



Non-Destructive Inspection of Brazed Joint by Pulsed Phase Thermography

Theerapol Sriyubol^{1*} and Udomkiat Nontakaew²

^{1,2} Department of Mechanical and Aerospace Engineering, Faculty of Engineering,
King Mongkut's University of Technology North Bangkok, Thailand 10800

^{1,*} Tel: 66(0)2 913-2500 ext 8313, Fax: 66(0)2 586-9541

E-mail: ^{1,*} tps@kmutnb.ac.th, ² unk@kmutnb.ac.th

Abstract

In this study, hot air was used as the pulsed heat source and infrared camera was used to record the variation of outside surface temperature of the joint. These temporal sequences of thermal images were transformed to frequency domain by using Fourier Transforms. The phase data in the frequency spectrum can be determined and used to specify the defects. The specimens are cylindrical lap joints of 10-millimeter diameter and were brazed by brass filler. This method can be used to detect the boundary of the voids by investigating the Phase difference at various locations.

Key words: Non-destructive Testing, Brazed joint, Defect, Pulse Phase Thermography

1. Introduction

In the past, the manufacturers inspected the brazed joint by destructive method i.e. cutting the joint, polishing, and investigating the penetration of the filler (brass) which is a waste of time and money. To meet the higher reliability, they need to randomly check the brazed joints in manufacturing process with the higher ratio of sampling so this destruction method is no longer appropriate. Thus, the applicability of Pulse Phase Thermography (PPT) was studied to replace the destructive testing method.

Pulse Phase Thermography (PPT) is a method for Non-destructive testing. It combines features of Impulse Thermography (IT) and Lock-in Thermography (LT) [1]. The experimental set-up and data acquisition of PPT are the same as IT, but the image analysis method is different. Whereas, PPT analysis is done in the frequency domain similar to LT.

The advantages of PPT are given mainly by the properties of the phase images, which are reported to be:

- Deeper detecting. (For LT, it has been demonstrated that phase images can detect roughly twice the thickness detected by amplitude images [4, 5]).
- Less influence of surface infrared and optical characteristics.
- In-sensitivity to non-uniform heating is seen in phase images as compared with thermal images and amplitude images [5, 6]. (In LT the phase image is related to the propagation time delay of the thermal wave and is therefore independent of surface features).
- Rapid image recording (surface wide inspection) [2, 5, 6].
- Better defect shape resolution [2, 5, 6].

- Phase processing of thermal images improves the visibility [5].

Amplitude images show the internal structure of a specimen up to a maximum available depth depending on the frequency (low pass filter behavior). Phase images show the internal structure within a certain depth range depending on the frequency (band pass filter behavior) [2, 6].

PPT method, each pixel (i,j) of a series of thermal images, as shown in Fig.1, which describes the transient heating and cooling down behavior of a specimen after a heating pulse, is analyzed by application of the Fourier Transformation as shown in Fig.2. Basic research on PPT has been accomplished by the group of Maldague, who reported about principle of PPT and gave a comparison between PPT, IT and LT [2, 3]. The method was tested on specimens made from aluminum and different kind of polymers.

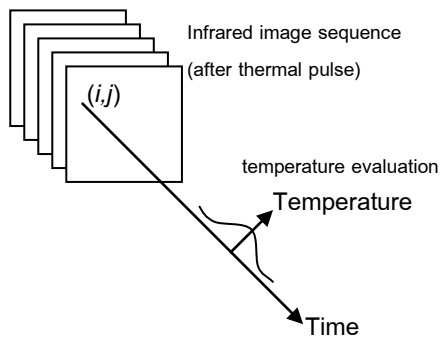
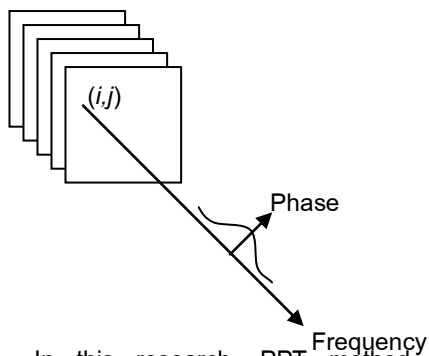


Fig. 1 Time domain



In this research, PPT method will be applied to the specimen.

Fig. 2 Data structure of phase spectra

2 Experiment

2.1 Experimental set up

The experimental set up consists of a thermal heating unit, an infrared camera and a computer system, which enables digital data recording in real time, as shown in Fig 3.

