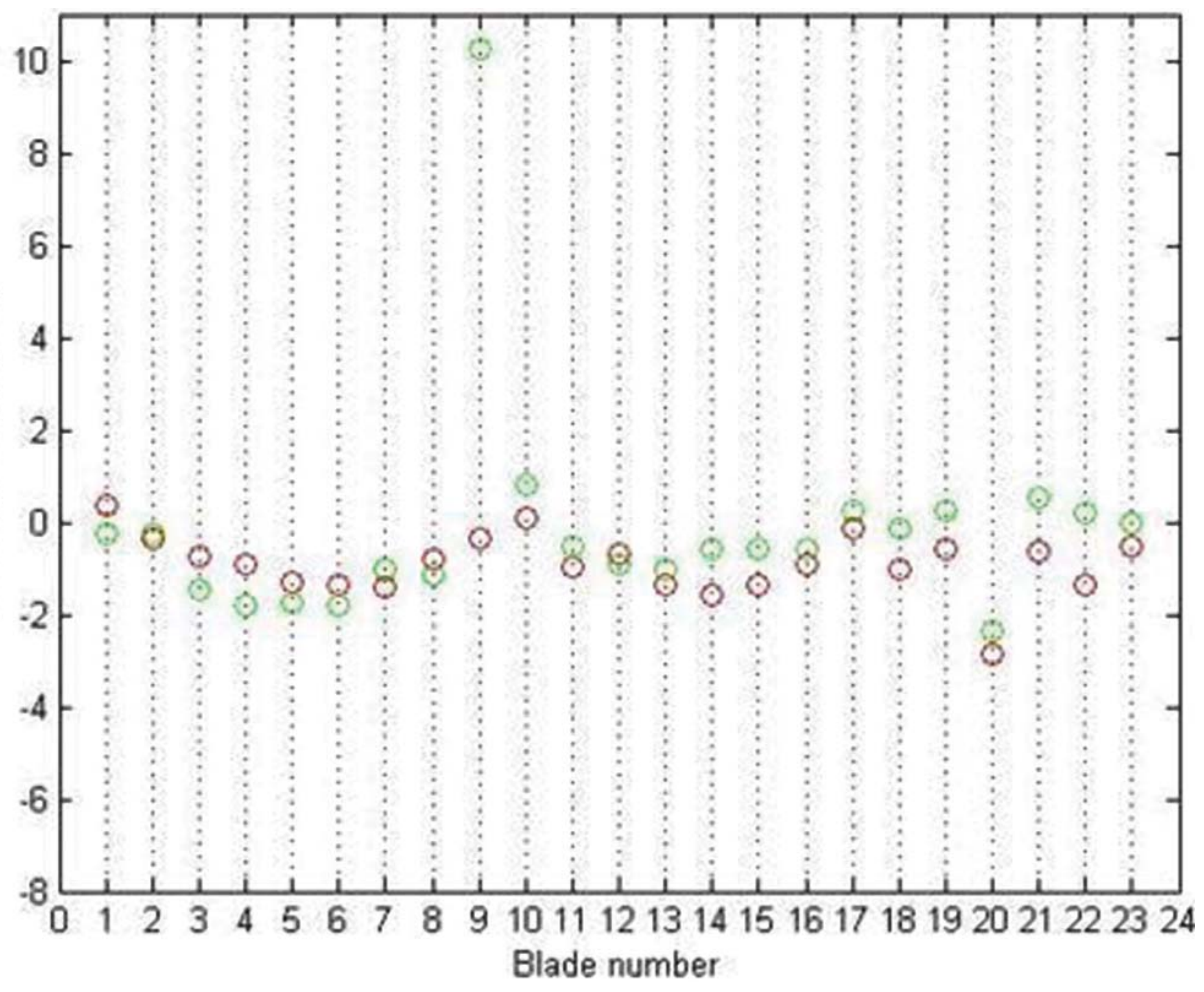

Figure 4: Average (red) and single rev (green) blade deflection.

Furthermore a comparison of optical sensor and eddy current sensor BTT data[1] showed each to be almost identical in quality, even into the high frequency regions. It had previously been thought that the poor frequency response of eddy current sensors compared to optical sensors was a limiting factor in their use in tip-timing measurements.

These results show that the T^3 eddy current sensor can acquire highly reliable blade timing data for use in engine condition monitoring and the detection of FOD-created damage and of FOD damage as it occurs.

[1]D Cardwell and K Chana: 'The Use of Eddy Current Sensors for the Measurement of Rotor Blade Tip-Timing – Sensor Development and Engine Testing.'

