Fatigue Crack Detection by Active Infrared Thermography with Low Power Laser

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Abstract. For maintenance management of steel structures, it is important to detect fatigue cracks early and non-destructively. This study focused on the active thermography method, which uses laser heating, as a remote non-destructive inspection method for fatigue cracks. Fatigue cracks are detected by remotely irradiating a laser near the crack and capturing the characteristic changes in temperature distribution that occur near the crack. In this study, a spot-shaped laser with low power was used. A method was developed to detect the overall shape of crack by calculating a differential temperature image from multiple infrared images obtained by scanning spot laser measurement.

Possible Sessions

8. Fatigue & Fracture, 10. Infrared & Thermal Methods

Introduction

Widely used inspection techniques such as magnetic particle testing and visual inspection require scaffolding for inspection at high places. Therefore, non-destructive testing method that can be performed remotely are desired. The infrared thermography method detects the discontinuities in the temperature change (called temperature gap) due to the adiabatic effect of cracks[1]. It has been reported that heating and temperature measurement can be performed remotely by using high-power laser and infrared thermography camera[2]. High-power laser requires large equipment and high-power supplies. In this study, the crack detection method using low-power laser that can be used simply at field and image processing were developed.

Laser Heating Infrared Thermography Method

When a laser is irradiated onto an inspection target, a local temperature rise occurs around the laser irradiation point. If a crack exists within the laser-induced temperatrue rise, temperature gap appears on the crack because the crack interferes with the heat conduction. The crack can be detected by capturing this temperature gap using infrared thermography camera. A 100W high power laser light source is commonly used for laser heating thermography method. A high-power leaser source make it possible to detect long part of cracks by heating large area or irradiating the laser in a line. In this study, a low-power laser of 1W was used, which does not require a laser shielding device or a large power supply.

Fatigue crack detection experiment

A plate bending fatigue testing machine was used to introduce a penetraing fatigue crack in a specimen of welded structural steel JIS SM490YA. A laser was irradiated from a distance of 0.5 m from the specimen, and the surface temperature distribution was measured using an infrared thermography camera (FLIR A65).

Figure 1 shows an infrared image of the laser irradiated for 0.25 seconds from distance of 4 mm from the crack. Figures 1(a) and (b) are infrared images taken 0.15 and 0.45 seconds after the start of irradiation respectively. These images show that the temperature increased in 10mm diameter range. It was found from both images that temperature gaps appear on the crack. Fig. 1(c) shows the line profile of the temperature change from before laser irradiation at the crack center position and 10mm away from the crack center in Figure 1(b). No temperatue gap due to the crack could be detected In Line (2), which is far from the laser irradiation point. This result indicates that the laser system in this experiment can detect a part of the crack in the range of 5mm from the laser irradiation point.

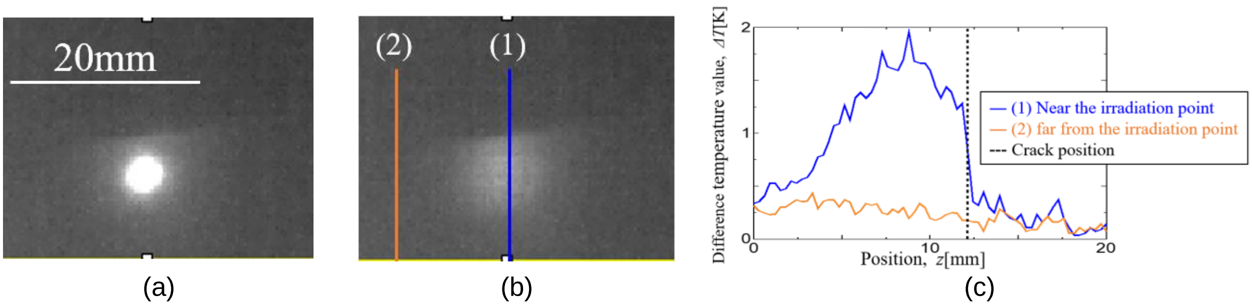

Fig. 1 Crack detection by spot laser irradiation; (a) 0.15[s] from the irradiation start; (b) 0.45[s] from the irradiation start; (c) line profile of the temperature change from before irradiation

Fatigue crack detection by the spot laser scanning measurement and image processing

