spot is scanned over an entire inspected material to generate elastic waves at many rastering points and the wave is detected at a fixed position. The measuremnet technique has important advantages for practical use; non-contact , single-sided access, and stable measurements due to the use of a fixed receiver. The authors have been developing the imaging technique using the SLS for defects and adhesive bonds in plate-like structures[1,2]. The following sections experimentally investigate the imaging of subsurface delamination in an aluminum block.

## 2. Experimental set-up and specimen

Thermal expansion at laser-irradiated point results in instantaneous stress and elastic wave propagation. In this study, elastic waves are generated and controlled with laser modulation. The energy of the generated flexural waves varies with the local bending stiffness at the irradiated point. In the case that there exists delamination near the surface, its apparent local bending stiffness is so small that the flexural wave with larger energy is generated. In the previous study, we obtained the images of defects and bonded areas in plates based on the above principle[1,2], and verified the results with calculation[3].

**Fig. 1** shows the experimental set-up. Wave data was provided to a digital-analogue converter (NI, USB-6364) from a personal computer (PC) to control the angle of Galvano mirrors and laser output from the fiber laser equipment (SPI Laser, G4 50W-S-HS). The waves were received by a laser doppler vibrometer (Polytec, OFV-5000) at a fixed position near the right edge of the surface, and then the signals were transferred to the PC through an analogue-digital converter. After repeating the wave acquisition at all rastering points, an image was obtained in the PC.

**Figs. 2**(a) and (b) show the specimens used in the experiments. Fig 2 (a) shows a specimen used in the first experiment with an aluminum plate of 50 mm × 80 mm ×1 mm was adhered on a 50 mm × 80 mm × 20 mm aluminum block having a circular dent of the diameter of 10 mm and the depth of 0.05 mm in its center of the surface. The other specimen is used in the second experiment. The aluminum plate of 1 mm thick was adhered on an aluminum block without a dent as shown in Fig. 2(b), on which the adhesive was not adhered on the dashed rectangular area intentionally.

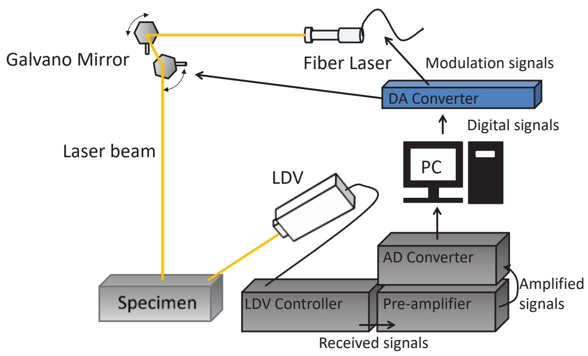


Fig. 1 Experimental set-up.

## 3. Result and Discussion

First, we conducted the imaging experiment for the specimen shown in the Fig. 2(a). In this experiment we selected the frequency of 46 kHz as the modulation signals because this frequency is corresponding to Local Defect Resonance (LDR) frequency in the delamination which was discussed in detail by Solodov[4]. A 40 mm × 40 mm square area around the artificial delamination was the imaging area where laser is scanned over at 1 mm increments. The duration of laser irradiation was 10 ms and the waveforms were recorded for 20 ms from the beginning of laser shot at each point. The values of spectrum peaks at 46 kHz were plotted in

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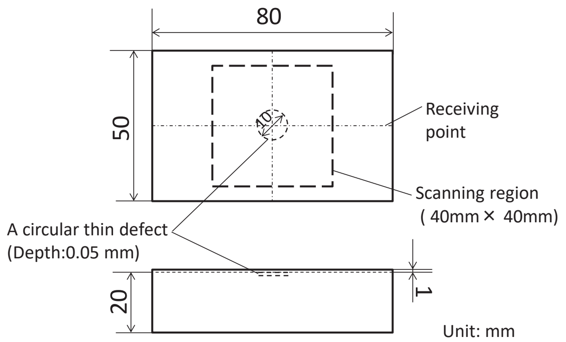
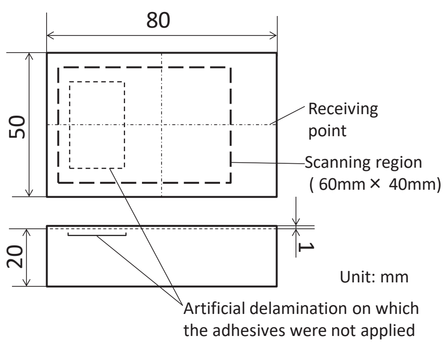
grayscale. **Fig. 3** shows the image for the specimen of Fig. 2 (a). The circular dark area can be seen, which agrees well with the position of the artificial delamination.

Next, the imaging experiment was executed for the specimen showed in the Fig. 2(b). The frequency of 127 kHz was used and 60 mm × 40 mm square area enclosed with dashed square in the Fig. 2(b) was scanned. **Fig. 4** shows the image, in which a darker area was obtained at the artificial delamination. The stripe pattern in the dark area was caused by the local resonance having nodes and antinodes in the delamination. To verify the image, an image in ultrasonic pulse echo technique was obtained as shown in **Fig. 5**, in which we used a 15 MHz center frequency transducer on the same specimen in the water. There exists an image of the delamination in the same position as Fig. 4.

In this experiment, a C-scan image as in Fig. 5 was obtained using ultrasonic pulse echo technique because the surface echoes and the echoes from the delamination was separated at 15 MHz. However, considering thin film with the thickness of the order of μm, the C-scan image cannot be created. Even in such case, the imaging technique with the SLS is feasible without the use of water. Hence, this is very promising as a new inspection technique for delaminations.




(a)




(b)

Fig. 2 Receiving point and scanning area on the aluminum specimens (a)with circular dent (b) with non-bonded area

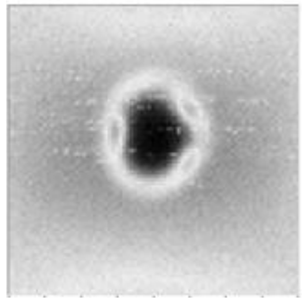


Fig.3 SLS imaging by using 46 kHz spectrum peak values

Fig. 4 SLS imaging by using 127 kHz spectrum peak values

Fig. 5 C-scan imaging

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**References**

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