A COMPREHENSIVE, NONDESTRUCTIVE INSPECTION OF TURBINE BLADES AND VANES USES ACTIVE THERMOGRAPHY

RUNNING HOT

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Modern aircraft and space vehicles are complex collections of thousands of subsystems and components, all of which must function flawlessly even under the most extreme conditions. To ensure that rigorous performance standards are met, parts ranging in size from an entire aircraft wing to a small jet engine turbine blade need to be tested for quality and integrity at various stages of manufacture, and then intermittently throughout the service lifetime of the part. Traditionally, much of the required nondestructive testing (NDT) has been performed with conventional methods such as ultrasound and/or x-ray.

But for a growing number of mission-critical inspections, key players in the aerospace, defense, automotive, and power-generation industries are turning to Thermal Wave Imaging (TWI)—a small, high-tech company based in Ferndale, Michigan—for innovative thermographic NDT.

Founded in 1993, TWI designs and manufactures inspection systems that use infrared (IR) cameras, dedicated software, and hardware to measure the flow of heat through materials, creating a subsurface image of the part. In 1998, TWI received a NAVAIR Phase II Small Business Innovation Research (SBIR) contract to develop a Handheld IR Nondestructive Inspection (NDI) system for composite materials. This program led to ThermoScope®, a portable system designed to move thermography from a laboratory setting to the inspection floor. ThermoScope bridged the gap between ultrasound, a point inspection method too slow for efficiently inspecting large areas, and standard thermography, which was capable of inspecting larger areas but is qualitative, subject to interpretation, and insensitive to some defect types. ThermoScope is widely used today for NDI applications in industries that include everything from composite sporting goods to military helmets, helicopter rotor blades, and space vehicles.

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As a result of TWI's commitment to continuous improvements, in 2001 the company introduced its patented Thermographic Signal Reconstruction (TSR) method, which has been widely recognized as a breakthrough in the field.

In addition to significantly improving the flaw-detection capability of thermography, the quantitative nature of TSR enabled automation and material characterization, including precise measurement of thickness, defect depth, and thermal diffusivity in a wide range of materials. The technology played an important role in the NASA Return to Flight program after the tragic Columbia Space Shuttle accident in 2003.

In 2008, through a NAVAIR Small Business Technology Transfer (STTR) award, TWI focused on the NDI of turbine blades and vanes for aircraft engines.

Dr. Steven Shepard, Physicist and TWI President, explained, "Turbine blades and vanes are critical components in every military and commercial aircraft engine. They're built to extremely tight tolerances and they must function in a highly adverse, high-temperature environment. If they are not manufactured properly, they may fail in flight, which can have catastrophic consequences. And they have a finite service lifetime, requiring periodic replacement. It is essential that a supply of parts be available for both new and in-service aircraft."

TWI Vice President Bharat Chaudhry added, "The manufacturing process involves casting, machining, and coating operations, and every part must be inspected at every stage of the process. However, in the traditional process, each inspection requires a different NDI technology, which means different equipment, training, certification, and often different inspectors."

Bharat Chaudry, left, and Dr. Steven Shepard

The result of TWI's follow-on STTR effort was T3S®, a modular thermographic inspection station designed to measure coating or wall thickness and detect blocked cooling holes in turbine airfoils. Requiring only a single thermography-trained operator, T3S replaces and streamlines a number of conventional inspection processes, saving both time and money.

Shepard and Chaudhry saw

A TAFIS inspection station, for cooling hole blockage detection in turbine engine blades, operates on TWI's plant floor.

an opportunity to leverage TWI's years of experience working with land-based turbine parts to equivalent airborne parts, which are smaller, with thinner walls and coatings. Moreover, they responded directly to a fundamental problem for turbine blade manufacturers: the need for a modular system so that customers could purchase the specific capabilities of interest to them.

The resulting Thermal Airflow Inspection System (TAFIS®) is a fully automated robotic inspection station with modular fixturing for rapid part change-out. TAFIS is a gamechanging innovation that is being used for blockage detection in blades and vanes. It has been successfully transitioned to military use and is becoming the de facto standard for inspecting high-pressure turbine (HPT) blades and vanes for blocked cooling holes and air passages. It is currently being used on the Joint Strike Fighter (JSF) and F-22 warfighter platforms.

"The overall quality control and throughput efficiencies have reduced inspection costs by more than 50 percent across all engine platforms in the aerospace, power generation, and automotive industries," said Chaudhry. "Industry has been very responsive to the innovations that T3S and TAFIS provide. The SBIR/STTR program has been invaluable in allowing us to bring the technology forward."

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Modernization Priority: General Warfighting Requirements (GWR)

SBIR contract: N68335-98-C-0281 • Agency: Navy • Topic: N97-030, Handheld IR NDI of Composites
STTR contract: N68335-08-C-0274 • Agency: Navy • Topic: N06-T011, Comprehensive Inspection of Turbine Hot Section Blades and Vanes Using Active Thermography

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