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A Welding Defect Inspection by using an Ultrasonic Infrared Imaging

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1. Introduction

A newly established inspection technique which combines an infrared imaging with an ultrasonic excitation, so called an ultrasonic infrared imaging, has been used in detecting fatigue damage both in isotropic and composite materials [1–3]. The mechanism of a heat generation at a defect's location is presumably a friction, rubbing, or clapping motion of the mating surfaces of a defect zone.

In this paper, the applicability of an UIR (ultrasonic infrared imaging) for a defect detection of an Al receptacle welded by using a Nd:YAG pulsed laser is described. A low frequency (20 kHz) ultrasonic transducer was used to infuse the outer surface of the welded Al receptacle with a short pulse of sound for 280 ms. The ultrasonic source had a maximum power of 2 kW. The surface temperature of the area under inspection was imaged by an infrared camera which was coupled to a fast frame grabber in a computer. Hot spots, which were in a small area around the crack tip and considerably heated up, were observed. From a sequence of the thermosonic images, the location of a crack in the welded Al receptacle could be detected in a real time. Also the crack position in the test specimen was verified by the LPI (liquid penetrant inspection) method.

2. Experimental Methods

The experimental set up is shown in Fig. 1. The experimental setup includes an ultrasonic transducer (sonotrode), an infrared camera, a high voltage power source (20 kHz / 2 kW) for an ultrasound excitation, and a pc-based image processing system. The IR camera was a Mitsubishi IR-M500™ large format (512 x 512 pixel) PtSi cell array, operating in the 3~5 micron spectral range. It is sensitive to surface temperature changes of 0.15°C, and can be operated at a full-frame resolution at frame rates up to about 60 Hz. Also it is equipped with a high brilliance IR objective. A 50mm/f1.2 lens was used for this experiment. In the experimental setup, as can be seen in Fig. 1, we used a mechanical fixture to hold the ultrasonic transducer firmly against the sample cross-section. The metal tip of the ultrasonic transducer is mechanically held against the specimen being tested to maintain a good mechanical contact. Also a vise was used to keep the specimen from a secession or a slippage when an ultrasound excited vibration was being injected into the welded aluminum receptacle. As shown in Fig.2, a circular aluminum plate (thickness 1.5mm, diameter 24 mm) laid on the top surface of a receptacle, is welded by using a Nd:YAG pulsed laser. A certain amount of effort was required to tune the ultrasonic transducer and the specimen. It is well known among those who use an ultrasound excited thermography that the amount of the contact force between the ultrasonic transducer and the test specimen is critical to obtain a screech (loudest chirp) and hence a high quality infrared image. This loudest chirp sound is a good indicator of a mechanical coupling between the specimen and the ultrasonic transducer. If the contact force is too little, the system is quiet, and very little ultrasound is coupled into the sample. If the contact force is too great, the result is the same. The exact amount of force necessary to produce a screech depends on the particular ultrasonic transducer used to inject the ultrasound, presumably because different transducers have different vibration amplitudes. It seems likely that a particular combination of a vibration amplitude and an applied force is crucial to generate a screech because, only under the right conditions will the tip of the transducer recoil from the surface during the negative half of an ultrasonic excitation period. Thus, being restricted by these experiment environments and equipment limitations, all the experiments were conducted under normal room temperature. Some unwanted parts, effected by the background thermo-radiation, are shown in the images taken. Also a sensor's noise have a great effect on the images. So it is important to find a way to eliminate all these negative effects and obtain clean images for a defect detection.

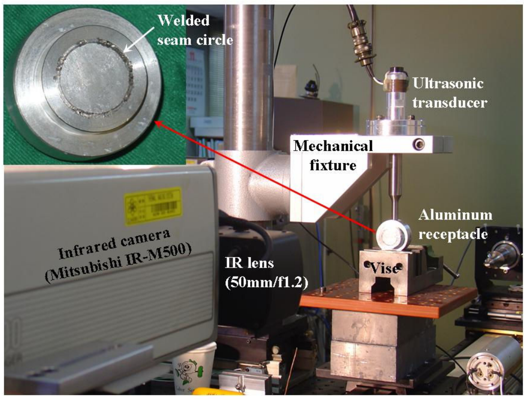
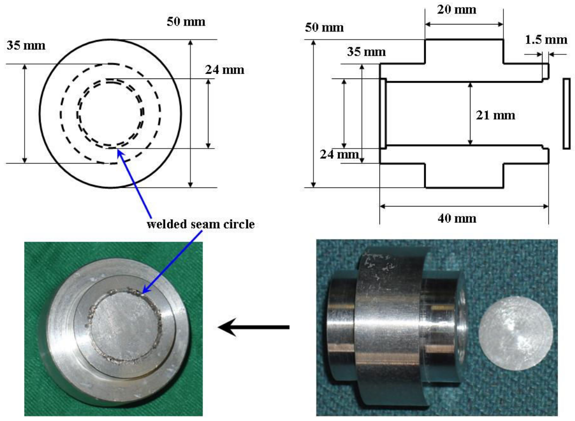


Fig. 1 A photograph of the experimental setup.

