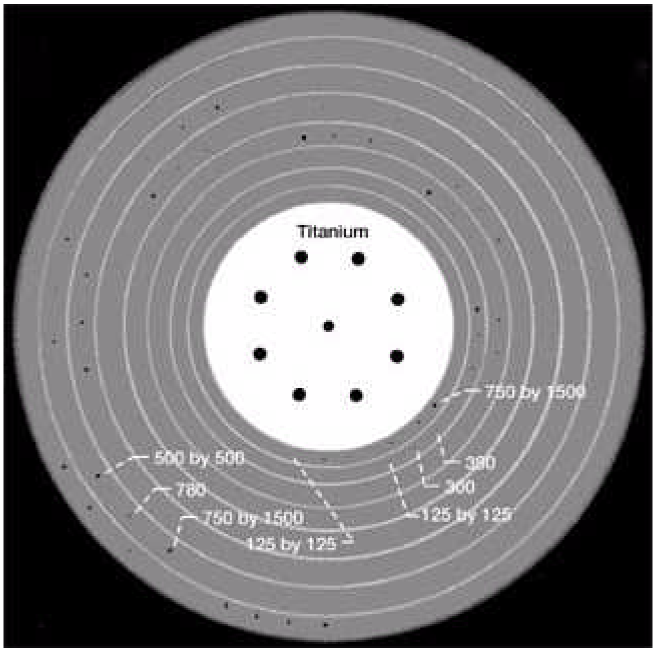
Nondestructive Evaluation Methodologies Developed for Certifying Composite Flywheels

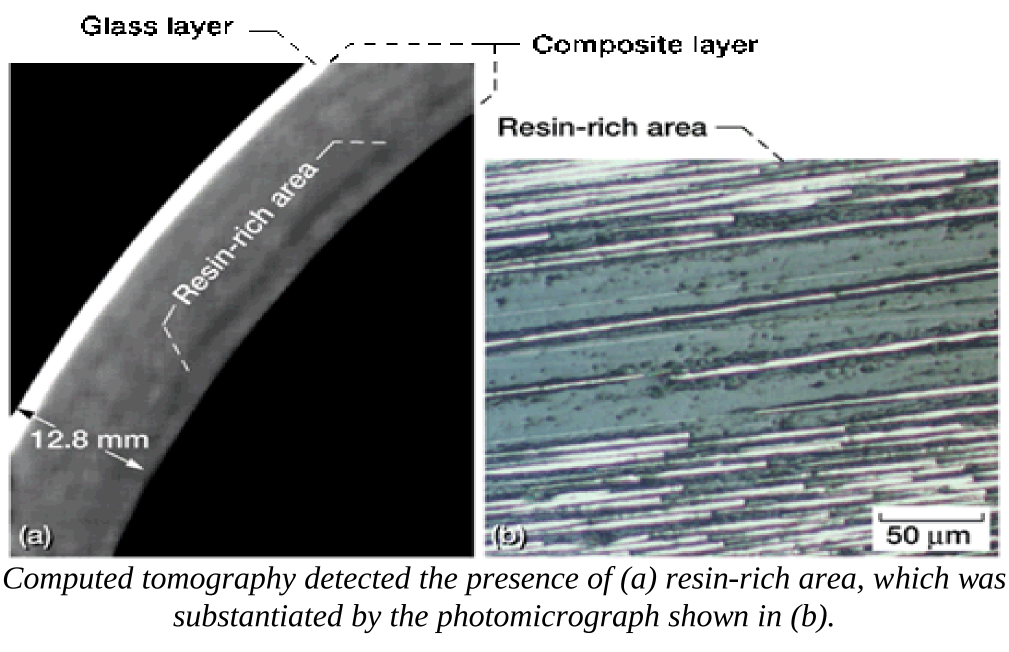
Manufacturing readiness of composite rotors and certification of flywheels depend in part on the maturity of nondestructive evaluation (NDE) technology for process optimization and quality assurance, respectively. At the NASA Glenn Research Center, the capabilities and limitations of x-ray-computed tomography and radiography, as well as advanced ultrasonics were established on NDE ring and rotor standards with electrical discharge machining (EDM) notches and drilled holes. Also, intentionally seeded delamination, tow break, and insert of bagging material were introduced in hydroburst-rings to study the NDE detection capabilities of such anomalies and their effect on the damage tolerance and safe life margins of subscale rings and rotors. Examples of possible occurring flaws or anomalies in composite rings as detected by NDE and validated by destructive metallography are shown. The general NDE approach to ensure the quality of composite rotors and to help in the certification of flywheels is briefly outlined.



Computed tomography slice of a multilayered rotor standard (composite rim and titanium hub) with EDM notches and drilled holes set (125 by 125, 300 diameter, 390 diameter, 500 by 500, 780 diameter, and 750 by 1500) in each layer. This set was duplicated in a spiral fashion starting at the innermost ring near the inner diameter and finishing at the outermost ring near the outer diameter. All dimensions given in micrometers.

Using the flywheel technology for energy storage systems is gaining broader support, more than it did for the last 25 years (refs. 1 to 4) because of current support from NASA and U.S. Air Force space programs. The drive is not only to improve energy storage systems where the state of charge can be known but also to concurrently perform attitude control depending on the specific application for a given spacecraft (ref. 5). Some of the major challenges in the flywheel technology for the International Space Station include high-speed rotors and carbon-reinforced composite materials that can meet the safe-life design requirements, reliability and durability to end-of-life, flight certification, and safety constraints while delivering the high energy density needed (ref. 6). This research was limited to the NDE of composite flywheel rotors and rings that are targeted under the flywheel energy storage system program (ref. 7). These composite rotors are to be flown on the International Space Station as a replacement for a battery charge/discharge unit.

Findings demonstrated that EDM notches as small as 125 by 125 µm and drilled holes as small as 300 µm in diameter can be detected in a thick multilayered rotor by using x-ray computed tomography (see the preceding figure). At the ring level, x-ray microfocus radiography, x-ray computed tomography, and pulse echo ultrasonic scans were able to detect EDM notches as small as 125 by 125 µm and drilled holes as small as 300 µm in diameter. Intentionally seeded delamination, tow break, and insert of bagging material were easily detected in hydroburst rings by using the ultrasonic pulse echo method. Possible occurring anomalies like delaminations in polymer matrix composite layers, voids in glass layers, and resin-rich regions in the composite layers (see the following figure), were all detected by NDE and verified by metallography. The general NDE approach to ensure the quality of composite rotors and to help in the certification of flywheels is described in greater detail in reference 8.



Computed tomography detected the presence of (a) resin-rich area, which was substantiated by the photomicrograph shown in (b).

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Glenn contacts: Dr. George Y. Baaklini, 216-433-6016, Fax 216-977-7150, George.Y.Baaklini@grc.nasa.gov; and Kevin E. Konno, 216-433-8373, Kevin.E.Konno@grc.nasa.gov
Cleveland State University contact: Richard E. Martin, 216-433-3684, Richard.E.Martin@grc.nasa.gov
University of Texas contact: Richard Thompson, 512-232-1615, r.thompson@mail.utexas.edu
Authors: Dr. George Y. Baaklini, Kevin E. Konno, Richard E. Martin, and Richard Thompson
Headquarters program office: OAT
Programs/Projects: FESS, RSL