The demand for more fuel-efficient turbine engines in aircraft is being driven by soaring fuel prices, unrest in oil-producing nations, global demand to save the environment, and corporate demand to cut costs. While there is immense pressure on design engineers to develop these engines, the “heat” is on test engineers to create new ways to validate component parts that will run, spin, and vibrate in hotter, harsher turbine engine environments that could reach temperatures over 2000°F.

Testing components is critical

When an engine runs at higher temperatures and pressures, it extracts more energy from the fuel, making the engine more efficient. However, extreme heat and higher running speeds put added stress on blades and rotors, which requires new classes of materials having improved performance. Engine components are subjected to stress and degradation through thermal interaction, creep, erosion, vibration, and hot corrosion.

Newer engines will create hotter, harsher environments than those in which their predecessor models operated. It is desirable to have testing options that simulate these conditions to validate the performance of critical components, especially when performance data for new materials are lacking. Isolating and controlling test conditions are critical to gather essential technical data in advance of the test phase of an engine program.

Test engineers and modelers must simulate what design engineers create to evaluate the performance of materials, coatings, and parts that will operate in the new generation of lighter weight, hotter-running engines. Test Devices is developing equipment and methodologies that better simulate real-world engine conditions (Fig. 1).

Some unique test capabilities that Test Devices offers are high cycle fatigue, radial or axial thermal gradient, radial growth, thermal mechanical fatigue, and strain surveys. The specific range and control of spin testing includes a maximum speed of 160,000 rpm with an accuracy of ±0.01% at maximum speed for overspeed testing and ±1 rpm for vibration mode (Dynamic Spin Testing). Drives for speed ranges are 20k, 30k, 40k, 60k, 100k, and 160k.

Need for material performance data

Historically, engineers and scientists have been able to refer in part to existing bodies of informa-
tion, models, test results, and field experiences as they refine and modify engine parts. But with manufacturers bringing dramatically new components, materials, and coatings to market, there is a limited body of knowledge scientists and engineers can rely on to confirm their assumptions. Some general examples of this are the introduction of nonmetallic airfoils into the flow path and advanced thermal barrier coatings. As engines run hotter and more efficient, different products of combustion and other chemicals are introduced and can be increasingly damaging in high-temperature environments. One of the best ways for developers to validate new designs, concepts, or analytic models of either new materials or designs is through rotational testing.

Managing resonant vibration of compressor and turbine blades presents a technical challenge for jet engine and industrial gas turbine (IGT) programs. Under certain conditions of operation, blades vibrate in response to pulsing flow from upstream stages. If common power settings coincide with blade resonant modes, blades can crack and fracture from high-cycle fatigue during operation.

**Spin testing**

Increasingly, engineers are using Dynamic Spin Testing to better understand and validate the life and integrity of airfoils and integrally bladed disks (Fig. 2). This testing evaluates blade resonance by simultaneously subjecting components to the centrifugal, vibratory, and thermal stresses of an operating engine. Bladed rotor components are tested fully assembled or with custom designed scaled rotors in a manner similar to how they operate in the engine. Rotor assemblies are accelerated to designated engine speeds while various excitation methods are used to produce resonant blade vibrations that simulate engine blade-to-stator interaction, producing of various bending, torsional, axial, “t-shirt,” and other modes.

Blade validation testing under these more realistic end-use conditions better simulates strain gradients, untwist, blade/rotor interaction, etc., when compared to current methods such as shaker tables and static tensile testing. Tests can be performed in ambient or high temperature (isothermal or gradient) conditions. This unique capability is beneficial as manufacturers accelerate research and development of high-efficiency engines using new innovative materials.

**Controlled testing parameters**

During Dynamic Spin Testing, high-cycle fatigue conditions can be introduced in a very controlled manner and accurately measured with nonintrusive stress-measurement systems. The test system is designed to dwell at specified resonant frequencies for 100-million cycles or more to perform Goodman Validations. By producing realistic resonant vibration, Dynamic Spin Testing accurately confirms expected modal frequencies. Precise speed control allows for very slow resonance crossings as well. This “slow sweep” capability helps to initially identify modes, distinguish between coupled modes, accurately measure amplification factors that take time to build, and determine damping (Q factors), thus allowing for very effective damping analysis and validation. Finally, the ability to hold resonance for long periods of time often results in broken blades, allowing for blade failure analysis, crack growth propagation, and validation of surface treatment and various repair methods (Fig 3).

Typical approaches to examining blade resonant behavior use shaker tables. These bench tests do not include the effects of centrifugal loads (strain gradients, untwist, blade/rotor interaction, etc.), a critical driver of blade behavior. Separate tests, in addition to shaker tables, are needed to exert thermal stress, and because each test is
conducted separately, they deliver isolated information that does not show the combined effect of heat, vibration, and centrifugal loads on a rotating part. In contrast, Dynamic Spin Testing provides focused data under more realistic engine conditions, offering a more robust, in-depth solution.

While Dynamic Spin Testing creates precise simulations, live engine testing remains the most comprehensive method of evaluation. However, it is risky and expensive, costing up to $100,000 per hour in operating and staffing charges. In addition, given the harsh operating environment and lack of accessibility, live engine testing may not provide clean data for component evaluation. An additional problem with engine testing is the danger of damage to the entire engine if an individual component should fail.

Dynamic Spin Testing provides critical performance data to speed project completion, reduces total testing costs, and lowers the risk of in-service component failure. This form of testing is becoming increasingly critical, in the rush to get new engines through certification as quickly as possible.

Dynamic Spin Testing is a registered trademark of Test Devices Inc.

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Fig. 3 — The ability of dynamic spin testing to hold resonance for long periods of time often results in broken blades, allowing for blade failure analysis, crack growth propagation, and validation of surface treatment and various repair methods.