The circular aluminum plate (thickness 1.5mm, diameter 24mm), laid on the top surface of the receptacle, is welded by using a Nd:YAG pulsed laser.



(a) front view (b) side view

Fig. 2 A schematic of the aluminum receptacle

3. Results and discussion

Figure 3 shows a selection from a sequence of the thermosonic images of this specimen which were acquired at the 6th frame after an application of the ultrasonic excitation pulse. The weak hot spot inside the dotted circle shown in Fig. 3 indicates a defect of the welded seam. The bright line shown at the top of Fig. 3 indicates the generated friction heat at the contact between the ultrasonic transducer and the surface of the aluminum receptacle. When the ultrasound pulse is turned on, there is a friction motion between the test specimen and the ultrasonic transducer which causes a temperature rise. From Fig. 3, we can clearly see the location of the welding defect of the aluminum receptacle.

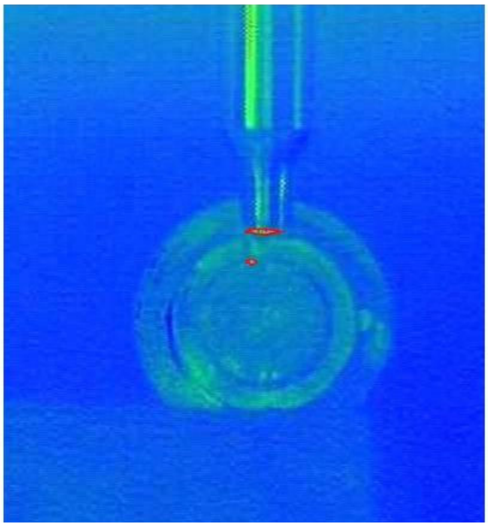
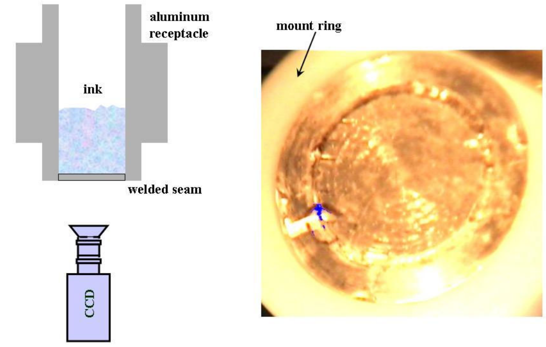


Fig 3. Thermosonic image of a welded aluminum receptacle

We found a welding defect in a welded seam circle by using the LPI (liquid penetrant infilteration) method as shown in Fig. 4a. In the LPI test as shown in Fig. 4a, we used blue-colored ink. After filling the blue-colored dyes into the aluminum receptacle, we observed a leakage from a welding defect of the aluminum receptacle by using a CCD camera. Fig. 4b is the image taken a few seconds after the injection of the blue-colored ink. From the LPI test, we can clearly infer that a welding defect exists in the welded seam circle of the aluminum receptacle.



(a) experimental setup for LPI test (b) elapse of a few seconds after injection of the ink

Fig. 4 LPI test of an aluminum receptacle

4. Conclusion

In this paper a fast detection of a welding defect in an aluminum receptacle by using an ultrasonic infrared imaging is described. A 280ms ultrasonic pulse from a 2 kilo joule transducer operating at a 75% amplitude was applied to the outer surface of a welded aluminum receptacle sample. The surface temperature of the area under inspection was imaged by an infrared camera which was coupled to a fast frame grabber in a computer. A hot spot, which was in a small area around the crack tip and considerably heated up, was observed. In order to accurately locate the position of a welding defect of the aluminum receptacle, image processing technologies such as a background subtraction averaging, a contour extraction, and the image superimposition method were used. And the defect position of the test specimen was verified by the LPI test.

REFERENCES

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