About the T^3 Eddy Current Sensor and Driver

Driver unit enclosure:	62.5 x 29.5 x 78.8mm; weight: 0.2kg.
Standard sensor dimensions:	12mm (d) with 25mm diameter mounting flange x 16.5m (h) including 8mm mounting flange.
Driver operating temperature range:	-20 to 85°C.
Sensor operating temperature range:	-20 to 250°C (continuous); -20 to 300°C (intermittent).
Applications:	Monitoring blade health in gas turbines, helicopters, aero engines; gear teeth for cracks and breaks; shafts for twists and eccentricities.

About Monitran Technology

Monitran has been a leading supplier of vibration, displacement and proximity monitoring equipment for over 20 years. During that time the company has established itself as an expert in the field and acquired an unrivalled reputation worldwide for the high quality and reliability of its products.

Now the founders of Monitran have set up Monitran Technology: a new venture that seeks to explore and exploit the growing demand for advanced sensor technology in a wide range of industry sectors – particularly where a substantial element of research and development or joint venture is involved.

Initial projects have made use of recent advances in eddy current technology, while future plans include the enhancement of Monitran's ever-popular range of accelerometers.

MONITRAN TECHNOLOGY LTD

Tel: +44 (0)1494 816569 Email: info@monitran.com Registered in England No. 2054040
Fax: +44 (0)1494 812256 Web: www.monitran.com VAT No: 9B442 4883 40

AERO ENGINE TESTS CONFIRM T^3 PERFORMANCE IN FOD DETECTION

Extracted from: THE USE OF EDDY CURRENT SENSOR-BASED BLADE TIP-TIMING FOR FOD DETECTION by KS Chana and DN Cardwell, QinetiQ Ltd Presented at ASME Turbo Expo 2008: Power for Land, Sea and Air

The Monitran T^3 eddy current sensor, jointly developed with QinetiQ Ltd, has undergone stringent trials as an in-service tip-timing measure of turbo-machinery blade vibrations in aero engines using non-contact systems.

Test results confirmed that the T^3 can acquire high quality blade timing data for use in engine condition monitoring and the detection of foreign object damage (FOD) as it occurs.

This is a significant development as rotor blade deterioration through FOD such as bird strikes, erosion by sand/water or low and high cycle fatigue all limit blade life, but cannot always be detected before a failure. Better operational monitoring of engine components with the T^3 will allow changes in blade vibration modes and levels to be detected, with corresponding improvements to the inspection, repair and replacement process.

Background

There is a continuous drive for modern aircraft to fly further and faster, and have lower whole life cycle costs.

High cycle fatigue is a major impact on fleet availability, safety and whole life costs, and is often associated with increases in aerodynamic forcing caused by blade damage. This is exacerbated, in turn, by there being no instrumentation currently available to monitor blade vibration levels on in-service engines.

Increasing engine component monitoring during operation is therefore key to reducing maintenance as it will detect potential failures and avoid unnecessary down time.

Yet, currently, the only useable monitoring system is optics based and applied solely on development engines, because vulnerability to contamination makes it impractical for in-service use.

MONITRAN TECHNOLOGY LTD

Tel: +44 (0)1494 816569 Email: info@monitran.com Registered in England No. 2054040
Fax: +44 (0)1494 812256 Web: www.monitran.com VAT No: 9B442 4883 40

Assessing Blade Vibration

The most advanced and widely used technique in assessing blade vibration in engine development testing is blade tip-timing (or non-contact strain measurement).

Blade tip-timing is typically measured by optical sensors mounted in the blade casing assembly. Here they record the blade's motion by focusing a narrow laser light beam on to the passing blade tip and reflecting it back to a photo sensor. Measurements are taken towards the leading edge of the blade tip for maximum sensitivity.

The time taken for a particular blade tip to reach the optical sensor – the blade arrival time – is dependant on the rotational speed of the blade. Any vibration will affect a blade's arrival time and be measured accordingly.

About the Tests

Tests on the T³ eddy current sensor have found it can provide robust, easy to deploy blade tip-timing measurements.

Results are comparable to an optical tip-timing sensor – without the contamination issues – while the associated electronics employed enable use on in-service engines, improved sensor life, higher temperature capability and better spatial resolution than is currently available with non-optical sensors.

The tests were conducted on the first and second stage fan rotors of a Spey RB 168-101 engine in an open-air test facility based at QinetiQ Shoeburyness.

