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THE DEVELOPMENT AND TESTING OF A GAS TURBINE ENGINE FOREIGN OBJECT DAMAGE (FOD) DETECTION SYSTEM

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ABSTRACT

This paper details the development of a prototype in-flight foreign object damage (FOD) detection system through various stages, resulting in a system capable of detecting objects as small as one gram (1g) mass. The system comprises an eddy current sensor based tip timing system and acoustic emissions vibration sensors controlled through a digital signal processor (DSP).

QinetiQ have developed light weight, contamination-immune eddy current tip timing sensors for use in engine health management. Engine tests confirmed these sensors' potential for detecting FOD events. FOD detection algorithms were developed and implemented in a prototype DSP that was built and tested on an uninstalled gas turbine engine. The trials showed that the prototype DSP FOD detection system could detect dynamic FOD events at full engine speed.

Further work was carried out to enhance the FOD detection system, overcoming limitations in the previous system through the implementation of enhanced algorithms and its extension to accept four eddy current sensor inputs as well as a vibration signal input from an acoustic emissions (AE) sensor. An algorithm that computes engine speed from the tip timing data was also implemented to alleviate the need for a separate 1/rev signal.

A number of engine trials were successfully completed in order to validate the system. The speed algorithm has been successfully validated on engine trials and comparisons with a conventional optical based 1/rev showed the DSP-generated 1/rev signals to be almost identical to the conventional system. Typically, the error was in the region of 0.03% speed.

The investigations culminated in a test series designed to ascertain the system's sensitivity to foreign object impacts. These demonstrated that the system was capable of detecting

objects down to one gram (1g) mass introduced at low speed into the engine intake.

INTRODUCTION

With the continuous drive for modern aircraft to have lower whole life cycle costs, increased monitoring of engine components during operation is required in order to detect potential failures and to avoid unnecessary down time.

High cycle fatigue has a major impact on fleet availability, safety and whole life costs and yet, today, no instrumentation is available to monitor blade vibration levels on in-service engines. Detection of unusual blade vibration levels caused by damage or foreign object impact gives additional information to inform the post flight inspection, repair and replacement process.

Foreign object damage is a major concern to both engine manufacturers and aircraft operators and can lead to engine damage causing loss of performance or efficiency and occasionally catastrophic failure. FOD detection systems fall into two main categories: those which scan airport runways, such as the Tarsier® system [1] and engine mounted systems. Engine mounted systems include stress wave detection systems as described by Board et al [2] and a Hall effect sensor system as described by Bridges et al [3]. This system utilizes the change in amplitude of the blade passing caused by FOD changing the magnetic signature of the magnetized blades. There is also the engine mounted radar system of Shephard et al [4]. The authors were unable to find other references to on-engine tip timing based FOD detection systems; however, tip timing is utilized in the disk crack detection system of Von Flotow [5].

QinetiQ have developed a light weight, contamination-immune eddy current tip timing sensor for engine health management [6]. This sensor, by measuring the arrival time of