Real-Time Crack Detection System

Component and tooling damage is detected before failure during low-cycle fatigue testing

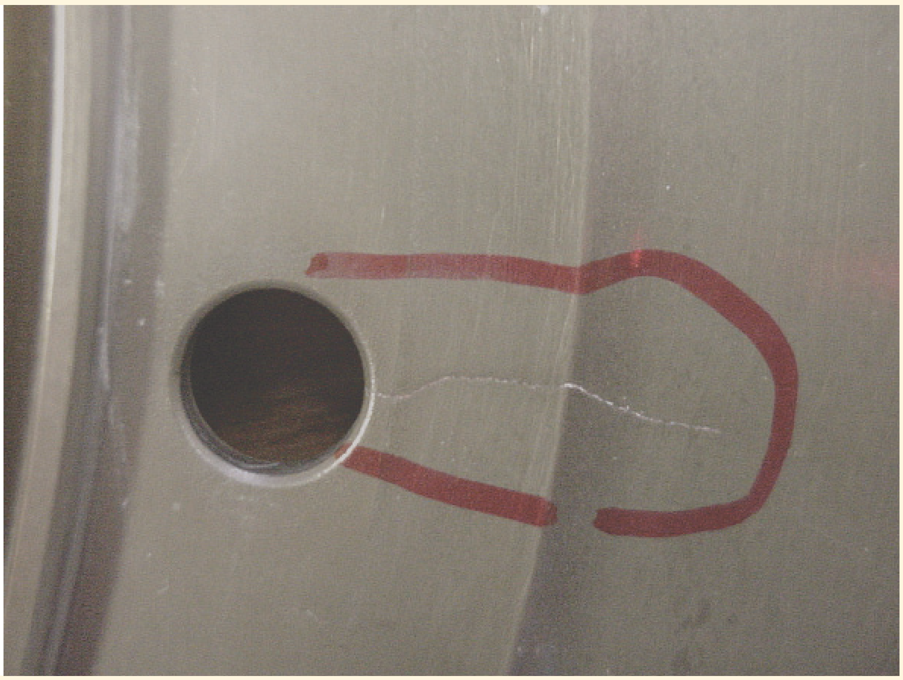

Fig. 1 — Example of a fatigue crack detected before the component failed. The test automatically stopped once the crack was detected.

The development of jet engines and other high-speed machinery requires extensive testing to establish the integrity and useful life of high-speed rotating components. A fundamental evaluation technique for turbine engine rotors is to empirically test and validate the number of cycles the rotors can withstand, either to a predetermined number or all the way to failure. This type of test is typically referred to as a low-cycle fatigue (LCF) test.

During a standard LCF test, an engine rotor component is cycled up and down in speed in a spin rig in order to validate a prescribed number of cycles. Traditionally, these LCF tests end in either successful completion of the full cycle count, or in a complete rotor burst caused by a fatigue-induced crack in the part. This often results in loss of the component and can also cause damage to tooling and other test facility equipment.

Preventing Component Destruction

In order to avoid premature component burst, either from crack formation in the component itself or the tooling (the arbor, or spindle, that holds the component in place), Test Devices, Inc. (TDI) developed a patented application known as the real-time crack detection system (RT-CDS), for detecting the initiation of cracks during LCF tests.

The crack detection system automatically detects fatigue-induced cracks during an LCF test with 80 to 90% accuracy — Fig. 1. When the beginning of a crack is detected, the system automatically stops the LCF test before component failure. This exclusive crack detection interlock capability allows an attended or unattended LCF test to be halted when components or tooling develop cracks — before a damaging rotor burst event.

Conventional LCF procedures require that the testing is stopped periodically in order to inspect for cracks in the component and tooling. This involves removing the test article from the spin rig frequently, thereby greatly extending the cost and schedule of the testing program. The real-time crack detection system can reduce the number of required inspections, thereby enabling more cycles between inspections.

Real-Time Crack Detection in a Critical Jet Engine Application

A major aerospace jet engine original equipment manufacturer (OEM) recently ran a series of low-cycle fatigue tests on a critical component, which involved the testing of multiple sets of rotors. The company contracted Test Devices and another vendor to perform testing on two rotor sets each. The RT-CDS was used for testing and monitoring by TDI, while the other vendor used a conventional LCF

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testing procedure.

The two companies began their testing at the same time. Early in the testing procedure, one of the rotors at the alternate vendor was destroyed at approximately 80% of its expected life because of a crack rupture in the spin tooling hardware. The spin test equipment incurred substantial damage.

During TDI's testing, a signature indicative of a crack was detect, and the crack detection system automatically stopped the test. The customer then performed a component ultrasonic inspection and found two cracks. Early detection by the RT-CDS prevented the destruction of the part, tooling, and equipment. If the cracks had not been discovered, the test article would have been lost without preserving the initiation site and crack face (which are critical for follow-up metallurgical analysis).

A second rotor failed at the alternate vendor after approximately 70% of its expected life as a result of an undetected crack in the OEM tooling. The RT-CDS detected and automatically stopped LCF testing of a second rotor when a crack occurred in the tooling.

The two rotors that were tested using conventional methods were destroyed as a result of fatigue-induced cracks in the tooling. As a result, the engine manufacturer lost two valuable components that could have been saved.

The RT-CDS has also been used during a low-cycle fatigue testing program for evaluating flaw tolerances in the weld plane between air foils and the rotors. Specifically, the test program was designed to evaluate the fatigue behavior of a blade replacement weld process. Crack growth and propagation of flaws in the weld plane were monitored.

Benefits of the New System

By detecting cracks in the rotors before they failed, cost savings were substantial and damage to the rotors under test, as well as the test equipment, was prevented. Time can be saved by reducing the number of periodic inspections, the number of interruptions, and avoiding time lost in replacing damaged components and equipment.

The system can also provide initiation and crack growth analysis data that gives customers the ability to determine the location, mode, and cause of a crack. The knowledge base of the fatigue life of spinning rotors and other application-critical components can be increased.

The system can be used on a variety of equipment including jet engine rotors, turbochargers, rocket pumps, electric motors, gas turbine rotors, and compressor rotors.◆