They were designed to:

- Evaluate the T³ eddy current sensor's ability to measure blade deflection and vibration in in-service engines.
- Measure the T³'s detection of simulated FOD (the deliberate damage of some rotor blades), and of dynamic FOD such as the release of small stones into the engine inlet.

Seven T³ eddy current sensors were machined into the Spey fan casing above the first and second stage rotor rows with five optical sensors interleaved with the eddy current sensor positions.

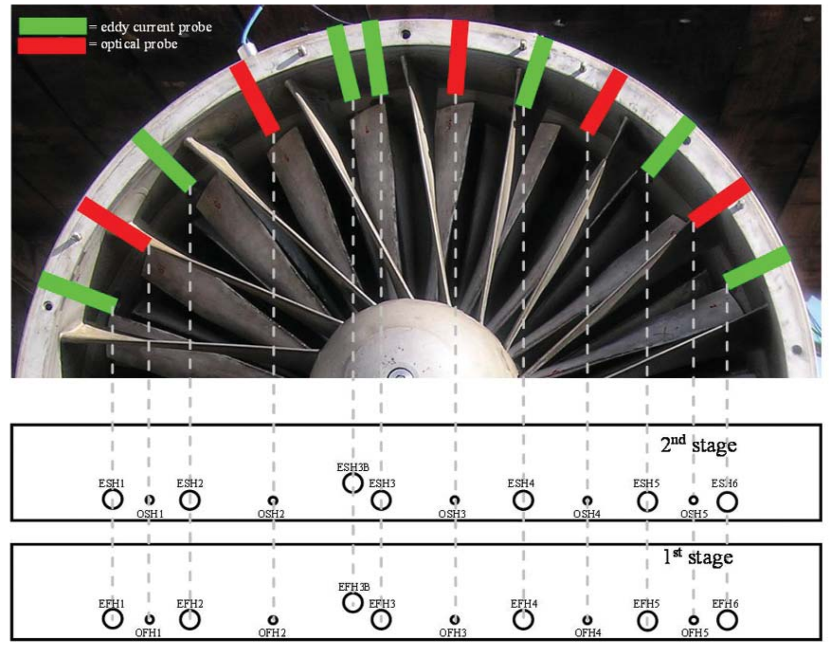

Figure 1: Position of eddy current and optical sensors on the Spey fan casing

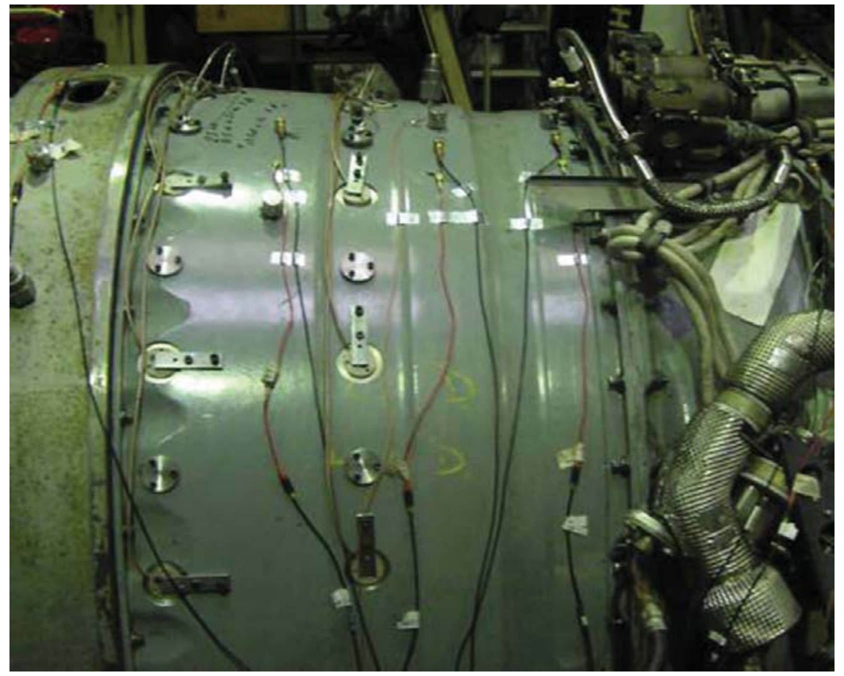

Figure 2: Eddy current and optical sensors fitted to the Spey fan casing

Their respective performance was measured across a number of engine runs starting at an idle speed of 2,300 rpm with accelerations to 8,000 rpm.

All the eddy current sensors successfully survived the engine running demonstrating high mechanical integrity, immunity from contamination and sufficient robustness to be used without any form of metallic shielding.