To measure the overall crack shape, scanning irradiation was performed by turning the laser on and off along the crack. The interval time of laser turning on and off were set at 0.25 seconds each. A schematic diagram of the crack and the scanning laser irradiation is shown in Figure 2(a). Infrared images were obtained at 0.22 seconds after the laser was stopped. The highest temperature value at each pixel was selected from the 80 infrared images obtained from the scanning measurement. The difference between the highest temperature value and the temperature value before the scanning measurement was calculated for each pixel, and the difference temperature image was obtained. A median filter and a differential filter were applied to the difference temperature image to enhance the crack shape. Fig. 2(b) shows the difference temperature image with the median filter and Fig. 2(c) shows the line profile at the position indicated in Fig. 2(b). It was found that the temperature gradient is constant at locations where there are no cracks, on the other hands, a temperature gap appears at locations where cracks exist. Fig. 2(d) shows the result of applying a differential filter in the vertical direction of the image. The differential filter extracts the temperature gradient change at the crack and emphasizes the overall crack shape. The scanning measurement using a low power laser and image processing were effective in detecting long fatigue cracks.

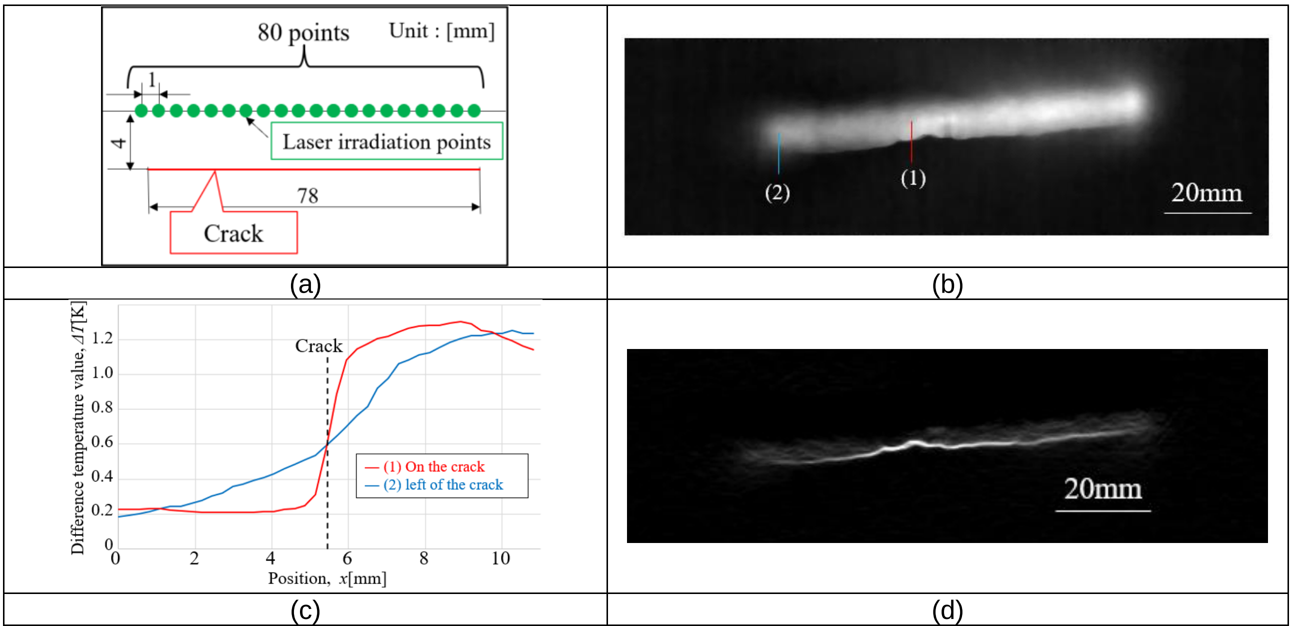

Figure 2 Detection of entire crack by image overlay; (a) Diagram of crack and irradiation points; (b) Difference temperature value image; (c) Line profile of difference temperature value; (d) Image of the entire crack using a differential filter

Conclusion

In this study, we developed a method to detect fatigue cracks at high places from a distance without contact using infrared thermography using laser heating. Overlaying infrared images obtained by infrared thermography using a low-power laser, we were able to detect the entire image of fatigue cracks.

References

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