A third generation robotic Eddy current system for the inspection of gas turbine engine components

Tercera generación robótica por corrientes Eddy para la inspección de los componentes de turbinas de motores de gas

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Abstract

Implementation of damage tolerance requires the characterization of nondestructive evaluation (NDE) capabilities in terms of the probability of detection as a function of flaw size. Quantification of NDE procedures is essential to provide both a confidence level in detection of required flaw sizes and in establishing periodic inspection/maintenance events as a function of part usage. Gas turbine engine components (aircraft engines) are highly loaded and critical the safe-life/operation of an engine. In general, detection of small flaws is required to provide the maximum mean time between inspection cycles and thus contribute to most economical engine operation. Reliable detection of small flaws in engine components has been demonstrated by precision eddy current inspection procedures. The procedures were implemented using a precision robotics scanner and various eddy current probes and scanning sequences. The eddy current system elements were integrated into scanning sequences to provide a quantitative, fully automated inspection of critical areas of engine components. The integrated system is identified as the RFC (Retirement for Cause) system and has been extensively applied to the inspection of rotating gas turbine engine components throughout the world. Since the introduction of the system in 1979, additional engine components and inspection features have been added to provide support of various engines types and to extend the life of aging components. The most recent system improvements have been an improved eddy current instrument, improved robotics controller and added computing and electronic communications capabilities. This paper described the retirement for cause system management principles; the RFC Eddy current system development and application; and the recent improvements to increase capabilities and reduce both system cost and system operating costs.

Key words probability of detection, nondestructive evaluation, flaw, inspection, maintenance, gas turbine engine, eddy current, robotics controller

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Resumen

La implementación de la tolerancia al daño requiere la utilización de las capacidades de evaluación no destructiva (END) en términos de la probabilidad de detección como una función del tamaño del defecto. La cuantificación de los procedimientos de END es esencial para proporcionar tanto un nivel de confianza requerida en la detección de los tamaños de defecto como en el establecimiento de eventos periódicos de inspección/mantenimiento en función del uso de las piezas. Los componentes de los motores de turbina de gas (motores de aeronaves) son altamente complicados y son críticos la seguridad y en la de vida de funcionamiento de un motor. En general, se requiere la detección de pequeñas fallas para proporcionar el tiempo medio máximo entre los ciclos de inspección y así contribuir al funcionamiento más económico del motor. La detección fiable de pequeñas fallas en los componentes del motor ha sido demostrada mediante procedimientos de inspección de corrientes parásitas de precisión. Los procedimientos se implementaron utilizando un escáner de robótica de precisión y varias sondas de corriente de Foucault y secuencias de escaneado. Los elementos del sistema de corriente de Foucault se integraron en secuencias de exploración para proporcionar una inspección cuantitativa y totalmente automatizada de áreas críticas de los componentes del motor. El sistema integrado se identifica como el sistema RPC (Retiro por Causa) y se ha aplicado extensivamente a la inspección de componentes de motores de turbina de gas rotativos en todo el mundo. Desde la introducción del sistema en 1979, se han añadido componentes adicionales del motor y características de inspección para proporcionar soporte a varios tipos de motores y para prolongar la vida útil de componentes viejos. Las mejoras más recientes del sistema han sido un mejor instrumento de corrientes parásitas, un controlador robótico mejorado y capacidades agregadas de computación y comunicaciones electrónicas. En este trabajo, se describieron los principios de gestión del sistema de RPC; el sistema desarrollado y la aplicación de corrientes de Eddy para el RPC; y las recientes mejoras para aumentar las capacidades y reducir tanto el costo del sistema como los costos operativos del sistema.

Palabras clave: probabilidad de detección, evaluación no destructiva, falla, inspección, mantenimiento, motor de turbina de gas, corriente de Foucault, controlador de robótica

Introduction

Early gas turbine engines have a very short operating life between overhaul/ maintenance cycles. Both economic and operational readiness requirements have demanded and every increasing operating life (mean time between overhaul). Structural deficiencies were a primary cause of failure. Improvements in design, materials and maintenance practices greatly increased the operational life, but were limited by knowledge and methods for anticipating service induced initiation and growth of flaws. The advent and introduction of fatigue and fracture mechanics as design and life- cycle management tools offered substantial improvements in life predictions and substantial improvements in both safety and operational reliability. A key to implementation of fatigue and fracture mechanics was the development of quantitative inspection capabilities (Berens, 1992).

In the United States, the USAF Material Lab (Man Tech Division) assembled a team of experts and funded a program to develop a state of the art inspection system in October of 1981. This system is known as the Retirement for Cause system and was awarded to System Research Laboratories Inc. (now VEDA Corporation). The initial program challenge was to reliably detect small (0.005 by 0.010 inch) cracks in parts that were being returned for overhaul or replacement. Without the inspection system, parts that had exceeded their 1,000-hour design life were retired to minimize the possibility of a catastrophic failure in flight. When confidence was gained with the new RFC inspection system, parts could be returned to service for an additional 1,000 hours and beyond with substantial savings in parts replacement.

