Developing Surface Characterization Maps for Microturbine Ceramic Rotors

Overview

Microturbines a few inches in diameter are critical components in compact co-generation units that produce electrical power. These modular distributed power systems are intended to operate on-site at manufacturing plants and other facilities as a source of economical and reliable electrical power, thus avoiding the high cost and vulnerability to power outage of public utility lines.

Advanced structural ceramics such as silicon nitride enable microturbines to operate at higher temperatures than conventional metal alloys, which translates into significant fuel savings and emissions reductions. However, ceramics exhibit large variations in fracture strength, particularly with inherent flaws resulting from various surface treatments. Accounting for these complex statistical strength distributions will lead to more accurate predictions of expected component life, expressed as component reliability as a function of time.

Two algorithms work in conjunction with one another to provide the probabilistic design approaches required in determining these ceramic reliability predictions: the CARES algorithm (originally developed at NASA Glenn Research Center) to determine component reliability based on temperature and stress fields and the CRT WeibPar algorithm (www.ceramicreliability.com) for determining probability of failure for ceramic components. These algorithms were upgraded under the U.S. Department of Energy (DoE) Distributed Energy Program to specifically utilize features of ANSYS Structural analysis software. As part of this DoE program administered by Oak Ridge National Laboratory, engineering consulting firm CRT utilized the software in a project for determining material requirements for a blade analysis developed for a microturbine manufactured by Ingersoll-Rand Company.

Testimonial

“ANSYS continues to be critical iterative software for design optimization and probabilistic lifing of structural ceramic components under consideration for advanced turbine engines. Ultimately, the ever-increasing versatility and capabilities of ANSYS are allowing structural designers to increase their confidence (and rate) in component designs.”

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Challenge

One of the challenges is defining and implementing a method that establishes Weibull distribution metrics for silicon nitride suppliers based on the particular component. In establishing these metrics, service stress states from the various treated surfaces of a rotor blade must be combined with a stipulated component reliability to develop material performance curves. These curves must be scaled to standard ceramic bend bar test specimens, making component requirements more readily understood by material suppliers.

Solution

Through the use of ANSYS Parametric Design Language (APDL), surfaces of a rotor component with specified finishes are identified, the ANSYS results file is queried and stresses are mapped to the relevant element surfaces. Failure data is analyzed using WeibPar. Using information generated by ANSYS (geometry and stress state), the CARES algorithm computes component reliability. The openness of ANSYS technology and the ease of integration with other software enabled the ANSYS, CARES and WeibPar programs to operate together in a smooth and efficient manner.

Benefits

The resulting design approach allows changes and improvements in system requirements to take place readily in parallel with enhancements in material properties. In the past, this typically was a series process in which system engineering would follow improvements in ceramic materials. Now material characterization maps can be generated quickly for a given component under specified operating conditions. The information can influence the goals of a ceramic materials development program and better guide engineers toward an optimal design.