On-Wing Ultrasonic Phased Array Inspection of Trent Fan Blades

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* With thanks to Dr Christopher Lane
Company Profile

Rolls-Royce is a pre-eminent, global engineering company, focussed on providing world-class, integrated power and propulsion systems.

We support our customers through a world wide network of offices, manufacturing and service facilities.

Rolls-Royce currently employs around 50,000 people over 46 countries.

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Our Businesses

CUSTOMERS

Civil Aerospace
Power Systems
Defence

GROUP BUSINESS SERVICES (GBS)

INNOVATION HUB

Lean HEAD OFFICE

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In-Service NDT

• Ever increasing demand for *in-situ / on-wing* inspection solutions for maintaining engines as serviceable.
• Naturally more complex in terms of design and deployment.

**Benefits**

• Fast, cost effective inspection solutions
• Reduces shop visits
• Enables efficient fleet management
• Reduces cost & disruption for our customers

**Challenges**

• Often no direct access to the defect
• Miniaturisation
• Maintaining accurate probe positioning
• Repeatable probe scanning
• High sensitivity inspection

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LP Compressor Stage 1 Fan Blades

20-26 Fan Blades

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Fan Blade Cracking

- Potential for cracks to initiate in the internal girder structure.
- Can propagate and eventually lead to blade failure.
- Requirement for a reliable sub-surface NDT inspection method.
Fan Blade Inspection – C-Scan

- Ultrasonic immersion technique using XYZ tank system.
- Well established, successful inspection over several decades.
- Relatively slow inspection times – Approx. 1hr per blade.
- Requires blades to be removed from the engine and transported to maintenance facilities.
Fan Blade Inspection – Phased Array

- Ultrasonic Phased Array system with on-wing capability.
- Potential alternative to current C-Scan method.
- Significantly reduces service disruption and maintenance burdens for our customers.
## Inspection Capability

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<th>C-Scan</th>
<th>Phased Array</th>
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<tr>
<td>Inspection Sensitivity</td>
<td>Equivalent</td>
<td></td>
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<tr>
<td>Inspection Speed (per blade)</td>
<td>1 hour</td>
<td>20 minutes</td>
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<td>Equipment Costs</td>
<td>£160k</td>
<td>£50k</td>
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<td>Portability</td>
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Technical Development

- Design of an optimised array probe using simulation models.
- Manufacture of array probe including a novel flexible wedge.
- Design and manufacture of bespoke scanning frame.
- In-house code written to optimise the array controller setup.

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Inspection Strategy

• The array probe emits a high frequency, longitudinal sound wave into the flexible wedge.
• The wedge couples the ultrasound to the fan blade panel where it mode converts into a 45° shear wave.
  • Any defects provide a corner reflection back to the probe for interpretation.
Inspection Strategy

- Pulsing groups of elements in the array allows electronic scanning along its length to build up an image of the inspection area.
Inspection Strategy

- The ultrasonic beam is electronically scanned across the array >200 times per second.
Ultrasonic Display
Probe Positioning

• The array probe is manually scanned down the length of the fan blade.
Probe Positioning

- The array probe is then indexed across the blade to achieve the required inspection coverage.
Scanning Frame

- Root-end Clamp
- Probe holder
- Ultrasonic probe
- Scan arm
- Encoder
- Scan rail
- Carriage
- Tip-end Clamp
Scanning Frame

- Probe holder
- Arm holder pins
- Index pin
- Scan arm holder
- Scan rail
- Carriage
- Scan arm
- Ultrasonic probe
Fan Blade Holder

- Off-wing inspection
- Training / Practice
- Examinations
Inspector Training and Approval

• Ultrasonic Level II as per EN4179/NAS 410 or alternative:
  – 80 hours classroom training.
  – 800 hours supervised practical training.
  – Passed theory, specific and practical examinations.

• Minimum of 8 hours of specific training:
  – 3 hours classroom training.
  – 5 hours practical training.

• On-Wing practical examination.
Inspection Validation

- 5 external UT Level II inspectors received specific training.
- Each inspected 10 fan blades on-wing in a blind trial.
- 2 blades contained artificial defects - EDM notches.
- All defects had to be detected with no false calls.
In-Service Inspections

- **107** engines inspected on-wing in first 7 months.

- **£4.9m** total cost saving as alternative to C-Scan.

- Enabled **compliance** with Airworthiness Directives.
Conclusions - Current Position

• 5 years of successful operation with over 50 customers.
• Growing customer base.
• High level of defect sensitivity demonstrated.
• Working on adaptations for similar applications.
Conclusions - Future Developments

• Generic probe design → minimal adaptation required for other hollow titanium fan blades.
• Enhanced sensitivity.
• Potentially suitable for the detection of delaminations in composite fan blades.
Pioneering the power that matters