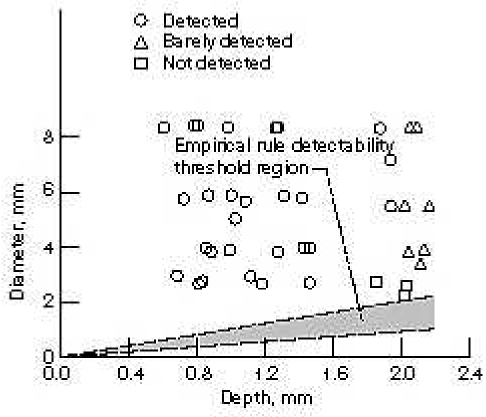
Capability of Thermographic Imaging Defined for Detection in High-Temperature Composite Materials

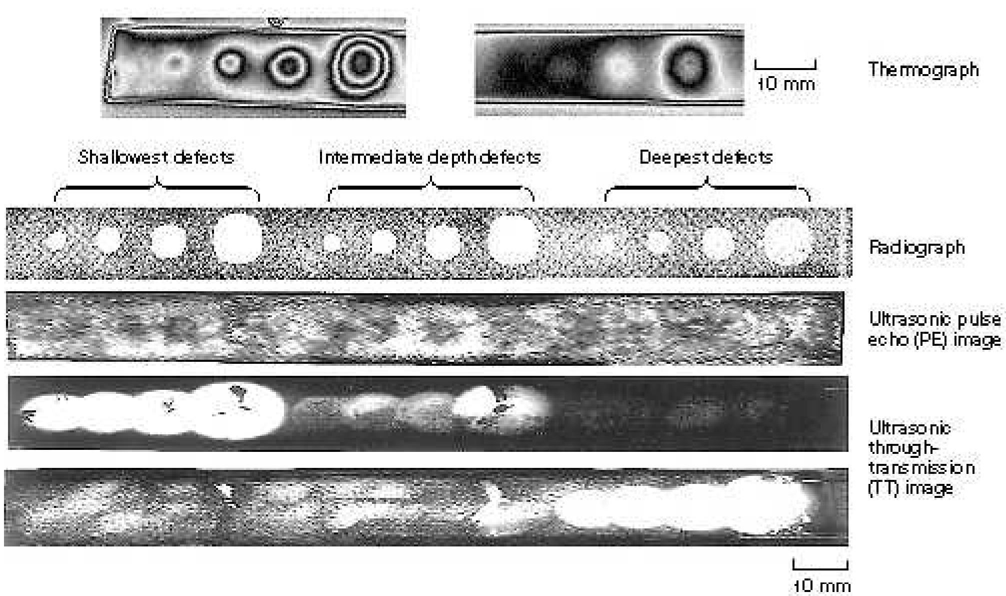
Significant effort and resources are being expended to develop ceramic matrix (CMC), metal matrix (MMC), and polymer matrix (PMC) composites for high-temperature engine components and other parts in advanced aircraft. In addition, composite structural material development is being actively pursued in other industries, such as the automobile and sports equipment industries. A portion of the development effort assesses nondestructive evaluation (NDE) technologies for detecting flaws in these materials. Recent technological advancements in infrared camera technology and computer power have made thermographic (infrared) imaging systems worth reevaluating as a reliable NDE tool for advanced composites. Thermography offers the advantages of real-time inspection, no contact with the sample, nonionizing radiation, complex-shape inspection capability, variable field-of-view size, and portability.

The objective of this NASA Lewis Research Center study was to evaluate the ability of a thermographic imaging technique for detecting artificially created defects (flat-bottom holes) of various diameters and depths in four composite systems (two CMC's, one MMC, and one PMC) of interest as high-temperature structural materials. In the thermographic imaging technique used, the heating source and camera were on the same side. The holes ranged from 1 to 13 mm in diameter and 0.1 to 2.5 mm in depth in samples approximately 2- to 3-mm thick. Limits of detectability based on the depth and diameter of the flat-bottom holes were observed for each composite material. This work was done in cooperation with Bales Scientific, Inc., a manufacturer of state-of-the-art thermography systems, via a Space Act Agreement. It was funded by the High Speed Research program, the Enabling Propulsion Materials (EPM) program, and the High Temperature Engine Materials Program (HITEMP) of which Pratt & Whitney and GE Aircraft Engines are major partners and customers with NASA. This study was completed in 1996, with results reported at EPM, HITEMP, and Quantitative Nondestructive Evaluation (QNDE) technical meetings.



SiC/SiC ceramic matrix composite defect distribution and thermography detectability data.

On the basis of the detectability results for the flat-bottom hole samples, the following conclusions were drawn. For the SiC/SiC CMC samples, defects with depths $\leq$1.8 mm and diameters $\geq$2.6 mm probably will be detected as shown in the graph. For the SiC/CAS CMC samples, defects with depths $\leq$1.8 mm and diameters $\geq$1.6 mm probably will be detected with the thermography methodology used in this study. For the SiC/Ti MMC samples, defects with depths $\leq$1.6 mm and diameters $\geq$3.2 mm probably will be detected. For the graphite/polyimide PMC samples, defects with diameters of ~3 to 12 mm and $\leq$1.8 mm in depth probably will be detected. Depth appears to be the limiting variable with regards to detectability in the PMC system. The thermographic images were compared with ultrasonic and conventional film radiographic images (see the images below) for the SiC/SiC composite samples. For these SiC/SiC samples, radiography clearly shows all defects. The ultrasonic pulse echo (PE) image shows very diffuse indications of most defects because of the porous nature (~15 percent) of SiC/SiC. The ultrasonic through-transmission (TT) image shows clear indications of most defects. Thermography clearly shows shallow and intermediate depth defects.



Comparison of radiographic, ultrasonic, and thermographic imaging for a SiC/SiC CMC inspection method development.

Probable detectability limits for the thermography method based on depth and diameter were defined for four composite systems that are of interest for use in high-temperature structural components. These baseline results allow material developers and component designers to determine whether this thermography method can detect a "critical" defect. Thermography images and detectability results were compared with those from conventional ultrasonic and radiographic imaging methods to highlight the relative strengths and weaknesses of the three imaging methods when applied to the composite systems used in this study.

Bibliography

Roth, D.J.; Bodis, J.R.; and Bishop, C.: Thermographic Imaging for High-Temperature Composite Materials--A Defect Detection Study. NASA TM-106950, 1995.

Roth, D.J.; Bodis, J.R.; and Bishop, C.: Capability of Single-Sided Transient Thermographic Imaging Method for Detection of Flat Bottom Hole Defects in High-Temperature Composite Materials. Proceedings From the 1996 Review of Progress in Quantitative NDE, Brunswick, ME, July 28 - Aug. 1, 1996.

Lewis contact: Dr. Don J. Roth, (216) 433-6017, smroth@popserve.grc.nasa.gov
Author: Dr. Don J. Roth
Headquarters program office: OA