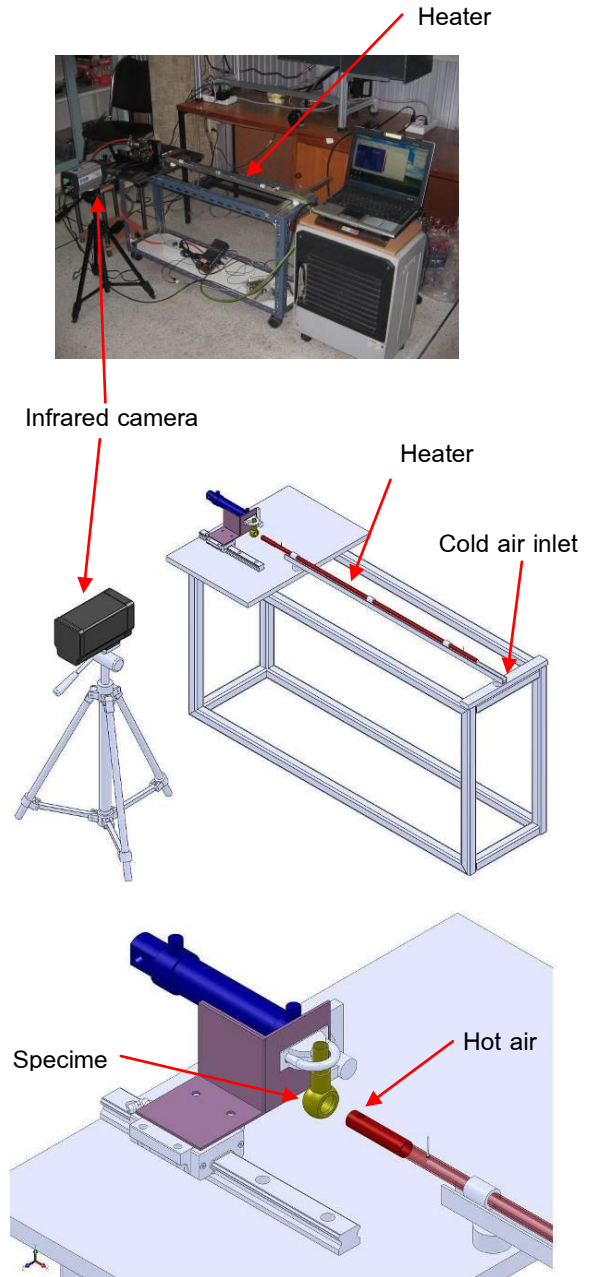


Fig. 3 Experimental set up for PPT.

The specimens are heated by blowing hot air into the inside of tube for 8 seconds that causes the outside surface temperature to be not higher

than 35°C, whereas the experiment runs under the room temperature condition (25°C).

The temperature of the test specimen surface is observed with an infrared camera (FLIR Model: A40M, 320 x 240 Pixel). The camera detects the emitted radiation from the surface of the specimen in a wavelength region from 7.5 to 13 μm. The observation is accomplished for 7 min. The time interval between the thermal images is 1 second.

The data are transferred to a computer in real time with a thermal sensitivity 80mK of each pixel. After receiving the thermal images, the computer is also used to analyze the data with software programs in the frequency domain.

The heating pulse causes a non-stationary heat flow. The propagation of the heat depends on the material properties such as thermal conductivity, heat capacity and density. If there are inhomogeneities in the structural element with different thermal properties, the heat flow will slow down or accelerate in these local areas. While observing the temporal changes of the surface temperature distribution with the infrared camera, inhomogeneities will be detected if they give rise to measurable phase differences on the surface.

The heating pulse is represented as a pulse shown in Fig. 8 which can be described as superposition of different frequencies with varying amplitudes. The available energy is concentrated in the low frequencies [2]. The duration of pulse stimulation determines the frequency spectrum in that way, so for longer duration the lower frequencies will contain more energy.

2.2 Specimens

In this paper, the results obtained from specimens with void will be presented. These specimens are shown in Fig. 4, defect is a annular shape parallel to the surface of tube of specimen. Fig. 5 show the cross-section of test specimen and Fig. 6 show the dimension of void.



