Exploring Additive Manufacturing for Your Company

Chris Wentworth, Additive Manufacturing Practice Lead, CMTC

Moderator:
Emily Tjaden Sylvester, AMP SoCal

AMP SoCal Webinar Series: Episode 6
September 21, 2017 10:00 a.m. – 10:30 a.m.
About AMP SoCal

• The Advanced Manufacturing Partnership for Southern California (AMP SoCal) is a collaboration of more than 135 different organizations.

• Its goal is to strengthen the industrial ecosystem for aerospace and defense manufacturers.

• AMP SoCal is led by the University of Southern California (USC) Sol Price School of Public Policy - USC Center for Economic Development.

• AMP SoCal supports the aerospace and defense manufacturing industry within the 10-county Southern California region.
Logistics

• All audio will stream through your computer speakers.

• Please submit your questions anytime throughout the presentation in the chat box, located on the bottom of your screen.

• Webinar recording and slides are posted within one week of the event.

 ampsocal.usc.edu/webinars
Today’s Speaker

Chris Wentworth,
Additive Manufacturing Practice Lead,
California Manufacturing Technology Consulting® (CMTC)
Additive Manufacturing: The Evolution of 3D Printing

Chris Wentworth
Additive Manufacturing Practice Lead
Experience

• Over 20 years of experience in manufacturing
• 12 years running product development companies
• Hands on experience running almost every type of 3D printer
• An invited speaker on Additive Manufacturing and Product Development at events and forums sponsored by UCI, IIT Tech, Saddleback CC and LBCC.

Skills
• 3D Printing
• CAD Design
• Electronic Assembly
• CNC Programming/Machining
• Polyurethane Casting
• Soft Tooling
• Product Development
• Sales

Software
• Solidworks
• GC Cam
• Master Cam
• AutoCAD
Who We Are

- CMTC is California’s Manufacturing Extension Partnership (MEP) Center and is affiliated with the National Institute of Standards and Technology (NIST)

- The MEP Program exists to assist small and mid-sized manufacturers in developing and deploying technology, increasing technical expertise and enhancing management and operational processes to improve competitiveness
Our Impact

- In 2016, CMTC provided the following benefits to our clients:

  - **$230 Million** Total Investments
  - **$150 Million** Cost Savings
  - **$504 Million** Total Sales
  - **7,107 Jobs** Created / Retained
  - **1,024 Mfgs Served**
Our Services

- Supply Chain
- HR
- Sales / Mktg
- Reduce Costs
- Improve Quality
- IT
- Innovation
- Strategic Growth

CMTC
Additive Manufacturing: What started it all?

Industrial revolutions

1st: Mechanization, water power, steam power
2nd: Mass production, assembly line, electricity
3rd: Computer and automation
4th: Additive Cyber Physical Systems
Before Computers
CNC Machining

This allowed much more complex geometries to be machined via CAM
Solid Modeling
Computers are responsible for AM
First SLA machine

This allowed much more complex geometries to be prototyped

Chuck Hull patented the first Stereolithography machine in 1986, then started 3D Systems
Solid Modeling CAD Packages

Cloud Based Solid Modeling Packages
3D Printing

First a geometric model is created

Software slices the model in layers

Then a 3D printer adds material layer by layer
Additive Technologies

Per ASTM standard

1. Vat Polymerization  Plastic
2. Material Extrusion  Plastic/Metal
3. Powder bed fusion  Nylon/Metal
4. Material Jetting  Plastic/Wax
5. Binder Jetting  Nylon/Metal/Plaster
6. Sheet Lamination  Paper
7. Directed Energy Deposition  Metal
Vat Photo-Polymerization

- XY Mirror
- UV Laser
- Resin Vat
- Z Stage build Platen

Recoater Blade
Vat Photo-Polymerization
Digital Light Projection (DLP)

Z Stage

Exposure membrane
Resin Pool

DLP Projector
Material Extrusion

Extrusion nozzle

Plastic spline

Build platen
Material Extrusion Innovation
Powder Bed Fusion

XY Mirror

CO2 Laser

Build Bay
Z Stage

Image by Renishaw

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California’s Manufacturing Resource
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## EOS Materials Metal

