# Evaluation of Defects in Carbon/Carbon Composites by Thermal Diffusivity Mapping

Yi-Cheng Peter Pan, Richard Miller, Tsu-chin Philip Chu
Department of Mechanical Engineering and Energy Processes
Southern Illinois University
Carbondale, Illinois 62901

## INTRODUCTION

The objective of this study is conduct a new NDE method for identifying subsurface defects in carbon-carbon C/C composites by through-thickness thermal diffusivity measurement. Step heating infrared thermograph method to do through-thickness thermal diffusivity measurements and NDE inspection for whole field carbon-carbon disk brake. In this work a brief description of the theory behind step heating method and a sample application are given. FEA analysis with the use of ANSYS was also used to compare with the experimental results and found that they were in good agreement with one another. As the result, this method is capable of evaluating defects in C/C composite materials.

Heat conduction equation:

$$\frac{\partial T}{\partial t} = a\frac{\partial^2 T}{\partial x^2}, \qquad 0 \le x \le l; \quad t > 0$$

Boundary conditions resulting from no heat losses on the slab surfaces:

$$T(x,0) = 0, \qquad 0 \le x \le l$$
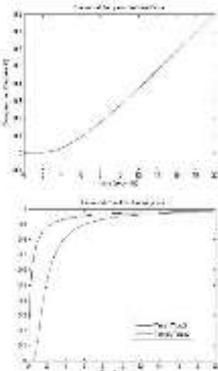$$\frac{\partial T(0,t)}{\partial x} = -\frac{Q}{k}, \qquad t > 0$$
$$\frac{\partial T(L,t)}{\partial x} = 0, \qquad t > 0$$

where $a$ is the through-thickness thermal diffusivity, $k$ is the thermal conductivity and $Q$ is the heat flux. The expression for the sample temperature as a function of position x = $L$ and time $t$ is:

