Shifting from Prototyping to Production

AM Research Symposium
October 18, 2013

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Facilities

<table>
<thead>
<tr>
<th>Plastics Facility</th>
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<tbody>
<tr>
<td>![Plastics Facility Image]</td>
</tr>
<tr>
<td>- Year Built: 2005</td>
</tr>
<tr>
<td>- Square Footage: 11,000</td>
</tr>
<tr>
<td>- Capacity: 26 machines, 67 personnel</td>
</tr>
<tr>
<td>- Operations: Prototyping Plastics</td>
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<tr>
<td>- Certifications: ISO 9001</td>
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<table>
<thead>
<tr>
<th>Metals Facility</th>
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<tbody>
<tr>
<td>![Metals Facility Image]</td>
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<tr>
<td>- Year Built: 2013</td>
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<tr>
<td>- Square Footage: 10,000</td>
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<tr>
<td>- Capacity: 3 machines, 8 personnel</td>
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<tr>
<td>- Operations: Rapid AM of high-value metal components</td>
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<tr>
<td>- Certifications: ISO 9001/ AS9100 (in process)</td>
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### Stereolithography

<table>
<thead>
<tr>
<th>Viper</th>
<th>iPro</th>
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<tbody>
<tr>
<td>![Viper Image]</td>
<td>![iPro Image]</td>
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</table>
| - 22 units in-house  
- High- and Normal-resolution  
- Prototyping workhorse | - 2 units in-house  
- Large build volume with high detail |
Selective Laser Sintering

SinterStation Pro

- 1 unit in house
- Used for prototyping and digital parts manufacturing
## Selective Laser Melting

### Mlab
- 2 units in house
- 316L, 17-4PH, Co-Cr, Inconel
- For prototyping (MIM) and production of highly detailed parts

### M2
- 1 unit in-house
- Ti 6Al-4V, 316L, 17-4PH and Inconel
- For direct production of large parts or high quantities
Path to Production

- Mastering one-piece flows – necessary for high-volume prototyping
  - Root cause analysis
  - Work instructions
  - Checklists
  - Scalability
  - Traceability
  - Reliability

- Beyond volume prototyping to production
  - Minimizing variability
  - Minimizing uncertainty
  - Reduction of costs
  - Further R&D
There are numerous things that can go wrong, and you only have one shot!

Root Cause Analysis is the only way to get to the heart of the matter.

Automation and Work Instructions to minimize recurrence.

Checklists for critical processes.
Mastering One-Piece Flows

Scalability

- Maximizing asset utilization
- Managing multiple materials
- Optimizing ship dates across multiple projects
- Establishing a visible plan for entire organization
Mastering One-Piece Flows

Traceability

Reliability
Proceeding into Production

- Minimizing Variability
- Minimizing Uncertainty
- Reduction of Costs
- Further R&D
Minimizing Variability

- Qualification and control of process parameters
  - Laser Power
  - Scan speeds
  - Scan algorithms
  - Layer thickness
  - Part orientation
  - Support structures

Qualification may include:
- Centering process within desired properties
- Coupling with customer-mandated test protocol
- Revision control
Minimizing Variability

- Qualification driven by material property verification
  - Stiffness
  - Tensile strength
  - Elongation to break
  - Hardness
  - Microstructure
  - Porosity
  - Fatigue strength
Minimizing Uncertainty

- Process Monitoring
  - Continuous evaluation of moving melt pool
  - Monitors process outcome for all vectors on all layers in every part
  - Could allow for verification of successful process on each specific part
Minimizing Uncertainty

- Raw Material Quality
  - Particle size distribution
  - Alloy composition
  - Moisture / oxidation / contamination status
More R&D Needed

- Surface finish improvement?
- Material recyclability?
- Internal stress reduction?
- More automation (process / finishing)
Plastics have come a long way since RP/AM was introduced

Metal-producing technologies have made the leap to production material properties/accuracy

The field continues to evolve, and with continued R&D it could indeed change the face of manufacturing going forward

Questions?

Thank you!