Fig. 4 Test specimen

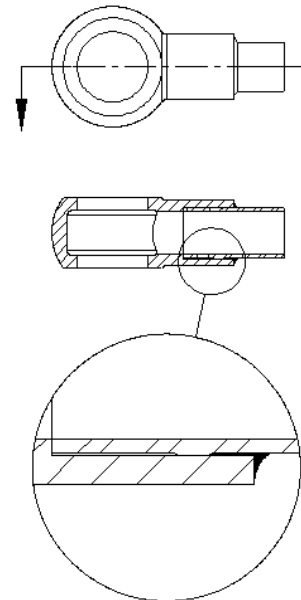


Fig. 5 The cross-section of test specimen

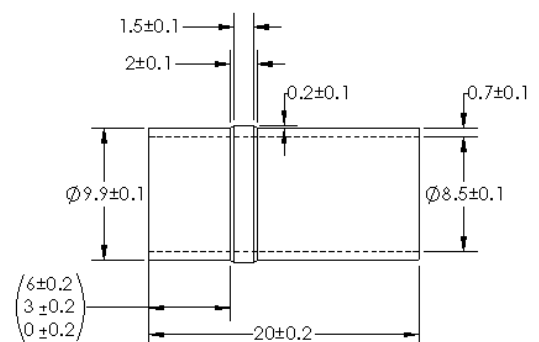


Fig. 6 The dimension of void

Observation area of the test specimen is shown in Fig. 7

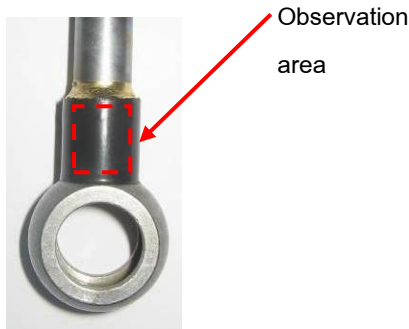


Fig. 7 Observation area of the test specimen

3 Results

The example of transient temperature wave forms on different point of the surface is shown in Fig. 8. Point A is the hot air temperature, Point B is good joint position and Point C is void position.

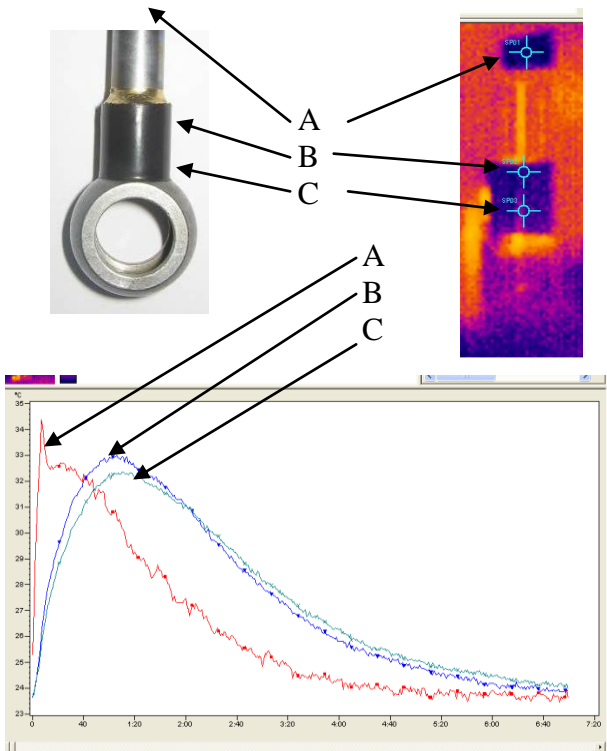


Fig. 8 Transient temperature wave form

The frequency step and the maximum frequency can be calculated from the experimental parameters. e.i. the process after a 8-second heating of the test specimen was observed with a time step of 1 seconds and a total number of 420 thermal images was recorded, according to an observation time of 7 minutes.

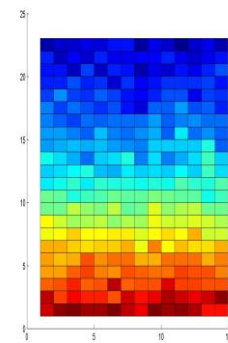
The frequency step is calculated from

$$f_n = \frac{n}{N\Delta}$$

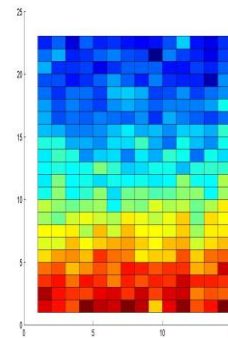
Where f_n are frequencies available, N is the number of thermal images in the sequence, Δ is the time interval, $n=0,1,\dots,N/2$

Therefore, the frequency step is 2.38 mHz and the maximum frequency is 0.5 Hz.

