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THERMOGRAPHIC QUALITY ASSURANCE OF TURBINE ENGINE COMPONENTS

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ABSTRACT

Although highly desirable from a cost and reliability standpoint, 100% inspection of Ni-super alloy components in the early stages of the manufacturing process has generally been regarded as overly time consuming, and ineffective at identifying subsurface irregularities in the internal structure. As a result, quality assurance is often limited in scope. To rectify the situation, we have implemented a 100% inspection system for quality assurance at Stolper Fabralloy using an active thermography system (EchoTherm, Thermal Wave Imaging, Inc.). Prior to installation, a series of tests were performed to insure that the system could meet customer requirements and match the resolution of the ultrasonic C-scan that had previously been used for QA of flat panels. As a result of these tests a calibration procedure was developed. The system is currently used to inspect flat and formed transition panels and other components using various thermal excitation methods. Operators have been trained per ASNT TC-1A Level I and II. Using the thermographic system, we have successfully identified defects including inter-layer disbonds and cooling channel blockage. The system software allows us to simultaneously view and analyze the results for an entire transition. Total inspection time has been reduced by an order of magnitude, to 30 minutes for a 2' x 3' transition.

Keywords: NDI, thermographic, cooling channel, transition, disbond, HIP, braze, TSR

INTRODUCTION

Over the last decade, growth in worldwide demand for electrical power has resulted in a consistent increase in installations of land-based turbine systems. However, the high cost of a new turbine installation, coupled with the severe internal operating conditions and the negative consequences of an outage have resulted in a growing emphasis on preventative maintenance and Nondestructive Inspection (NDI) of the equipment. The same factors have led power generation OEM's and their primary suppliers to understand the importance of maintaining the highest possible levels of quality control in the manufacturing process, as warranty costs associated with replacement or repair quickly undermine profitability. Unfortunately, it has been difficult to reconcile the need for high precision NDI of turbine components with the materials, structures, throughput, and economics of the industry. As a major supplier of turbine components to several OEM's, Stolper-Fabralloy has been aggressive in our ongoing attempt to maintain the highest quality standards. In this paper, we will describe our experience with Thermal Wave Imaging, an NDI approach we have implemented which has allowed us to improve component quality, while reducing costs and increasing throughput and reliability.

THERMAL WAVE IMAGING OF TURBINE ENGINE TRANSITIONS

Transitions (Fig. 1) are an integral part of the combustion section (stage 3) of a turbine engine. Since the actual burn process occurs in this section, components run hottest and hardest, and robust design is essential for service longevity. There are a variety of transition designs based on the OEM and specific model offerings. One such design employs a three-layer nickel super alloy body. The outer and inner layers are solid while the middle layer has channels machined into it. These layers are bonded together either by brazing techniques or hot isostatic pressing (HIP). The channels in the middle layer serve as cooling passages to keep the operating temperatures of these components below their melting point when running in environments where temperatures are typically greater than 2000ºF. During the manufacture of transitions, the quality of the joining process (braze or HIP) of the layered panels may vary for a number of reasons, including contamination, improper application of the bond coat, or variations in other process parameters. The most serious instances result in inter-layer disbonds that can ultimately lead to component blowout and in-service failure.

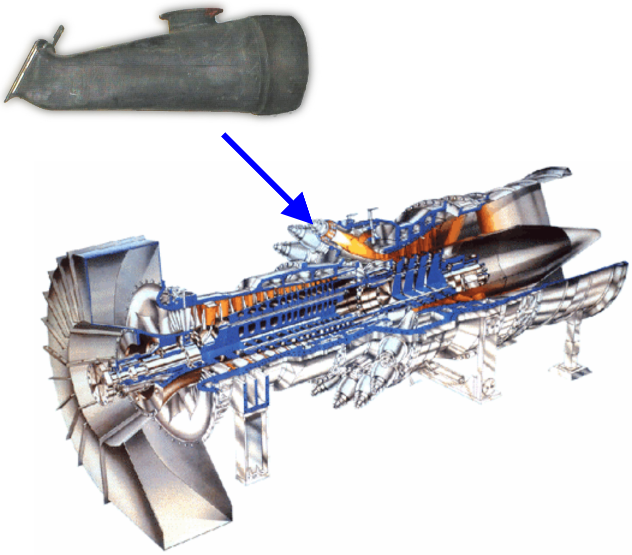

Fig. 1: Turbine Engine Transition

Inspection of transitions in the production cycle has typically been challenging. Since even small subsurface disbonds can weaken the structure under operating conditions, high-resolution inspection covering the entire component surface is required. Thus, single point NDI methods that only sample the part (e.g. ultrasonic A-scan) are not acceptable. Although ultrasonic C-scan can cover the entire surface, it requires immersion of the component into a water tank, and requires long inspection times that slow down production. X-ray inspection provides extremely high resolution of the cooling channels, but is not particularly sensitive to interlayer disbonds, and requires installation of special facilities.

