Additive Manufacturing and Metals: the perspective of the Machine Tool industry

Maastricht, 27 January 2015
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CECIMO Project Manager - Additive Manufacturing

"where manufacturing begins"
CECIMO is the European Association of the Machine Tool Industries

It represents:

- 15 National Associations
- 1500 companies – 80% SMEs
- almost the entire metalworking machine tool production in Europe (98%)
- €23 bn sales in 2013
- 83% of the production is exported
- 34% of the global production
- 49% of the world’s exports
CECIMO and Additive Manufacturing

Time Frame:

- **June 2014:** General assembly - Prague
- **September 2014:** Establishment of CECIMO AM Project and AM Working Group

Main scope:

- Establish CECIMO as voice of the **Metal** Additive Manufacturing total value chain in Europe and worldwide

Main activities:

- Creation of CECIMO AM WG
- Participation to European research projects on AM
- Participation to Standard bodies on AM
- Visibility, Raising Awareness and Media partnerships
- Organization/ Participation to AM related events
• CECIMO Organization/Participation to AM related events

• CECIMO partner of the “3D Printing event” – Eindhoven, 10 October 2014
• CECIMO Magazine - Media partner of the conference “3D Printing Medical Revolution”- Brussels, 4 November 2014
• CECIMO partner of the conference “Opportunities and Challenges of 3D Printing”- Vicenza, 20 November 2014
• CECIMO partner of “3D printing electronics” conference at High Tech Campus - Eindhoven, 20 January 2015
• CECIMO partner of “3D Printing Material” event – Maastricht, 27 January 2015
• CECIMO participating to the AM Platform stakeholders meeting – Turin, 5-6 February 2015
• CECIMO partner of “Commercial Applications for Additive Manufacturing” - Amsterdam, 9-11 February 2015
• CECIMO partner of Additive World Conference - Eindhoven, 4 March 2015
• CECIMO speaking at “Additive Manufacturing: Production Application Initiative” – Berlin, 26–27 March 2015
• CECIMO partner of ADNEC – UAE – Abu Dhabi 20-21 May 2015
• CECIMO partner of “Manufacturing Performance Days” - Tampere, 8-10 June 2015
• CECIMO partner of FEAL2 - Lille, 25 June 2015
• CECIMO partner of EMO MILANO 2015 with a key focus on AM - Milan Italy, 5-10 October 2015
• CECIMO participating to the Manufuture Conference, Luxembourg 22-24 Nov 2015
• CECIMO partnership and organization of IAMA
• CECIMO partner of additiveworld.com/Design-challenge
<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machining Centers</td>
<td>1,370,263,514</td>
<td>1,692,451,742</td>
<td>2,798,197,458</td>
<td>2,657,677,070</td>
<td>3,028,744,260</td>
<td>3,625,578,078</td>
</tr>
<tr>
<td>Turning Centers</td>
<td>448,061,571</td>
<td>678,324,820</td>
<td>1,253,836,655</td>
<td>1,291,956,320</td>
<td>776,853,640</td>
<td>1,300,455,194</td>
</tr>
<tr>
<td>Lathes</td>
<td>708,698,880</td>
<td>498,577,646</td>
<td>1,315,722,068</td>
<td>1,511,390,345</td>
<td>1,113,576,132</td>
<td>1,116,383,396</td>
</tr>
<tr>
<td>Grinding</td>
<td>204,331,180</td>
<td>130,451,475</td>
<td>290,170,275</td>
<td>427,256,387</td>
<td>368,568,657</td>
<td>525,819,809</td>
</tr>
<tr>
<td>Screw Machines</td>
<td>76,327,403</td>
<td>103,345,524</td>
<td>72,384,306</td>
<td>74,951,959</td>
<td>83,795,656</td>
<td>174,873,860</td>
</tr>
<tr>
<td>EDM</td>
<td>35,438,192</td>
<td>49,422,750</td>
<td>53,327,120</td>
<td>97,800,715</td>
<td>94,427,191</td>
<td>144,210,548</td>
</tr>
<tr>
<td>Additive</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>45,128,326</td>
<td>43,324,990</td>
<td>42,450,701</td>
</tr>
<tr>
<td>Other Metalworking</td>
<td>369,699,073</td>
<td>556,601,368</td>
<td>538,000,481</td>
<td>690,274,384</td>
<td>753,785,923</td>
<td>502,441,361</td>
</tr>
<tr>
<td>Total Metalworking Equip</td>
<td>3,212,819,813</td>
<td>3,709,175,324</td>
<td>6,321,638,363</td>
<td>6,796,435,506</td>
<td>6,263,094,444</td>
<td>7,442,212,948</td>
</tr>
</tbody>
</table>