The RFC Inspection System

The RFC system was conceived as a fully automated inspection system that could be operated by mechanics in the engine overhaul facilities. Extensive subcomponent development and testing were completed to assure that the basic inspection capabilities could be met. The subcomponents were then integrated into the automated system and further system level testing and validation was completed before each inspection sequence (scan plan) was accepted for production application. These practices and disciplines have extended to all subsequent system versions and improvement packages.

The resulting RFC Eddy Current Inspection System (ECIS) was a computer -controlled eddy current inspection station with standard communication interfaces, and extensive computer capability. Mechanical scanners provide a 7-axis automated scanning of complex engine part geometries; automated probe positioning and changing to enable inspection of multiple features; and set-up "Standardization" reference artifacts for automated NDE set-up and diagnostics. The RFC system was originally applied to the USAF F-100 engine and provided cost savings that far exceeded the development costs.

The system provided inspection of simple geometries (holes, radius areas, slots, etc.) in initial applications, but has been extended to complex geometries and part types. The flexibility in growth has been enabled by the precision of the system robot and by the addition of articulated probe assemblies. The success for the program has resulted in extension to other engines (both military and commercial) and the incorporation of improvements to implement new technology and improved system components. Figure 1, shows a Version 3 system with an engine disk in the inspection fixture.

Figure1. A Version 3 Retirement for Cause (RFC) Inspection Station

The system has been continually improved to implement new technology and to accommodate additional engine components and features. The common feature of all versions and operational sites has been independence from operator variations. In all systems, the operator loads the component on the inspection fixture; enters the part identification (part number, etc.) and related maintenance service information; activates the system; and then visually monitors the progress to assure that "calibration" is completed in a reasonable time. He continually monitors for probe damage; and general progression of the inspection task. When the inspection is complete, a report is printed out and the data up loaded into an archival database (characters of machine). Inspection malfunction is generally due to part preparation – cleanings, wear, etc. Experienced operators anticipate the system requirements and station parts that have been accepted by visual and dimensional inspection. Figures 2 shows probe positioning on an engine component.(Rummel, 1992).

Figure 2. Probe positions on an engine component

Furthermore, Figure 3 shows multiple RFC stations at an engine overhaul facility the station hardware has been reduced to a single with a resulting increase in capability, increase in operating speed / through-put; and reduces system cost. All features and capabilities of previous versions have been retained.

Figure 3. RFC inspection stations operating at an engine overhaul facility

Figure 4 shows the elements of the Version 4 system and the inspection record out-put.,

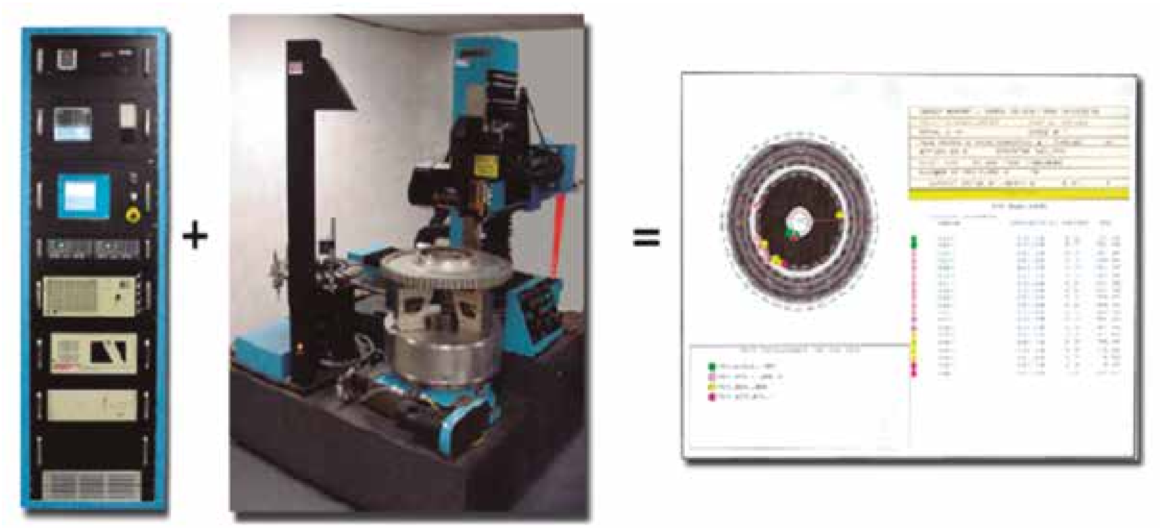

Figure 4. The single bay (Version 4) RFC system

Conclusions

The Retirement for Cause system is a unique, fully automated inspection system with flaw detection capabilities that exceed other known systems. The result of a skilled and specialized team from industry and government that was focused on a specific maintenance capability and requirements. Implementation of the system has generated significant benefits to users in the form of: increased engine availability, fewer engine spares required, increased engine reliability. Additionally, on a single engine, $1 billion overhaul cost savings have been projected / realized for a 25:1 return on investment.

The system has undergone continual improvement and upgrade to implement new technology decrease system cost and decrease operating cost. Systems have been implemented at various locations around the world and have increasing interest in both military and commercial applications. The system and technology implemented on the system is anticipated to be a continuing part of gas turbine engine life-cycle maintenance for high performance engines in future service.

References

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