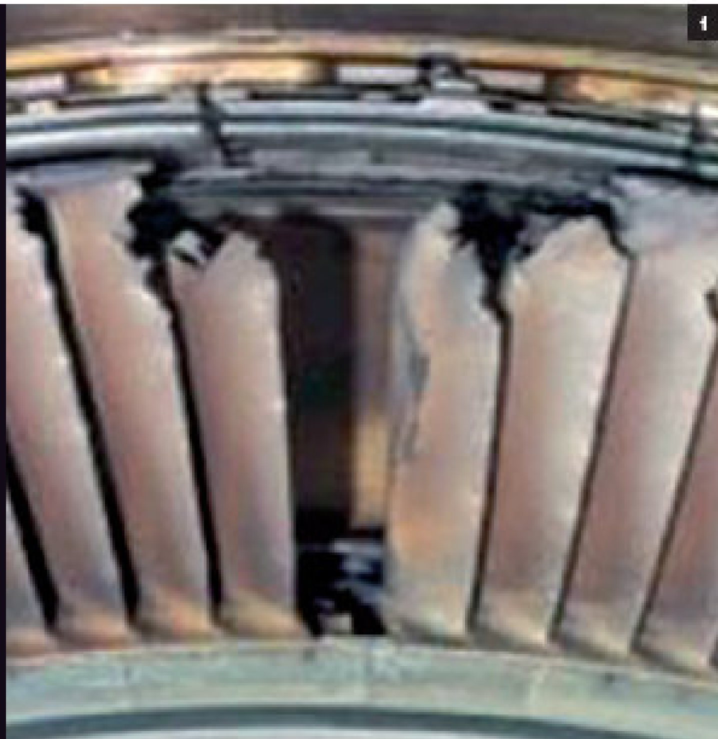

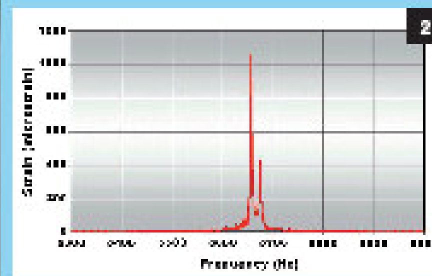

1. Engine damage caused by a blade failure

2. High amplitude blade resonant response

The spin doctor

Managing resonant vibration of jet engine rotor blades presents a technical challenge for engine programs. Under certain conditions of operation, blades vibrate in response to pulsing flow from upstream stages. When the vibration matches a natural frequency the blades can crack and fracture from high frequency fatigue, causing major engine damage. Blade failure is a serious economic problem for aircraft operators, and the US Department of Defense has reported that blade resonant failure costs US$200 million per year in engine repair and reduced availability of aircraft.

To address this issue, engine developers can modify blade, disk, and stator geometry, and introduce dampers to attenuate dynamic response. In order to evaluate resonant behavior and the effectiveness of improvements, engine builders use a variety of methods. The first of course, is computer Finite Element Analysis (FEA) to model blade vibratory behavior. This is important, but it cannot fully duplicate blade vibratory response in service because of the inherent difficulty in modeling boundary conditions or effects of manufacturing variations. Another approach is to test blade behavior on the bench using shakers and various kinds of vibrometry. These 'bench tests' do not include the effects of centrifugal loads, a critical driver of blade behavior, so frequencies and mode shapes determined with bench methods are not adequate to understand resonance in service.

Live engine testing is the most accurate method of evaluation, but engine testing is very expensive, costing up to US$100,000 per hour in operating and staffing charges. An additional problem with engine testing is the danger of damage to the entire engine if an individual component should fail. This risk of engine loss during test significantly reduces the scope of investigation and makes it impossible to explore conditions near failure.

A new approach to blade resonance evaluation, called 'dynamic spin testing' has recently been developed by Test Devices Inc to help engine manufacturers evaluate blade resonance behavior and avoid or resolve blade failure issues. Individual bladed rotors are tested in fully assembled, engine ready states. The rotor assemblies are accelerated to actual engine speeds while the blades are subjected to vibratory stress matching the stresses experienced in engine operation.

The excitation force used to produce the resonant blade vibrations simulates engine blade-to-stator interaction, which causes significant blade distortion. The thermal stresses can also be applied by performing dynamic spin tests at engine operation temperatures.

Dynamic spin testing produces realistic resonant vibration of the blades so that modal frequencies can be determined accurately. Precise speed control allows very slow resonance crossings for characterization of fully developed resonant modes and assessment of blade/damper performance. Slow resonance crossing also enables calculation of blade amplification factors for measuring the severity of various modes and the risk they present.

By including the static centrifugal stress and tailoring tests for specific rotor configurations by adjusting speed, temperature, and excitation force, dynamic spin testing provides a powerful new method for testing bladed turbine engine assemblies. It accurately evaluates the blade and damper performance of complete turbine engine stages than traditional test methods and is both less risky and an order of magnitude less costly than live engine testing.

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