- Machining centers will account for nearly 50% of all machine tool spending
- Turning centers and screw machines will nearly double
- Horizontal machines continue to be strongly preferred relative to vertical machines
- Grinding and EDM are up significantly over any previous year

Source: Gardner
New solutions to high tech equipment challenges

- Design freedom
- Weight reduction, increased relative strength
- Complexity not impacting costs
- Temperature regulation (flow channels integrated for maximum cooling)
- Reduction/Elimination of tooling (less parts and assembly work)
- Reduction/Elimination of production steps
- Shorter product development / project time / time to market
- Unique coding of parts (track and trace, documentation)
- Personalization/customization
- Distributed and on-demand manufacturing (spare parts, long tail items)

Courtesy of EADS, Laser Zentrum Nord, Concept Laser, Compolight.dti.dk
# Materials used in AM Technologies

<table>
<thead>
<tr>
<th>Organic materials</th>
<th>Ceramic materials</th>
<th>Polymeric materials</th>
<th>Metallic materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waxes</td>
<td>Alumina</td>
<td>ABS</td>
<td>Aluminium</td>
</tr>
<tr>
<td>Tissue / cells</td>
<td>Mullite</td>
<td>Polyamide (nylon)</td>
<td>Tool Steel</td>
</tr>
<tr>
<td></td>
<td>Zirconia</td>
<td>Filled PA</td>
<td>Titanium</td>
</tr>
<tr>
<td>Silicon Carbide</td>
<td>PEEK</td>
<td>Thermo setting epoxies</td>
<td>Inconel</td>
</tr>
<tr>
<td>Beta-Tri calcium Phosphate</td>
<td>Ceramic (nano) loaded epoxies</td>
<td></td>
<td>Cobalt Chrome</td>
</tr>
<tr>
<td>Silica (sand)</td>
<td>PMMA</td>
<td>Polycarbonate</td>
<td>Copper</td>
</tr>
<tr>
<td>Plaster</td>
<td>Polyphenylsulfone</td>
<td></td>
<td>Stainless steel</td>
</tr>
<tr>
<td>Graphite</td>
<td>ULTEM</td>
<td></td>
<td>Gold / platinum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aluminium loaded polyamide</td>
<td>Hastelloy</td>
</tr>
</tbody>
</table>
# Main AM Technologies and impact on Metal

## Additive manufacturing technologies

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>MATERIALS</th>
<th>TYPICAL MARKETS</th>
<th>RELEVANCE FOR METAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powder bed fusion – Thermal energy selectively fuses regions of a powder bed</td>
<td>Metals, polymers</td>
<td>Prototyping, direct part</td>
<td>🟢</td>
</tr>
<tr>
<td>Directed energy deposition – Focused thermal energy is used to fuse materials by melting as the material is deposited</td>
<td>Metals</td>
<td>Direct part, repair</td>
<td>🟢</td>
</tr>
<tr>
<td>Sheet lamination – Sheets of material are bonded to form an object</td>
<td>Metals, paper</td>
<td>Prototyping, direct part</td>
<td>🟢</td>
</tr>
<tr>
<td>Binder jetting – Liquid bonding agent is selectively deposited to join powder material</td>
<td>Metals, polymers, foundry sand</td>
<td>Prototyping, direct part, casting molds</td>
<td>🟢</td>
</tr>
<tr>
<td>Material jetting – Droplets of build material are selectively deposited</td>
<td>Polymers, waxes</td>
<td>Prototyping, casting patterns</td>
<td>🟢</td>
</tr>
<tr>
<td>Material extrusion – Material are selectively dispensed through a nozzle or orifice</td>
<td>Polymers</td>
<td>Prototyping</td>
<td>🟢</td>
</tr>
<tr>
<td>Vat photopolymerization – Liquid photopolymer in a vat is selectively cured by light-activated polymerization</td>
<td>Photopolymers</td>
<td>Prototyping</td>
<td>🟢</td>
</tr>
</tbody>
</table>

Source: Roland Berger/Gardner/AMT
In 2012, around 190 metal AM systems were sold worldwide, of which 69% were made by the five German manufacturers.

