NONDESTRUCTIVE EVALUATION OF COMPOSITE BOGIE USING INFRARED THERMOGRAPHY TECHNIQUE

J. Kim[1]*, J.S. Kim[1], H.J. Yoon[1]
[1] Vehicle Dynamics Department, Korea Railroad Research Institute, Uiwang, South Korea
* Corresponding author (jkim@krri.re.kr)

Keywords: *Nondestructive evaluation, Composite bogie, Flaw detection, Railway, Infrared lock-in thermography*

1 Introduction

As increases in the speed of train, the running safety of the railway rolling stocks has become one of important issues. Also, recent concerns on the environmental issues have made the progress on energy efficiency. In the areas of railway rolling stocks, there has been every effort to reduce the weight of overall rolling stock in terms of energy efficiency. The possible example of this trial could be the use of composite materials for the carbody or bogies in railway rolling stocks. The composites provide the characteristics of lightweight, a good corrosion resistance, and a reasonable strength as compared with metallic materials [1].

Especially, the continuous fiber reinforced polymer matrix composites, recently, have been used for bogie materials in railway application. Therefore, in order to facilitate the use of composite materials in railway fields, in this research, the defect evaluation of composite bogie with polymer matrix composite materials has been investigated.

Also, infrared (IR) thermography is a powerful NDE technique for the characterization of thermal phenomenon in engineering components and/or systems including engineering materials [2,3]. The high-speed IR camera provides the measurement of temperature change during mechanical testing as well as the images of temperature contour on the surface of object [4].

In this investigation, the lock-in thermography was employed to evaluate the defects in a composite bogie. Prior to the actual application on a composite bogie, in order to assess the detectability of known flaws, the calibration reference panel was prepared with various dimensions of artificial flaws. The panel was composed of polymer matrix composites, which was the same material with actual bogies. Through lock-in thermography evaluation, the optimal frequency of heat source was determined for the best flaw detection. Based on the defects information, the actual defect assessments on composite bogie were conducted.

Therefore, the main objectives of this investigation are to (1) perform the thermographic detection of artificial flaws on epoxy polymer matrix composites (PMCs) using the infrared thermography method with a high-speed infrared camera, (2) assess the detectability of known flaws in PMCs panel and composite bogie using the infrared thermography technique, and (3) develop a nondestructive evaluation tool for the detection of flaws in PMCs and railway composite bogie.

2 Expeimental Procedures

Prior to the actual nondestructive evaluation of the bogie, in order to assess the detectability of known flaws, the calibration panel was prepared with various dimensions of artificial flaws as shown in Figs. 1 and 2.

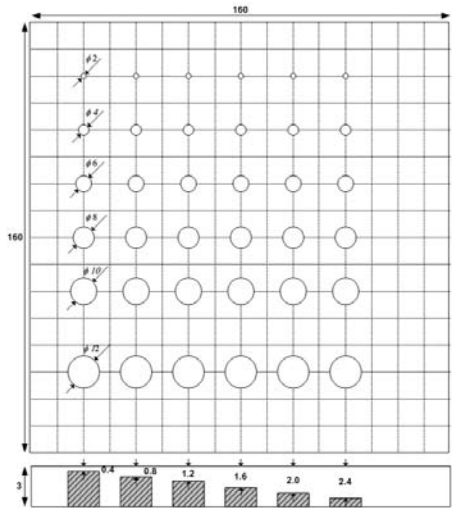


Fig.1. The drawing of composite panel with different dimensions of flaws

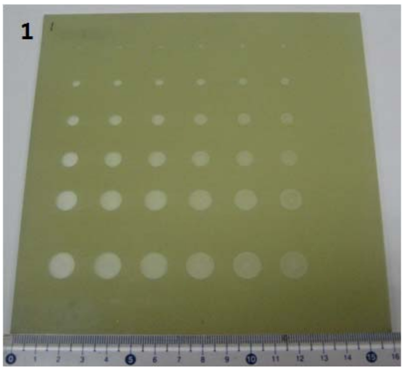


Fig.2. The actual composites panel with artificial flaws

The panel was composed of E-glass fiber reinforced epoxy matrix composites, which was the same material with actual bogies. Through lock-in thermography evaluation, the optimal frequency of heat source was determined for the best flaw detection.