<table>
<thead>
<tr>
<th>Product class</th>
<th>Product name</th>
<th>Material type*</th>
<th>Typical applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managing steel</td>
<td>EOS MaragingSteel MS1</td>
<td>18 Mar 300 / 1.2709</td>
<td>Series injection molding tools; mechanical parts</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>EOS StainlessSteel GP1</td>
<td>Stainless steel 17-4 / 1.4542</td>
<td>Functional prototypes and series-production parts; mechanical engineering and medical technology</td>
</tr>
<tr>
<td></td>
<td>EOS StainlessSteel PH1</td>
<td>Hardened Stainless steel 15-5 / 1.4540</td>
<td>Functional prototypes and series-production parts; mechanical engineering and medical technology</td>
</tr>
<tr>
<td></td>
<td>EOS StainlessSteel 316L</td>
<td>1.4404 / UNS S31673</td>
<td>Lifestyle: jewelry, functional elements in yachts, spectacle frames, etc. Aerospace: supports, brackets, etc. Medical: functional prototypes and series-production parts in e.g. endoscopy and orthopedics</td>
</tr>
<tr>
<td></td>
<td>EOS StainlessSteel CX</td>
<td>Tooling grade steel</td>
<td>Manufacturing of injection moulding tools for medical products or products from corrosive plastics</td>
</tr>
<tr>
<td></td>
<td>EOS StainlessSteel 17-4PH</td>
<td>Stainless steel 17-4PH / 1.4542 / X55NiCrCb17-4</td>
<td>Medical instruments (surgical tools, orthopedic instrumentation) Acid- and corrosion resistant parts.</td>
</tr>
<tr>
<td>Nickel alloy</td>
<td>EOS NickelAlloy IN718</td>
<td>Inconel 718, UNS N07718, AMS 5662, mat. # 2.4668</td>
<td>Functional prototypes and series-production parts; high-temperature turbine components</td>
</tr>
<tr>
<td></td>
<td>EOS NickelAlloy IN625</td>
<td>Inconel 625, UNS N06625, AMS 6666M, mat. # 2.4856 etc.</td>
<td>Functional prototypes and series-production parts; high-temperature turbine components</td>
</tr>
<tr>
<td></td>
<td>EOS NickelAlloy HX</td>
<td>UNS N06002</td>
<td>Components with severe thermal conditions and high risk of oxidation, e.g. combustion chambers, burner components, fans, roller hearths and support members in industrial furnaces</td>
</tr>
<tr>
<td>Cobalt chrome</td>
<td>EOS CobaltChrome MP1</td>
<td>CoCrMo super alloy, UNS R31638, ASTM F75</td>
<td>Functional prototypes, series-production parts, mechanical engineering, medical technology, dental</td>
</tr>
<tr>
<td></td>
<td>EOS CobaltChrome SP2</td>
<td>CoCrMo super alloy</td>
<td>Dental restorations (series-production)</td>
</tr>
<tr>
<td></td>
<td>EOS CobaltChrome RPD</td>
<td>CoCrMo super alloy</td>
<td>Removable partial dentures</td>
</tr>
<tr>
<td>Titanium</td>
<td>EOS Titanium Ti64</td>
<td>Ti6Al4V light metal</td>
<td>Functional prototypes and series-production parts; aerospace, motorsports etc.</td>
</tr>
<tr>
<td></td>
<td>EOS Titanium Ti64-4ELI</td>
<td>Ti6Al4V ELI</td>
<td>Functional prototypes and series-production parts in medical technology</td>
</tr>
<tr>
<td></td>
<td>EOS Titanium Ti64CP</td>
<td>Ti6Al4V ELI</td>
<td>Medical implants (trauma plates, CMF Implants, spinal cages, dental implants)</td>
</tr>
<tr>
<td>Aluminium</td>
<td>EOS Aluminium AlSi10Mg</td>
<td>AlSi10Mg light metal</td>
<td>Functional prototypes and series-production parts; mechanical engineering, motorsports etc.</td>
</tr>
</tbody>
</table>
Powder Bed Fused Metal

Design by Robert Smith and Michael Hollenbeck at www.optisys.tech
Injection Molding

Conformally cooled mold insert
Reduction of cycle time with
Improved thermal conduction
New low cost SLS Nylon

Formlabs just released a SLS Nylon printer for $9,999. Make high strength end use parts fast and cheap without tooling.