Metal AM system manufacturers

AM SYSTEM MARKET

- Around 190 metal AM systems were sold in 2012
- Leading metal AM system manufacturers are located in Germany with a combined market share of 69%
- Recent consolidation (e.g. 3D Systems acquired Phenix Systems, DM3D acquired POM)
- Other small companies include Beijing Longyuan (CHN), DM3D (USA), Fabrisonic (USA), Irepa Laser/BeAM (FRA), Instek (KOR), Matsuura (JPN), Sciaxy (USA), Optomec (USA), Wuhan Binhu Mech. & Elect. (CHN), which sold 2 systems or fewer in 2012

Sources: CECIMO, Roland Berger, Gardner, AMT, Wohlers
Hybrid Manufacturing has two specific implications

- Hybrid manufacturing processes
- Hybrid machines (AM + conventional combined)
CECIMO is already active in the following International Standards Committees:

- CEN TC 143 (Safety of Machine Tools)
- ISO TC 39 (Machine Tools)
- NFPA 79/EN 60204 (Electrical Standard for Industrial Machinery)

AM Standards related to Machine Tool Sector:

- ASTM F42 [www.astm.org/COMMITTEE/F42.htm](http://www.astm.org/COMMITTEE/F42.htm)
Additive Manufacturing Standards

Structure of AM Standards

General AM Standards
- Terminology
  - ASTM F2792-12a
  - ISO 17296-1
  - ISO/ASTM 52921-13
- Processes/Materials
  - ISO 17296-2
  - Qualification and Certification Methods
  - Requirements for Purchased AM Parts
  - Non-Destructive Evaluation Methods
- Test Methods
  - ISO 17296-3
  - Test Artifacts
  - General Test Methods
  - Performance Test Methods
- Design/Data Formats
  - ISO 17296-4
  - ISO/ASTM 52915-13
  - Data Structures and Metrics for AM Models

Raw Materials
- Material Category-Specific
  - Metal Powders
  - Polymer Powders
  - Photopolymer Resins
  - Ceramics
  - etc.

Process/Equipment
- Process Category/Material-Specific
  - Powder Bed Fusion
    - Ti6-4
    - IN525
    - Others
  - Material Extrusion
  - Directed Energy Deposition
  - etc.

Finished Parts
- Standard Protocols for Round Robin Testing
  - Mechanical Test Methods – e.g., Part 1: Tensile Tests, Part 2: Porosity Tests, Part 3: Fracture Toughness, etc.
  - Metals
  - Polymers
  - Others
  - Part Specifications
  - etc.

Material-Specific Standards
- Material-Specific Size Specification
- Material-Specific Chemical Composition
- Material-Specific Viscosity Specification
  - etc.

Process/Material-Specific Standards
- Process-Specific Performance Test Methods
- Process-Specific Test Artifacts
- System Component Test Methods
  - etc.

Application-Specific Standards
- Aerospace
- Medical
- Automotive
  - etc.

General Top-Level AM Standards
- General concepts
- Common requirements
- Generally applicable

Category AM Standards
- Specific to material or process category

Specialized AM Standards
- Specific to material, process, or application

CECIMO presentation | January 2015
ASTM F42 and subcommittees

ASTM Committee F42 on Additive Manufacturing Technologies was formed in 2009 and meets twice a year, usually in January and July, with about 70 members attending two days of technical meetings. The Committee, with a current membership of approximately 215, has 4 technical subcommittees; all standards developed by F42 are published in the Annual Book of ASTM Standards.

Subcommittees and Standards - Standards under the jurisdiction of F42
Each main committee in ASTM International is composed of subcommittees that address specific segments within the general subject area covered by the technical committee. Click on the subcommittee links below to see the title of existing standards for each subcommittee. Then, click on the resulting titles to see the standard's scope, referenced documents, and more.

- **F42.01** Test Methods
- **F42.04** Design
- **F42.05** Materials and Processes
- **F42.90** Executive
- **F42.91** Terminology
- **F42.94** Strategic Planning
- **F42.95** US TAG to ISO TC 261
ISO TC 261 and other related standards

ISO/TC 261 was formed in 2011 and has the following scope: standardization in the field of Additive Manufacturing (AM) concerning their processes, terms and definitions, process chains (Hard- and Software), test procedures, quality parameters, supply agreements and all kind of fundamentals.

3) Existing Standards for other sectors relevant to AM

AM technologies are interdisciplinary and many materials, test methods and defined properties, some process steps and data preparation are similar to other industrial processes. For example:

- ISO/TC 61 "Plastics"
- ISO/TC 106 "Dentistry"
- ISO/TC 119 "Powder Metallurgy"
- ISO/TC 172/SC 9 "Electro-optical systems"
- ISO/TC 184/SC 4 "Industrial Data" i.e. data exchange of CAD/CAM systems
- ISO 13485 “Medical Devices”
- ISO 9001 “Quality management systems”
- CEN/TC 121: “Projects which affect welding”
- CEN/TC 138: “Non destructive testing”
ACTIVE standards under the jurisdiction of F42.05


- F3001-14 Standard Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium ELI (Extra Low Interstitial) with Powder Bed Fusion

- F3049-14 Standard Guide for Characterizing Properties of Metal Powders Used for Additive Manufacturing Processes


- F3056-14e1 Standard Specification for Additive Manufacturing Nickel Alloy (UNS N06625) with Powder Bed Fusion

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