Electron Beam Direct Manufacturing (EBDM) On the F-35 Lightning II

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Lockheed Martin Aeronautics

NC State Advanced Manufacturing & Logistics Symposium, Oct 17, 2013
Outline

- EBDM Process
- Benefits
- F-35 EBDM Qualification Efforts
- Other Programs Supporting EBDM Qualification
- Summary
**Sciaky Electron Beam Direct Manufacturing**

- **Deposit Weld Wire on Base Plate**
  - *High Deposition Rates*
    - 15 lbs/hr
  - *Closed Loop Control*
    - *Consistent Material Properties*

- **Weld Wire Feedstock**
  - *Special chemistry wire*

- **Very Large Part Capability**
  - 245” x 62” x 55” Build Envelope
Benefits of EBDM

- Minimal Tooling Required
- Cost Savings
  - *Up to 60%*
    - *Reduced BTF*
- Lead Time Savings
  - *Up to 80% vs Die Forgings*
EBDM Process Steps

NC Path Planning

Deposition

Finished Part

NC Machining
F-35 EBDM Qualification

F-35A
Conventional Takeoff and Landing (CTOL)

F-35B
Short Takeoff and Vertical Landing (STOVL) Capability

F-35C
Carrier Variant

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## F-35 EBDM Qualification Program

<table>
<thead>
<tr>
<th>Year</th>
<th>Business Case Dev</th>
<th>Trade Studies</th>
<th>Phase 1</th>
<th>M&amp;P Specs</th>
<th>Phase 2</th>
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Materials Qualification Effort

• Deposition of Large Preforms
• Preforms
  – 11 Preforms
  – 270 lbs of Deposit
  – 3 Wire Sources
• Specimen Testing
  – 139 Test Coupons per Preform
    – Static Testing
    – DaDT Testing
    – Metallography

Ref: Needler, Steve, “F-35 Direct Manufacturing: Material Qualification Results” presented at Aeromat 2012 Conference
# Material Qualification Testing

## DM Material Qualification Test Matrix

<table>
<thead>
<tr>
<th>Test</th>
<th>Replicates per</th>
<th>Preform</th>
<th>Test Program</th>
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<td>Tensile</td>
<td>60 (x10) / 9 (x1)</td>
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<td>Fatigue – Crack Growth</td>
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<td>Metallography</td>
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<td>Chemistry</td>
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<td><strong>Totals</strong></td>
<td>175 (x10) / 32 (x1)</td>
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EBDM Design Allowables

Ti-6Al-4V ELI, BA: EBDM vs. Wrought

- Static Properties ~5% Lower
- Damage Tolerance Equivalent
F-35 EBDM Applications
Potential F-35 EBDM Applications

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Ht (in)</th>
<th>Wid (in)</th>
<th>Lg (in)</th>
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Next Step for F-35 EBDM

• Part Qualification & Business Case Update
  – Begin 1Q 2014
Other EBDM Programs

• Sciaky SBIR Studies
  – Commercialization of Technology –
    – Refined Closed Loop Control System
  – Supply Chain Integration –
    – Validated Industry’s Capabilities to Produce EBDM Components

• NDI of EBDM CRAD

• LM Missiles & Space Applications
EBDM Fabrication Studies (Sciaky SBIRs)

Notional Part

Trial Part
NDI of EBDM CRAD

- Administered by Concurrent Technologies Corporation
- Runs in Parallel to F-35 EBDM Qualification Pgm
- POP
  - Oct 2012 thru Jul 2014

- Objectives
  - Quantify
    - Capabilities of Existing NDI Methods
    - Effects of Surface Finish and HT Condition
  - Estimate NDI Impact on Final Part Cost & Lead Time
Representative EBDM Flaws

- Defects of Concern for NDI of EBAM Product Forms:
  - Porosity
  - Crack Like
    - Incomplete Fusion
    - Geometric
      - Undercut
      - Under fill
  - Inclusions
EBDM Grain Structure/HT Impacts NDI

Beads

Build Dir

Columnar Grains

>18dB Variation in Thru Transmission UT

“As Deposited”

“Post Beta HT”

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NDI of EBDM – UT Results

UT Response to FBH vs. Std

Delta dB from Std

Total Step Thickness (In)

-8 -6 -4 -2 0 2 4 6

12 to 15 dB Added for DAC for BA

#2 FBH - As Fab
#3 FBH - As Fab
#5 FBH - As Fab
#5 FBH - BA

Ultrasonic Inspection Capability (#3 FBH)
As Deposited Condition – 3”
BA Condition - ~1” (Est)

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EBDM Space Application

- Spacecraft Forward Bay Cover Deck
Summary

• **EBDM Process**
  - *Potential for Significant Cost & Lead Time Savings*
  - *Currently being Qualified for F-35 & Space Applications*
    - Process Specs & Design Allowables Established
    - Certification Testing Starts 1st Qtr 2014
  - *Candidate Applications*
    - Wing & Empennage Components

• **NDI of EBDM CRAD**
  - *Evaluating NDI Methods Required for EBDM*
Future Work

• **EBDM Process Refinement**
  – *Control Microstructure*
    – *Reduce Columnar Grain Formation*
    – *Improve NDI*
  – *Achieve Parity With Wrought Materials Properties*

• **Additional NDI Development**
  – *Economical*
  – *Production Viable*
Questions
Additive Mfg Sessions at Aeromat 2014

- June 16-19, 2014 @ Orlando FL
- Deadline for Abstracts is January 13, 2014

- AM Methods
  - Comparison of various AM methods and equipment

- AM Applications
  - Existing or planned use of AM in prototype or production applications

- Materials & Processes Used for AM
  - Aerospace alloys converted for AM
  - Secondary processing operations
    - heat treatment
    - surface finishing
    - NDI
    - repair

- Design Practices for AM
  - Best practices for AM designs