$$\Delta T = T(L,t) - T_r = \frac{QL}{k}\left[\frac{\alpha t}{L^2} - \frac{1}{6} - \frac{2}{\pi^2}\sum_{n=1}^{\infty}\frac{(-1)^n}{n^2}e^{-(n\pi)^2\frac{\alpha t}{L^2}}\right]$$
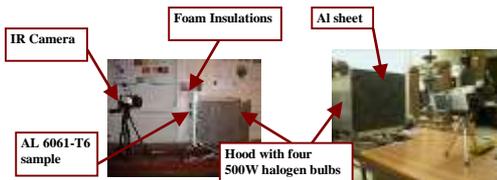
$$V = \frac{T_1(L,t_1) - T_r}{T_2(L,t_2) - T_r} = \frac{\frac{\alpha t_1}{L^2} - \frac{1}{6} - \frac{2}{\pi^2}\sum_{n=1}^{\infty}\frac{(-1)^n}{n^2}e^{-(n\pi)^2\frac{\alpha t_1}{L^2}}}{\frac{\alpha t_2}{L^2} - \frac{1}{6} - \frac{2}{\pi^2}\sum_{n=1}^{\infty}\frac{(-1)^n}{n^2}e^{-(n\pi)^2\frac{\alpha t_2}{L^2}}} \qquad (t_2 > t_1)$$
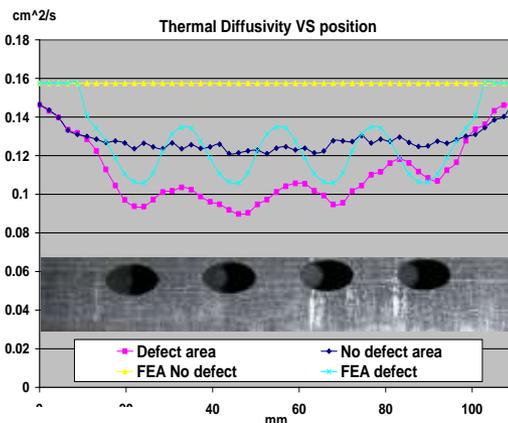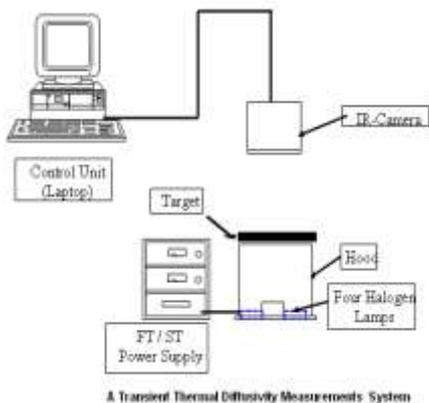
where $T_i$ is the initial temperature.
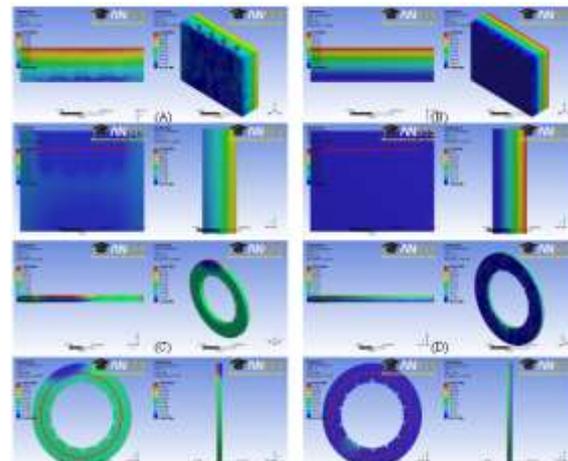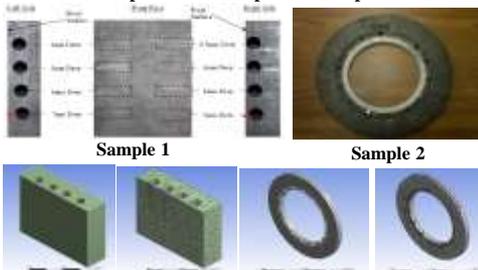
A Transient Thermal Diffusivity Measurements System

## NEW APPROACH

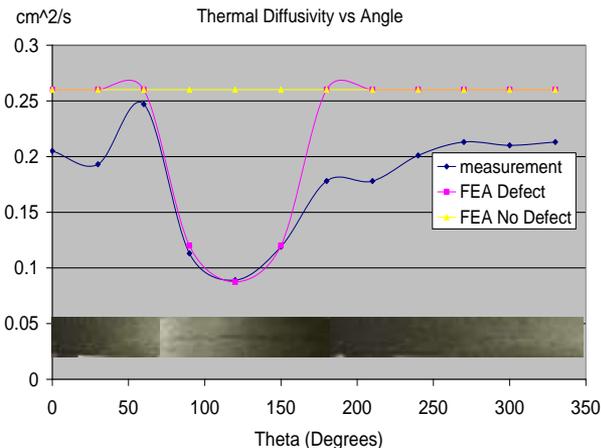The thermograph step-heating method is suitable for rapidly determining the defect and the whole-field trough-thickness thermal diffusivity of C/C bulk composite brake. This method is capable of evaluating defects in C/C composite materials. With more research, this method can become efficient, economically feasible, easy implementation, and rapid assessment of detecting defects in C/C composite materials that will be able to be incorporated into a manufacturing process quality control system.

IR Camera    Foam Insulations    Al sheet

AL 6061-T6 sample    Hood with four 500W halogen bulbs

**Experimental setup for Al sample**

Sample 1    Sample 2

**Thermal Diffusivity VS position**

cm^2/s

- Defect area
- No defect area
- FEA No defect
- FEA defect

mm

Comparison of the Results

**Thermal Diffusivity vs Angle**

cm^2/s

- measurement
- FEA Defect
- FEA No Defect

Theta (Degrees)

Comparison of the Results

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