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Test Devices by SCHENCK

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.

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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 by SCHENCK 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.

Case Study: Application of RT-CDS in a jet engine disk spin test

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 Test Devices, while the other vendor used a conventional LCF 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 a re-test of the LCF cycles at Test Devices, an early onset of a crack was detected, 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 bursted without preserving the initiation site and crack face (which are critical for followup 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 without the RT-CDS were destroyed as a result of fatigue-induced cracks in the tooling. As a result, the engine manufacturer lost two valuable test parts 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.

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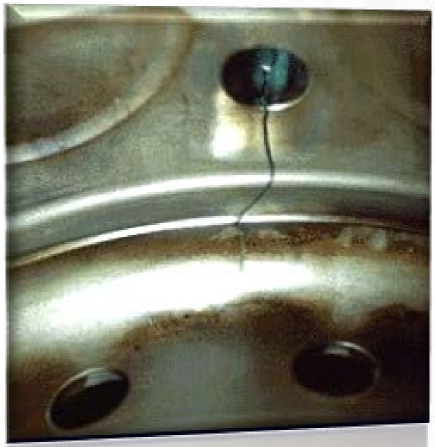
Why use Test Devices Real Time Crack Detection System?

One may argue that similar changes in the vibration trend may be observed in the raw vibration data; Test Device's experience shows that not to be the case. Unprocessed vibration data contains a mix of information from the complex mechanical interactions of the test rig and surrounding environment. Simply, the signal is noisy. Test Devices has developed an algorithm to extract the most relevant diagnostic information related to the development of rotor cracks. A good analogy to this situation is a cocktail party; your brain efficiently filters and extracts the target information (in this case, conversation) from the surrounding noise. What sets Test Devices RT-CDS apart from other less sophisticated monitoring is its ability to detect and monitor emerging rotor cracks at a much earlier phase.



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Benefits of Real-Time Crack Detection 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.

- **Faster & better test results -** The use of TD RT-CDS enables customers to halt LCF tests without destroying the test specimen. This makes the diagnosis (locating and determining the size of a crack) infinitely faster and more accurate than traditional investigative analysis following a rotor failure which requires tedious review of burst fragments to determine the failure origin.

- **Studying crack growth -** The other noteworthy application of the RT-CDS is its value in studying crack growth. The ability of the system to detect a rotor crack at its infancy allows engineer and scientists to monitor its growth from the point of detection. Determining the size and rate of crack growth requires a careful correlation of the understanding of the rotor material, damage evolution behavior and geometry. The result of the non-destructive LCF test enabled by TD RT-CDS offers a significant advantage for OEMs. This type of test capability does not only benefit the customer from a standpoint of the fatigue lifing penalty, which would be lower, but also from the value gained from a detailed understanding of the failure mechanism and damage evolution from the test data.

- **Detecting other rotor anomalies -** Since Test Devices crack detection system is designed to detect a very small change in rotor unbalance, it is also useful in detecting incipient risks associated with rotor assembly and installation errors that would not be apparent in raw vibration measurements. Those flaws could unexpectedly end a test and destroy an invaluable test asset if not detected prior to failure.