NASA TECH BRIEF

Automatic System Nondestructively Monitors and Records Fatigue Crack Growth

An ultrasonic system has been devised to automatically detect and record the propagation of a fatigue crack in a test specimen undergoing fatigue cycling. The system employs ultrasonic reflection techniques to monitor the location of the tip of a propagating fatigue crack. A piezoelectric transducer, which is water-coupled to a test specimen, generates an ultrasonic beam which is partially reflected from the crack tip, and partially reflected from a reference reflector plate which is mounted beyond the area containing the fatigue crack. The transducer's position is adjusted until the amplitudes of the signals reflected from the crack tip and from the reflector plate are equal. Growth of the fatigue crack causes an imbalance in the amplitude of these reflected signals producing an error voltage. This error voltage activates a servo-motor which moves the transducer across the specimen surface until the reflected signals are again balanced. The distance the transducer moves to balance the reflected signals is equal to the advance of the fatigue crack.

The advantage of employing a reflector plate to obtain a reference signal is that the latter is conditioned through the same environment as the signal passing to and reflected from the crack. Therefore, the effects of variables such as surface conditions, stress loading, and transducer coupling are minimized. The system does not depend on a particular signal amplitude. The required error voltage to monitor fatigue-crack propagation depends only on the difference between the amplitudes of the signals from the crack and the reference plate.

The system includes an ultrasonic transmitter–receiver (commonly used in flaw detection) to excite the transducer and display the received signals. Video and sync pulse outputs are processed through external circuits. The video output includes the voltage transmitted to the transducer and the reflected signal voltages. This video output feeds two gated switches which select the reflected signals in a prescribed time interval, thus rejecting extraneous signals including noise. The gating action is initiated from the sync pulse of the ultrasonic unit. The two reflected signals are amplified and integrated to provide an error signal to a servo amplifier and motor drive unit.

In a typical setup, a 0.125-inch-thick aluminum alloy, with a 0.156-inch-diameter-hole in the center to simulate a crack-starting notch, was used as a test specimen. A 0.125- × 0.625-inch reflector plate of the same alloy was clamped to the specimen on one side of the hole. The reflector plate extended across the width of the specimen and was ultrasonically coupled to it by a film of oil. The ultrasonic transducer unit was positioned to face the reflector plate on the opposite side of the hole and to travel parallel to the reflector plate. The transducer unit was comprised of a 0.5-inch-diameter piezoelectric crystal (5.0 MHz); a water-filled, hollow acrylic plastic block; and a servo-drive motor. An O-ring gasket was used to seal the ends of the water column which coupled the transducer ultrasonically to the specimen. The transducer was pivot-mounted so that the injection angle of the ultrasonic beam could be varied. A lead screw, which was coupled to the servo-motor through a flexible shaft, guided the transducer across the specimen.

Tests were conducted with the setup described above on a specimen in which a slot was being machined to simulate the propagation of a fatigue crack. Increments as small as 0.001 inch were detected and automatically tracked. The repeatability of the system

(continued overleaf)

was ±0.005 inch for a number of specimens tested. A slot was cut starting 0.125 inch from the hole and extending to a length of 1.000 inch, with a maximum error range of ±0.012 inch.

Note:

Complete details of this development may be obtained from:

Technology Utilization Officer
Langley Research Center
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Patent status:

Inquiries about obtaining rights for the commercial use of this invention amy be made to NASA, Code GP, Washington, D.C. 20546.

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