Advanced Composite Damage Identification, Inspection and Repair for Engine Components

Tim Mathis Director of Engineering, Components

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Agenda

1. StandardAero Components Overview
2. Evolution of Metallic Component Repair to Composites
   Component Repair
3. Overview of Polymer Matrix Composite (PMC) Inspection & Repair
4. Overview of Ceramic Matrix Composite (CMC) Inspection & Repair
5. Questions
StandardAero Overview

- $1.7B+ in annual sales
  - 85%+ engine MRO related
- 3,700+ team members
- #1 or #2 market share on majority of engine platforms we serve
- OEM aligned on all platforms

StandardAero Component Services

- Cincinnati, Ohio (250,000 ft2)
- 400+ employees across 3 shifts
- 5,000 engine part repair capabilities
  - Many dedicated OEM repairs
- 70,000 repair capabilities
- 35,000+ parts repaired/year
- 15-21 day TAT
- Dedicated repair development cell
- “One stop shop” capabilities on everything but blades & vanes
Composite Technology evolution is here today

Boeing’s 787 and the Airbus A350 are now made up of more than 50 percent composite material versus the Boeing 777 at 20 percent composites

Powerplant components moving from composites panels to composite structures

Repair techniques move from weld repairs and dimensional restoration to precision ply lay up repairs

Increased use of fasteners for transitions between composites and non composites components

On wing repair of composites moving to a Must Have versus a nice to have

Higher emphasis on internal repair development, inspection technologies, manufacturing technology and work force development
Paradigm shift in Workforce, Manufacturing and Repair

Higher level of technical skill required with limited training facilities available. Technical skill acquired by internal training.

Shift in capital equipment from metal rework and inspection to composite rework and inspection

Digital data driven with a higher emphasis on technical skills for interpretation

Traditional two dimensional drawings and inspection shifting to 3D CAD and digital data

Leadership team will need to transform into a digital mindset and skills

New kid in town, to teach old dogs new tricks!
Ceramic Matric Composite (CMC) expansion into structural components

Prime OEM’s (PW, RR and GE) moving to CMC with no return to metallic back ups, leaving no choice but to adapt or fail.

CMC’s bring a higher emphasis on coatings and surface protection.

Transition from traditional repair methods, moving to more sophisticated methods such as diamond grinding, vapor deposition and 3D ply layups.

Cost and process time of inspection will increase from metallic part inspection.

Limited skilled employees available with specific CMC experience – OEM’s have all the knowledge.

Aluminum components moving to PMC and Nickel & Steel components to CMC.
At StandardAero, we have a dedicated composites MRO cell with broad capabilities...

- Autoclave
- Curing Ovens
- Bond Rooms
- Paint Rooms
- Freezer

Guide Vanes
- Tedlar Replacement
- Leading edge
- Bushing repairs

Fan Cases
- Honeycomb Abradable Repairs
- Corrosion repairs
- Bushing repair

Acoustic Liners
- Face sheet repairs
- Replace honeycomb
- Replace bushings
- Surface coatings

Stationary Seals
- Replace abradable seals
- Replace bushings
- Wet layup repairs to structure
### Inspection & Repair for Polymer Matrix Composite (PMC) Engine Components

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<thead>
<tr>
<th>PMC engine components</th>
<th>Inspection</th>
<th>Repair</th>
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| • PMC – Polymer Matrix Composites  
  ➢ Structural components – Fan cases, Fan Blades, Platforms, liners or acoustical components  
  ➢ Non oil carrying components  
  • Current PMC investment is in line with CMC allowing full transition from metal to PMC, then to CMC | • Current inspection techniques include: Tap test, Ultrasonic, CT Scan, visual and dimensional inspection  
  • Inspection will need to move from static to dynamic inspection with part under a load to determine breakdowns in glue or for delamination | • *Deep cracks* – autoclave repairs, scarf joints, fiber resin fill  
  • *Topical repairs* – on wing, surface treatments, blending and coating repairs  
  • Repairs need to be mobile for large parts (Fan Cases) |
### Inspection & Repair for Ceramic Matrix Composite (CMC) Engine Components

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<th>CMC Engine Components</th>
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| • CMC OX-OX, heat blanket structures – 1,700°F  
  ➢ Structural components - Combustor liners, Fan cases  
• CMC Silicone Carbide, Structural Components – 2,400°F  
  ➢ Hot section – Blades, Vanes, Shrouds, Nozzles & Exhaust | • Current inspection techniques include: Infrared, CT scan, visual and 3D dimensional inspection  
• Inspection used for metal will have to be adapted to composites for live dimensional feedback  
• Cracks in CMC may be acceptable as where metallic is bad | • Resin fill – Autoclave repairs, scarf patch repairs, full face repairs  
• Burnouts for moisture removal and resin re-fusion  
• Higher emphasis on EBC coatings and heat treat |
Summary

• **Composite components will continue to grow**
  • MRO shops have to begin to transform business to expand composite capabilities
  • Investments in longer term technologies focused on composites repair and inspection

• **Range of materials, processing parameters, inspection methodologies has significant implications for a repair facility**
  • Introduce more employees to PMC repair and inspection methods, expand experience through job rotation
  • Transition workforce from 2D drawings to using 3D models and data sets for work instructions

• **CMC components embraced by OEM’s**
  • Stronger partnership with OEM’s and early engagement in the R&D cycle is critical
  • Either Good or Bad, no “MRB” to determine acceptable limits
  • Significant implications from a capital and IP investment perspective

• **Out-of-autoclave or mobile processing (fabrication and repair) continue to make inroads “How do we get to the engine faster?”**