The spherical or rectangular flaws with different diameters and depths were prepared from the panels of glass fiber reinforced epoxy polymer matrix composites. The lock-in thermography with flash lamp was used for the integrity evaluation of composite panel.

Figures 3 and 4 present the experimental setup and the principle of lock-in thermography for the current investigation.

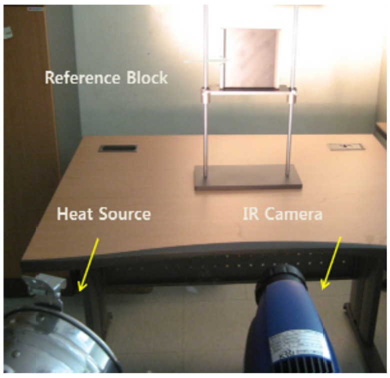


Fig.3. The experimental setup for lock-in thermography

The principle of lock-in thermography is based on the synchronization of the infrared camera with the source of heating, which can be optical excitation, ultrasound, cyclic loading of the material, etc.

In the case that a specimen undergoes cyclic loading, heat waves are generated and the resulting oscillating temperature field in the stationary regime is recorded remotely through thermal infrared emission.

The frequency of modulation varies with the nature, size and shape of the defects to be detected. Using this method, the influence of emissivity and non-uniform heating on the temperature measurement is reduced allowing inspection of large areas of samples with high repeatability and sensitivity.

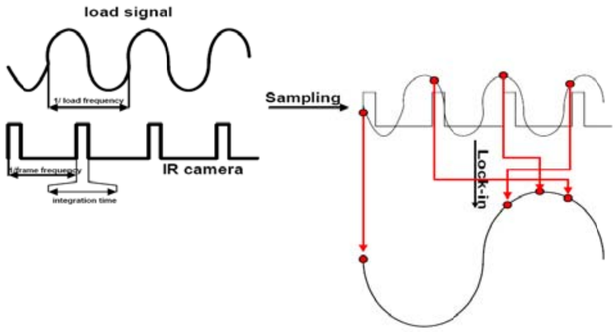


Fig.4. The principle of lock-in thermography [5]

3 Results and Discussion

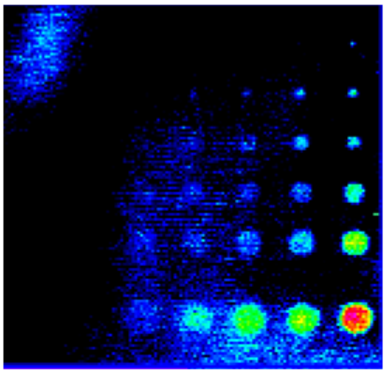
Figure 5 presents the evaluation results of lock-in thermography for the composite panel. Several different levels of frequency were applied on the composite panel, and the optimal frequency was determined as 0.09 Hz as shown in Fig. 5(b). Also, the defect detectability of composite panel using lock-in thermography was determined as 4 mm in diameter and 0.4 mm in depth, respectively.

Based on the defects information, the actual defect assessments on composite bogie were conducted, which was prepared for the actual operation. The results were exhibited in Figs. 6 and 7.

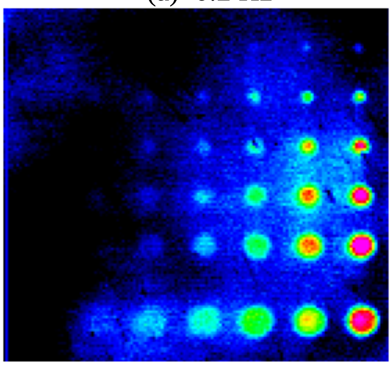
Figure 6 shows the surface defect at the corner of composite bogie, and note that the white dots on the surface are the sticker type tapes showing the location on the surface for the other purpose.

Figure 7 shows the thermographic images with the frequency of 0.07 Hz in terms of the differences in phase, temperature, and amplitude, respectively. The surface defect was clearly appeared through the results of lock-in thermography as shown in Fig. 7.