165 x 165 x 320 mm build volume for bigger parts and higher throughput.
Powder Bed Fused Nylon
Material Jetting

Solid Part

UV Lamp

Part and support jets

Soluble Support

Build Platen
AM used for Injection molding
Material Jetting Wax

Design → Print → Models → Cast
Binder Jetting

Inkets spray liquid binder on powdered material

Powder spreading roller

Powder feed bay

Z Stage Build Platen

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Binder Jetting Foundry sand and metal powder
This Binder Jetting technology uses heat and chemicals to bind nylon powder for high volume part production.
Forecast 3D

A well established 3D service bureau in Carlsbad California, has 12 HP MJF machines and says it can make up to 600,000 nylon parts per week at max capacity.
Material Lamination

Laminated Material

Cutting Laser
Directed Energy Deposition

Material is deposited into the path of the beam and sintered to the part

Z Stage Platen
RTV Molding
Room Temperature Vulcanization

Liquid polyurethane resin

Silicone mold made from AM master pattern
Factors prohibiting AM adoption:

- Material cost
- Speed
- Material strength
- Appearance
AM vs Conventional

Factors prohibiting AM adoption:

- Material cost
- Speed
- Material strength
- Appearance
The benefits to manufacturing

Jabil Circuits Driving adoption of AM

The HP JF can make 50,000 parts a year without tooling. As Jabil pushes this out to OEM’s it will become mainstream.
3D Printed PCB

[Images of 3D printed PCBs and related equipment]
Paths for AM adoption

Framework for understanding AM paths and value

Path III: Product evolution
- **Strategic imperative:** Balance of growth, innovation, and performance
- **Value driver:** Balance of profit, risk, and time
- **Key enabling AM capabilities:**
  - Customization to customer requirements
  - Increased product functionality
  - Market responsiveness
  - Zero cost of increased complexity

Path IV: Business model evolution
- **Strategic imperative:** Growth and innovation
- **Value driver:** Profit with revenue focus, and risk
- **Key enabling AM capabilities:**
  - Mass customization
  - Manufacturing at point of use
  - Supply chain disintermediation
  - Customer empowerment

Path I: Stasis
- **Strategic imperative:** Performance
- **Value driver:** Profit with a cost focus
- **Key enabling AM capabilities:**
  - Design and rapid prototyping
  - Production and custom tooling
  - Supplementary or “insurance” capability
  - Low rate production/no changeover

Path II: Supply chain evolution
- **Strategic imperative:** Performance
- **Value driver:** Profit with a cost focus, and time
- **Key enabling AM capabilities:**
  - Manufacturing closer to point of use
  - Responsiveness and flexibility
  - Management of demand uncertainty
  - Reduction in required inventory

Graphic: Deloitte University Press
Anyone doing layup or assembly could quickly produce complex fixtures and jigs. This helps speed up the production process, change over, and improve quality.
Tools & Patterns

INJECTION MOULDING  SHEET METAL FORMING  COMPOSITE LAY-UP TOOLS & CORES  VACUUM FORMING & BLOW MOULDING

Being able to quickly create tooling is a huge benefit to Small and Medium Mfg’s by reducing cycle time and tooling costs
Shop Tooling
AM eliminates need for tooling

Type A machines in northern California is producing machine pods that can produce over a million plastic parts per year with no tooling. A digital BOM is all you need, the software distributes the parts among the printers.
New AM Metal Technology

Desktop metal combines extrusion and sintering to make metal parts from 10 to 100 times faster than other laser based additive metal machines. Also safer without the need to worry about static and powder. The high volume machine also rivals conventional metal casting on speed and price. 200 Plus materials
AM in Medical
AM in Aerospace
GE Paving the way for AM

Reasons they chose AM:

- From 20 parts to 1
- Huge reduction in production time
- Better strength, 5x more durable
- Topology optimization

GE just purchased Arcam and Concept Laser
To create a complete in house supply chain of AM
GE Additive: Changing aerospace design

Aerospace companies optimize designs for AM any by coalescing assemblies and applying topology optimization. Taking advantage of the availability of producing extremely complex parts.