Pulsed thermographic inspection, also known as Thermal Wave Imaging, provides an attractive alternative to traditional NDI methods for transitions (Fig. 2). It is fast, non-contact, curvature tolerant, and environmentally benign. In the basic process, the surface of the component is heated with a brief (~ 2 msec) light pulse, while an infrared camera monitors the surface temperature response of the part. The IR camera signal is collected and processed by an integrated computer system, and an image of the subsurface structure is generated. We have implemented an integrated commercial system (EchoTherm®, Thermal Wave Imaging, Inc.) specifically for transition inspection. The system handles excitation, acquisition, data analysis and archiving of results.

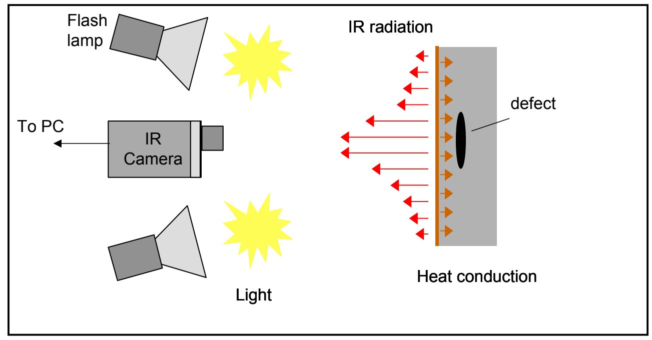

Fig. 2: Schematic of the Thermal Wave Imaging process

In addition, it achieves significant signal to noise improvement, compared to the raw output of the IR camera, through a process known as Thermographic Signal Reconstruction (TSR), in which the time history of each pixel (comprising data from several hundred individual frames) is represented as an equation that is free of temporal noise (Fig. 3). This equation can be easily manipulated to create derivative images and depth maps with extremely high spatial resolution and depth sensitivity.

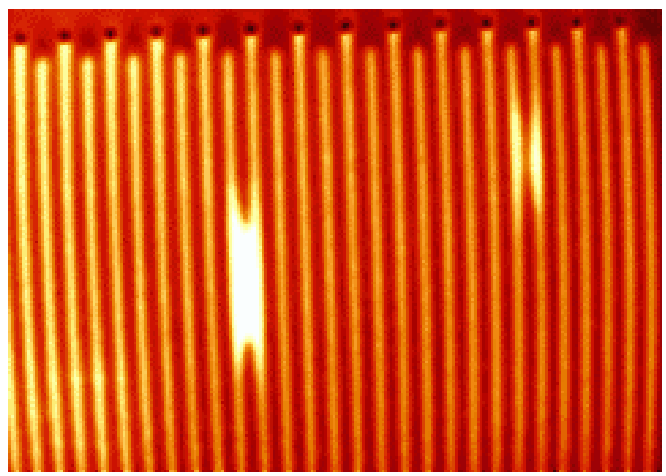

Fig. 3: TSR picture of disbonded cooling channels

The Thermal Wave Imaging inspection process has reduced inspection times nearly 10 fold compared to the ultrasonic C-scan method we used previously. Defective regions on components are identified early on in the production cycle and repaired in a timely fashion (Fig. 4). Quantitative measurement capability has allowed operators to make pass/fail calls in real time based on maximum allowable defect size criteria specified in their quality manuals. Data may be easily stored and archived in electronic format and can be readily recalled and reviewed at any time if required.

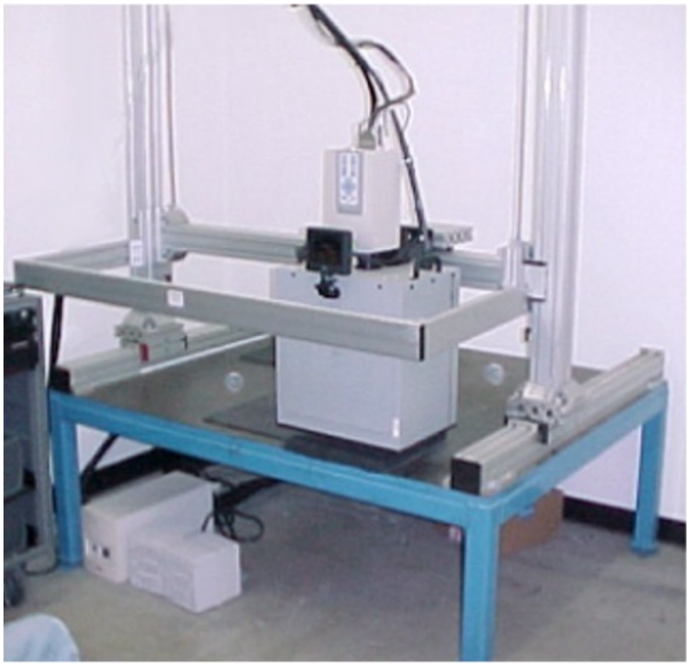

Fig. 4 – Thermal Wave Imaging XYZ Gantry for inspection of transition panels

ACKNOWLEDGMENTS

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