Revolutionary Improvements for Investment Castings via 3D-Printed Ceramic Tooling and Process Aids

Investment Casting Institute – Technical Conference & Expo
October 23, 2018
Presentation Outline

• Tooling/Process Aids for Investment Casting
• Ceramic Additive Manufacturing
• Case Study: 3D-Printed Ceramic Mold
• Summary
Tooling from Ceramic Additive Manufacturing

Focus is 3D-printed ceramic components to support investment casting
Why 3D-Printed Ceramics?

Cores

- Complexity of new core designs that surpass capability of injection molding
- Small quantity of cores needed during casting development

Molds

- Part designs that challenge the dipping of traditional 3D-printed wax patterns

Filters

- Desire to provide a consistent flow system and material cleanliness
- Avoid inclusions introduced by traditional foam filters

Provide capabilities not available via traditional manufacturing processes
Designing Cores, Molds, Filters for 3D Printing Process
Mixing Special Materials for Ceramic 3D Printing
3D Printing the Ceramic Components
Cleaning the 3D-Printed Ceramic Components
Firing the Ceramic Components for Investment Casting
Performing 3D Inspection on the Ceramic Components
Focus for 3D-Printed Cores and Molds

Best fit for 3D printing are parts that are low volume and/or high complexity
• Improve capture of material contaminants
• Reduce inclusions introduced from foam filter tentacles
• Ensure consistent flow rate for mold fills
3D-Printed Ceramic Cores

Start with Customer’s ‘Finished Part’ CAD Model

Modify Customer Supplied Data to Develop Core Model

Create Model for 3D Printing

Build Support Geometry and Nest on Platform

Establish “Slice File” for Individual Layers

Print Parts on Platform

Remove & Clean Parts

Check & Inspect Parts
Traditional Investment Casting Flow

Machining Pattern Die

Injecting Wax Patterns

Assembling Wax Mold Tree

Coating with Slurry

Coating with Ceramic

Machining Pattern Die

Injecting Wax Patterns

Assembling Wax Mold Tree

Coating with Slurry

Coating with Ceramic

Melting Out Wax

Firing Ceramic Mold Tree

Pouring Metal Into Mold Tree

Removing Ceramic Mold

Cleaning the Castings
Investment Casting with 3D-Printed Molds

3D Print Ceramic Mold

Pouring Metal Into Mold Tree

Removing Ceramic Mold

Cleaning the Castings
Case Study: F108 Gearbox Housing

Part Number: 335-300-402-0
A-357 Aluminum Casting
F108 Housing Removed from Service

Start with part removed from airplane to enable reverse engineering
Overview of Rapid Casting of F108

From condemned part without a TDP to new raw casting in 28 days
Complete set of mold tree components created via 3D printing
F108 Gearbox Housing Clean-Up

The raw casting from the ‘tool-less mold’ -- foundry: PCC Structurals
<table>
<thead>
<tr>
<th>3D-Printed Ceramic Products</th>
<th>Cost Impact</th>
<th>Cycle Time</th>
<th>Performance</th>
<th>Hard Tooling</th>
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<tbody>
<tr>
<td><strong>Cores</strong></td>
<td>Eliminate non-recurring core die tooling cost</td>
<td>One week from design to first cores compared to multi-month conventional process</td>
<td>Comparable to conventional cores; ability to rapidly iterate designs days versus months</td>
<td>None required, saving time and money; “CAD as tooling” highly flexible rapid response</td>
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<td><strong>Molds</strong></td>
<td>Eliminate wax die tooling cost and eliminate wax patterns</td>
<td>From mold design to casting in 30 days compared to at least 12 month conventional cycle</td>
<td>Castings comparable to conventional; no issues with broken wax patterns that cause casting scrap</td>
<td>None required, saving time and money; “CAD as tooling” highly flexible rapid response</td>
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<td><strong>Filters</strong></td>
<td>Comparable to current conventional filter cost, depending on size and application</td>
<td>Capacity sufficient to meet foundry demands with delivery comparable to conventional filters</td>
<td>Tightly controlled flow rates compared to conventional results; stopped all impurities versus 40% inclusions for conventional filters</td>
<td>None required; 3D-printing enables on-demand filters designed to meet specific foundry needs</td>
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