

# Nondestructive Evaluation Approaches Developed for Material Characterization in Aeronautics and Space Applications

At the NASA Glenn Research Center, nondestructive evaluation (NDE) approaches were developed or tailored for characterizing advanced material systems. The emphasis was on high-temperature aerospace propulsion applications. The material systems included monolithic ceramics, superalloys, and high-temperature composites. In the aeronautics area, the major applications were cooled ceramic plate structures for turbine applications,  $\gamma$ -TiAl blade materials for low-pressure turbines, thermoelastic stress analysis for residual stress measurements in titanium-based and nickel-based engine materials, and acousto-ultrasonics for creep damage assessment in nickel-based alloys. In the space area, applications consisted of cooled carbon-carbon composites for gas generator combustors and flywheel rotors composed of carbon-fiber-reinforced polymer matrix composites for energy storage on the International Space Station. The role of NDE in solving manufacturing problems, the effect of defects on structural behavior, and the use of NDE-based finite element modeling are discussed in reference 11. NDE technology needs for improved microelectronic and micromechanical systems as well as health monitoring of micromaterials and microcomponents are briefly discussed in reference 11, and many relevant papers can be found in reference 12.

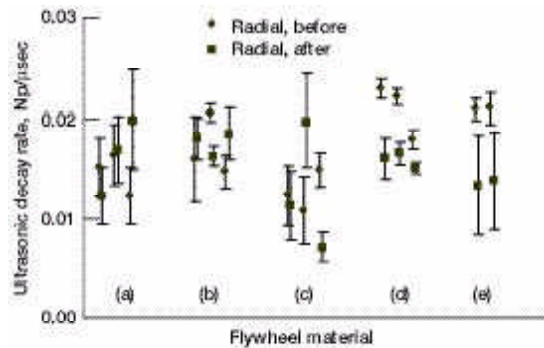
The aeronautic applications include

1. Cooled ceramic vane material optimization (refs. 1 and 2)
2. The resistance to defects of superalloy  $\gamma$ -TiAl blade materials (ref. 3)
3. Thermoelastic stress analysis that can gauge residual stress in Ti- and Ni-based materials (refs. 4 and 5)
4. Creep damage/remaining life in superalloys by acousto-ultrasonics (ref. 6)

The space applications focus was on assuring material/component quality and uniformity via the NDE of cooled carbon-carbon composites for gas generator combustors, and on demonstrating the importance of integrating NDE and the finite element method (FEM) for the rapid, reduced-cost proof testing and material development of advanced polymer matrix composites for a flywheel-energy-based storage system (refs. 7 to 10).

The critical role of nondestructive evaluation as a material characterization modality was demonstrated for several aerospace applications. NDE was successfully used for ceramic process optimization and  $\gamma$ -TiAl effect of defect investigation on fatigue life. Thermoelastic stress analysis was found to be a viable NDE method to monitor the residual stress-state of structural materials. Acousto-ultrasonics parameters could quantify creep damage starting at 50 percent of used-up life, and they correlated well with the time-

to-failure and used-up life in superalloys. Microfocus radiography and computed tomography in conjunction with finite element modeling and fracture analysis proved to be useful for the rapid, reduced-cost proof testing and material development of advanced composites. Lastly, acousto-ultrasonics was able to classify flywheel material systems and gauge degradation due to spin testing of composite rotors (see the figure). The reader is directed to study reference 11 for more details.



*Acousto-ultrasonic measurements along the profile of the stepped creep specimen (75.7 ksi 1350 °F and 260 hr). Indicated are percentages of used-up life.*

## References

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**Glenn contacts:** Dr. George Y. Baaklini, 216-433-6016, [George.Y.Baaklini@grc.nasa.gov](mailto:George.Y.Baaklini@grc.nasa.gov); Harold E. Kautz, 216-433-6015, [Harold.E.Kautz@grc.nasa.gov](mailto:Harold.E.Kautz@grc.nasa.gov); Dr. Andrew L. Gyekenyesi, 216-433-8155, [Andrew.L.Gyekenyesi@grc.nasa.gov](mailto:Andrew.L.Gyekenyesi@grc.nasa.gov); and Dr. Ali Abdul-Aziz, 216-433-6729, [Ali.Abdul-aziz@grc.nasa.gov](mailto:Ali.Abdul-aziz@grc.nasa.gov)

**Cleveland State University contact:** Richard E. Martin, 216-433-3684, [Richard.E.Martin@grc.nasa.gov](mailto:Richard.E.Martin@grc.nasa.gov)

**Authors:** Dr. George Y. Baaklini, Harold E. Kautz, Dr. Andrew L. Gyekenyesi, Dr. Ali Abdul-Aziz, and Richard E. Martin

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