ATP Engine

12 AM parts replaced 855 parts
5% Weight Reduction
20% Lower Emissions

Reduction in manufacturing cost
Increase in power & fuel efficiency
GE Additive: Changing aerospace manufacturing

GE Purchased
Concept Laser
Arcam
Open 125,000 sq. foot facility
Topology optimization

Moog actuator:
Combine parts
No welds or gaskets
Less weight
Titanium
Design to complex to CNC
Topology optimization
Automated AM

Today over 170,000 dental models are made every day with AM equipment. New high volume technologies are being released to accommodate this type of production.
High Volume Additive Technologies
New AM materials

New materials are:

- Biocompatible
- Production Grade
- CE-certified.
“CLIP – Continuous Liquid Interface Production – is a photochemical process that makes it possible to produce parts with excellent mechanical properties, resolution, and surface finish.” carbon3d.com
Client Benefits of AM Adoption

- Reduce Risk and time to market
- Tooling Fixtures & Jigs for assembly
- No tooling for small volume plastic parts
- Supply new wave of AM Aerospace parts
- Increasing product customization
- Replace antiquated supply chains
- Open up new income streams
Case Study - Molds

How does Polyjet compare to traditional methods for Seuffer?

<table>
<thead>
<tr>
<th>METHOD</th>
<th>COST</th>
<th>PRODUCTION TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal Mold*</td>
<td>$52,725</td>
<td>56 days</td>
</tr>
<tr>
<td>PolyJet Mold</td>
<td>$1,318</td>
<td>2 days</td>
</tr>
<tr>
<td>Savings</td>
<td>$51,407(98%)</td>
<td>54 days (96%)</td>
</tr>
</tbody>
</table>

*Production Mode

Seuffer’s polyethylene housing created with a PolyJet tool.

Cavity side of 3D printed injection mold.
Case Study - Castings

Male FDM pattern (foreground) and finished casting being inspected with coordinate measuring machine touch probe.

For RLM Industries, investment castings were produced to specifications in only seven days using FDM method.

RLM used FDM patterns to meet a critical deadline for the US Army’s MIM-104 Patriot, a surface-to-air missile system.

How Did Stratasys Compare to Traditional Tooling Methods for RLM?

<table>
<thead>
<tr>
<th>METHOD</th>
<th>COST</th>
<th>PRODUCTION TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection Molding</td>
<td>$5,000 to $20,000</td>
<td>2 months</td>
</tr>
<tr>
<td>FDM</td>
<td>$1,250</td>
<td>1 week</td>
</tr>
<tr>
<td>Savings</td>
<td>$3,750 to $18,750</td>
<td>7 weeks (88%)</td>
</tr>
<tr>
<td></td>
<td>(75% to 94%)</td>
<td></td>
</tr>
</tbody>
</table>
## Case Study – Sheet Metal Form Tools

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>PRESSURE RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS-M30</td>
<td>Up to 3,000 psi</td>
</tr>
<tr>
<td>PC</td>
<td>3,000 to 8,000 psi</td>
</tr>
<tr>
<td>Ultem 9085</td>
<td>Up to 10,000 psi</td>
</tr>
</tbody>
</table>

Recommended forming pressure range for FDM materials.

How Did FDM Compare to Traditional Tooling Methods for Pryor?

<table>
<thead>
<tr>
<th>METHOD</th>
<th>COST</th>
<th>TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNC Machining</td>
<td>$1,500</td>
<td>5 days</td>
</tr>
<tr>
<td>FDM Tooling</td>
<td>$450</td>
<td>1 day</td>
</tr>
<tr>
<td>Savings</td>
<td>$1,050 (70%)</td>
<td>4 days (80%)</td>
</tr>
</tbody>
</table>

- Ultem 9085 female tool and intensifier.
- Initial forming on FDM tool and pressure intensifier to be applied.
- Structural component formed in 2024-0 aluminum.
AM Practice model

Awareness

Classes
Speaking
Webinars
Lunch N Learn
Newsletter

Discovery

Ascertain & Analyze:
Tech Readiness
Process Engineering Facility

Determine Solutions:
ROI Case
Delivery Risk Profile Options

Strat plan

Define:
Roles
Services
Time frame
Capital

Implement

Design for AM Prod Dev Strategy
 Equip/ Service Selection
Training Process Integration
Change Mgmt.
The world of tomorrow will be Additively Manufactured
Questions?
Projects I’ve Worked on
Automotive
Toys
Restoration
Art
Architectural
Consumer Products
Medical Devices
Aerospace
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