Multi-Metal 3D Printing of Heat Exchangers

Mark Norfolk, PE
President
mnorfolk@fabrisonic.com
614.688.5223
3D Printing

...process of joining materials to make objects from 3D model data
Metal 3D Printing

Directed Energy Deposition

Powder Bed Fusion

Sheet Lamination
3D Printing Enables

- Complex internal geometry
- Low/no cost part to part variation
- Organic optimization
Deposition Rate vs. Resolution

Increased Deposition Rate

Decreased Resolution

As deposited

During machining

Finish machined

Courtesy Boeing
What Shape Can You Dream?

- Internal complexity is part of the process
- Flow paths not limited to planer arrays
- Slope, turn, slant in any direction
- Microchannel panels can be built without welding/brazing
Base plate: milling for flatness
Channels of every scale

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<thead>
<tr>
<th>Scale</th>
<th>Size</th>
<th>Photo</th>
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<tbody>
<tr>
<td>Micro scale</td>
<td>10-100μm</td>
<td>![Micro scale photo]</td>
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<tr>
<td>Meso-scale</td>
<td>0.1mm-1mm</td>
<td>![Meso-scale photo]</td>
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<tr>
<td>Mm-scale</td>
<td>1mm-5mm</td>
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<tr>
<td>Cm-scale</td>
<td>5mm-2cm</td>
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<tr>
<td>Macro-scale</td>
<td>2cm +</td>
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Multi Material Solutions

make metallic structures with multiple materials
Flexible path cross section
Embedding Sensors & Electronics While Printing

- Low temperature welding allows embedding
- Manual or automatic placement
- Strain gauges
- Thermocouples
- Pressure Transducers
- IO
YOU CAN EVEN

3D-Print large metal parts

- 6 ft x 6 ft x 3 ft working envelope
- Up to 60 cubic inches per hour
- Integrated 3-axis CNC machining
Bonus – Low Cost Honeycomb

- Honeycomb advantages
  - Low density – current designs similar to aluminum
  - High stiffness – defined by face sheet materials
  - High surface to volume ratios
  - Small thermal diffusion distances

- Heat exchanger performance implications
  - More efficient transfer of energy to emission surfaces
  - High flow volumes per unit area
  - Fabricable into structural shapes

Cross Section of a 1.5-mm Thick Honeycomb Panel (Courtesy CellTech Metals Inc.)
Roll to Roll Continuous Production

5-10 m²/min
Example - 6061 Al for Mars Rover

- Helium leak check below $1 \times 10^{-4}$ scc/sec
- Average burst > 3300 PSI