In summary, the defect assessment results with lock-in thermography method showed a good agreement as compared with the visual inspection results. Moreover, it was found that the novel infrared thermography technique could be an effective way for the inspection and the detection of surface defects on composite bogies since the infrared thermography method provided rapid and non-contact investigation of the composite bogies.



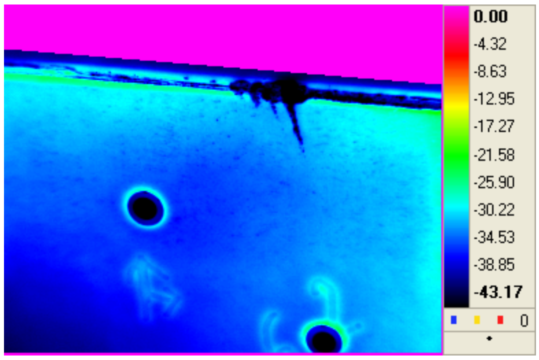
(a) 0.2 Hz



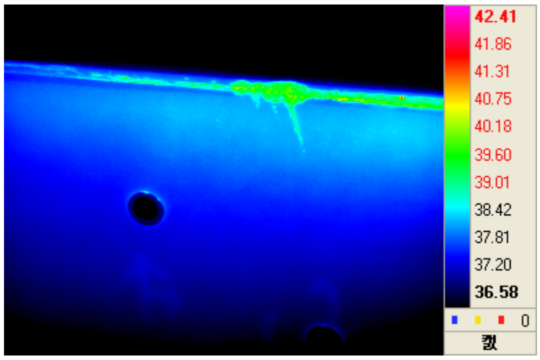
(b) 0.09 Hz

Fig.5. The thermographic phase images at 0.09 Hz in lock-in thermograhpy

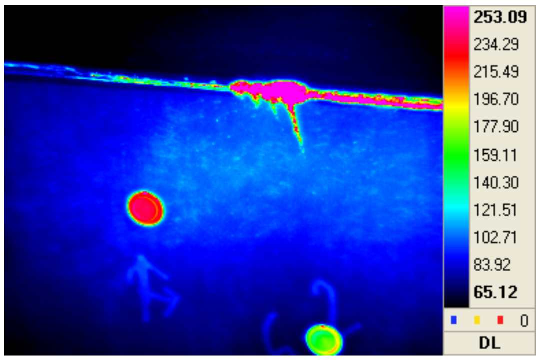
Fig.6. The surface defect at the corner of composite bogie



(a) Phase image



(b) Temperature image



(c) Amplitude image

Fig.7. The thermographic images with the frequency of 0.07 Hz

4 Conclusions

The research on nondestructive evaluation of composite bogie using infrared thermography technique leads the following conclusions.

(1) The infrared lock-in thermography nondestructive testing system is an effective tool of

nondestructive testing for the detection of artificial flaws in polymer matrix composites.

(2) The lock-in infrared thermography technique provided a qualitative nondestructive tool for the integrity evaluation of railway composite bogie materials.

(3) The defection of flaws with 4 mm in diameter and 0.4 mm in depth has been obtained, and based on the results, the evaluation of actual defects could be possible for polymer matrix composite bogie.

(4) The results can be used in the calibration data of defects in polymer matrix composites.

(5) It was found that the novel infrared thermography technique could be an effective way for the inspection and the detection of surface defects on composite bogies since the infrared thermography method provided rapid and non-contact investigation of the composite bogies.

References

[1] J. Kim and P.K. Liaw, "Characterization of Fatigue Damage Modes in Nicalon/CAS Composites," Journal of Engineering Materials and Technology, Vol. 127, pp. 8-15, 2005.

[2] X. P. V. Maldague, "Nondestructive Testing Handbook: Infrared and Thermal Testing," Vol. 3, ASNT, 2001.

[3] C. J. Hellier, "Handbook of Nondestructive Evaluation," McGraw-Hill, pp. 9.1-9.47, 2001.

[4] J. Kim and P. K. Liaw, "Tensile Fracture Behavior of Nicalon/SiC Composites," Metallurgical and Materials Transactions A, Vol. 38A, No. 13, pp. 2203-2213, 2007.

[5] ALTAIR LI User Manual, Cedip Infrared Systems, 2008.