Sixth European Aeronautics Days

Aerodays 2011

Innovation for a Sustainable Aviation in a Global Environment

30th March - 1st April 2011
Madrid (Spain), Palacio Municipal de Congresos
http://www.aerodays2011.org/
1D3 - A Technique for the Rapid Production of Large Aerospace Components

- Dr Rosemary Gault
- AMRC, University of Sheffield
• Understand SMD process
• Characterise material properties
• Develop welding parameters
• Develop automatic controller
• Understand environmental benefits of SMD
• Develop business case
• Develop training route
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Advanced Manufacturing Research Centre

Samtech

DIAD

FOOTPRINT TOOLS

mtec

TECNOLGIE
## Manufacturing Readiness Level (MRL)

<table>
<thead>
<tr>
<th>Phase</th>
<th>MRL</th>
<th>State of Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 3: Production Implementation</td>
<td>9</td>
<td>Full production process qualified for full range of parts and full metrics achieved</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Full production process qualified for full range of parts</td>
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<tr>
<td></td>
<td>7</td>
<td>Capability and rate confirmed</td>
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<tr>
<td>Phase 2: Pre-production</td>
<td>6</td>
<td>Process optimised for production rate on production equipment</td>
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<td>5</td>
<td>Basic capability demonstrated</td>
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<tr>
<td>Phase 1: Technology assessment and proving</td>
<td>4</td>
<td>Production validated in lab environment</td>
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<tr>
<td></td>
<td>3</td>
<td>Experimental proof of concept completed</td>
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<tr>
<td></td>
<td>2</td>
<td>Application and validity of concept validated or demonstrated</td>
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<tr>
<td></td>
<td>1</td>
<td>Concept proposed with scientific validation</td>
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</tbody>
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**Where does SMD fit?**
Shaped Metal Deposition (SMD)

- State-of-the-art process, patented by Rolls-Royce
- Additive manufacture of fully dense metal parts
- Constructs parts by welding successive layers of wire
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Advantages

- Produce near-net parts from CAD models
- Material properties better than cast
- Reduce material waste
- Reduce lead time and cost
- Tooling not required for wholly SMD parts
- Easy incorporation of design changes
- Hollow parts
- Parts with bosses, flanges or other features
- Customisation / Redesign
- One-offs which require expensive tooling
- Production of legacy / spare parts
- Repair
• Standard robotic TIG-welding equipment
• Hardware integrated with simulation and control software
• Automated deposition with adaptive control
• Test cell can build parts up to 1m - production cells can be any size
Detailed process modelling

• Evolution of Von Mises stresses and proportion of α-colony in part
• Mixed models (rigid-, super- and finite-element)
• Topology Optimisation
- Layered structure
- Epitaxial growth of large, elongated prior $\beta$ grains
- Prior $\beta$ grains slightly inclined following the heat flux during welding
- Part composition similar to wire
- Low energy welds give brighter parts but with lower tensile strength
Microstructure by optical microscopy

- Parallel bands in the bottom, none in the top
- Convex bands throughout
- Large grains
- Widmanstätten, martensitic structure
Proven material properties

- Widmanstätten $\alpha/\beta$ microstructure (colony, basket weave)
- UTS: 880 - 1054 MPa (slight dependence on parameters)
- HCF: >770 Mpa (better than wrought)
- Micro-hardness: 3.2 GPa
- Mechanical properties are competitive to cast material
- No strain rate sensitivity
- Some Porosity (<200µm)

AMS4999A
Parameters can be chosen for:

- Bead width
- Surface finish
- Microstructure
- Build speed
• Shrinkage related to energy input and part size
• FEA modelling -> optimum pre-heat strategy and adjustment in path dimensions
Proven Machinability of Parts

- Improved machinability compared to standard materials
- No difference in machinability between different parameters
- Low grain deformation (<10μm)
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Next Steps

- Qualify for aerospace
- Investigate other materials
- Improve programming route
- Develop in-process location methods
Conclusion

• Material conforms to AMS4999A
• Knowledge of welding parameter windows
• Understanding of shrinkage
• Optimisation of pre-heat parameters
• Defined mechanical properties
• Understanding and prediction of microstructure
• Machining characteristics well understood

• Dedicated data-capture equipment
• Understanding of temperature evolution
• Mechatronic models developed
• Weld models developed
• Automatic control of welding process
A European project

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