The differences in phase of data corresponding to a defect and a sound area can be seen, most of the information is contained in few low frequencies as show in Fig. 9



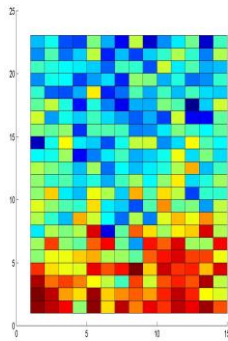
n=2



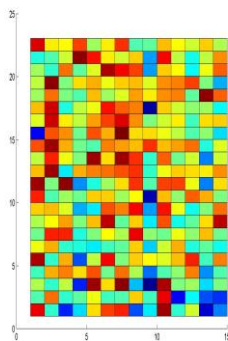
n=3

Fig 9 Phase images of the test specimen with

void 3 mm.



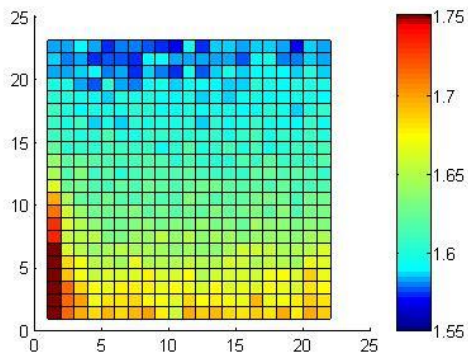
n=7



n=15

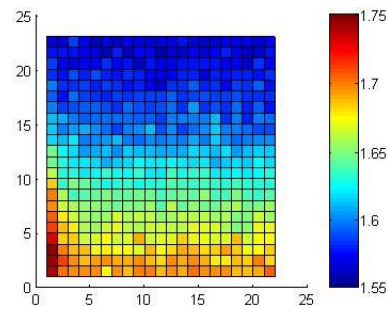
Fig 9 (Cont.) Phase images of the test specimen with void 3 mm.

In Fig.10 Shows phase images of specimens with different void dimension

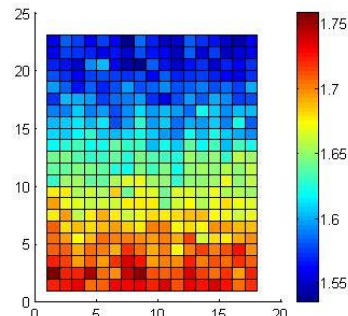


Non-Defect

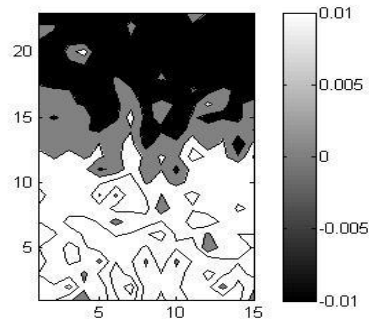
Fig.10 Shows phase images of specimens with different void dimension



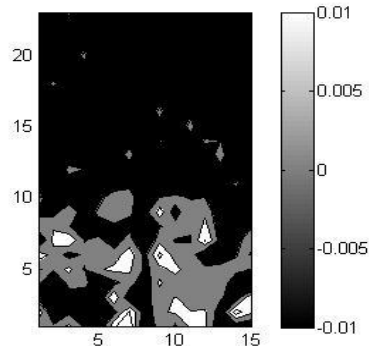
Void 3 mm



Void 6 mm



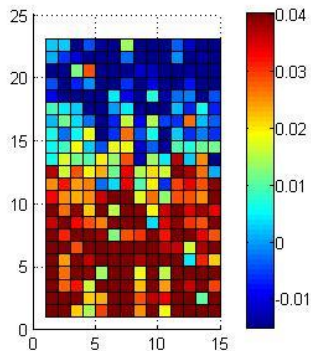
Difference Void 6 mm and Non-Defect Gray scale



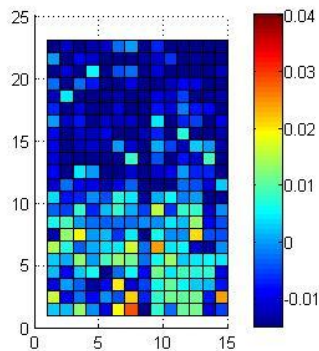
Difference Void 3 mm and Non-Defect Gray scale

Fig.10 (Cont.) Shows phase images of specimens with different void dimension

specimens. However, the relationship between phase image and defects will be further studied



Difference Void 6 mm and Non-Defect RGB



Difference Void 3 mm and Non-Defect RGB

Fig.10 (Cont.) Shows phase images of specimens with different void dimension

4. Conclusion

In this case, the phase images at low frequencies represent the defect better than the phase image at high frequency

Pulse Phase Thermography proves to be useful for applications in inspection of the brazed joint. Images created in the frequency domain facilitate the visibility and detectability of defects. Phase images are slightly influenced by curved surface. The geometrical configuration of the defects can be determined from the size of phase images that differs from the non-defected

5. Acknowledgements

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6. References

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