In the simulated FOD tests, averaged blade passing data showed the sensors capable of detecting changes in blade position resulting from damage, thereby helping to record fluctuations in blade behaviour.

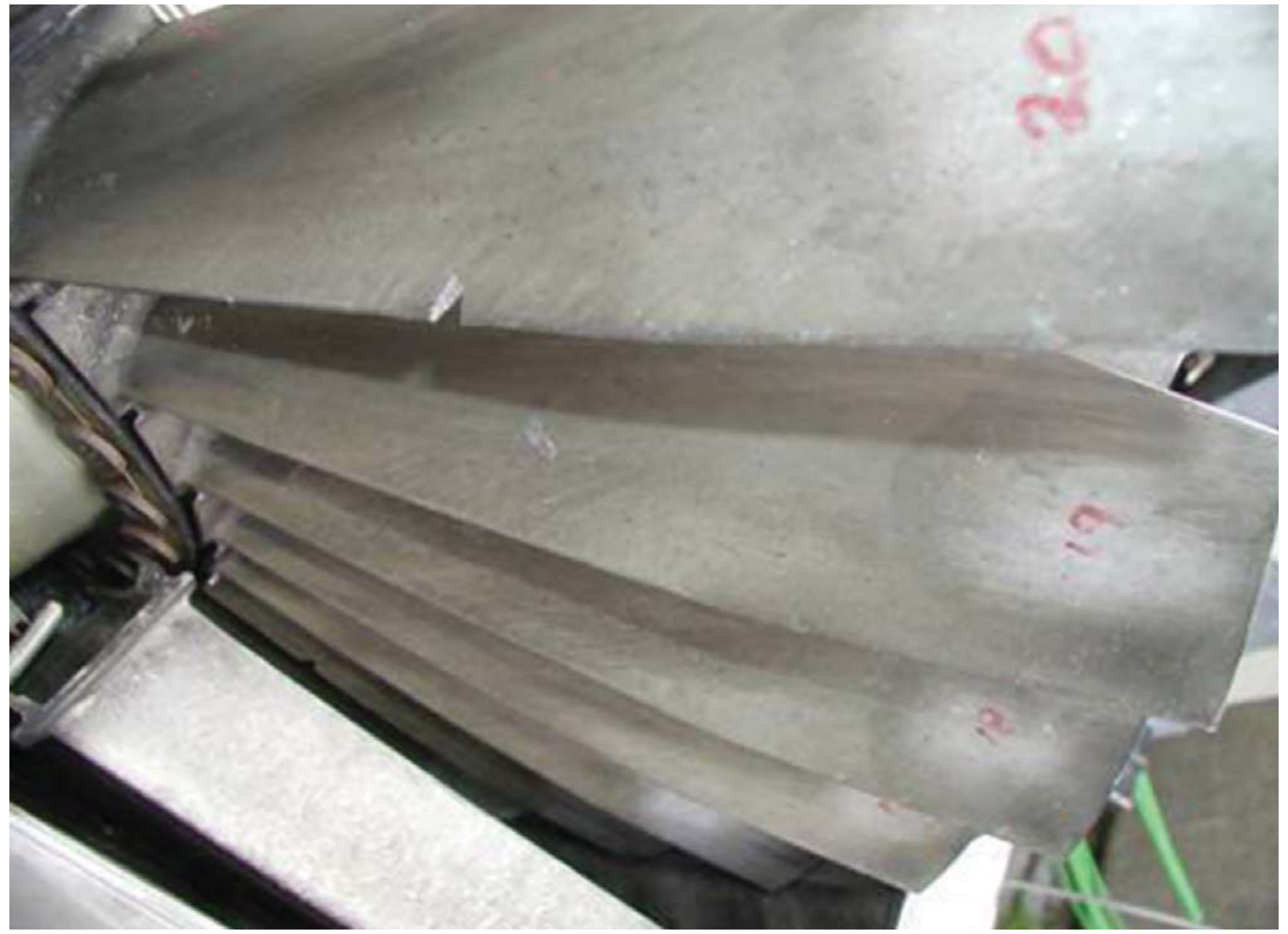

Figure 3: Simulated FOD on blade number 20. This was damaged in mid height on the leading edge with a 'v' cut.

In the dynamic FOD tests, both soft and hard FOD impact events were successfully captured with the tip-timing system revealing both the impact and subsequent behaviour of the affected blades. Figure 4 records the effects of using a stone as a FOD item, in particular the average and instantaneous deflection at the point of impact.