Additive Manufacturing and AMC

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Outline

- **EWI**
  - Joining and allied technologies

- **Additive Manufacturing (AM)**
  - Metals - Laser and EB powder bed, EBFFF, Arc Welding, and VHP UAM
  - Plastics – FDM, SLA, SLM, VHP UAM

- **Additive Manufacturing Consortium (AMC)**
  - Need for collaboration, especially for design allowables data
  - Response and formation of AMC with 26 partners and members

- **Summary**
About EWI

- EWI, in Columbus, is an applied engineering services company that develops and commercializes advanced manufacturing technologies
- A global leader in materials joining technology
- Non-profit R&D organization whose mission is to advance our customers' manufacturing competitiveness through innovation in joining and allied technologies
- Serves over 230 member companies across all manufacturing sectors, with operations in over 1,200 locations worldwide
- $30M revenue, 140 staff, balanced portfolio of government and commercial projects
EWI - Advanced Manufacturing Technologies

- Additive manufacturing
- Advanced arc welding
- Automation, sensors, controls
- Brazing and soldering
- Dissimilar materials joining
- Friction welding and processing
- Hot forming
- Laser processing
- Nondestructive examination
- Numerical modeling and simulation
- Plastic and composite fabrication
- Resistance welding
- Ultrasonic joining
- Ultrasonic machining
- Weldability testing, mechanical testing, and metallurgical analysis
AM can eliminate joints between parts by integrating them.

But, the whole thing is a weldment made of 100’s or 1000’s of weld beads whether by EB, Laser, or other processes.

Rules of metallurgy and welding engineering apply!

These are ostensibly already available – e.g. bead spacing to avoid lack of fusion between beads – euphemistically called ‘porosity’.

Develop and optimize through DOE techniques to avoid ‘pores’ and minimize/eliminate need for HIP.

Need to inspect volumetrically as a weldment.
Additive Manufacturing

- Definition – Building a part from a 3D CAD model one layer at a time – defined by ASTM F42 committee for AM
- Genesis in Stereolithography in 1986 – curing a resin bath using a laser, one z-axis indexed layer at a time
- Possible now in machines for some metals, some polymers, and much interest in novel materials from hybrid metallic/polymer combinations to
- A field encompassing modeling/simulation, 3D CAD, materials, processes, sensors & controls, NDE
- Much interest in high-value added aerospace and medical fields and of growing interest in other markets
...to AM Part Fabrication

- Ultimately from machine directly to part

One step: reduces handling, logistics and supply chain, capital equipment, tooling, time, material waste, environmental impact
AM Processes for Metals

- EBW freeform fabrication - EB(FFF) (kg/hr)
- Laser powder and wire FFF from companies such as POM, Optomec (LENS)
- Laser and EB powder bed, from companies such as EOS, and Arcam in confined envelope (g/hr)
- Emerging - Arc processes – SMD, MER, GTAW-HW, GMAW-P, PTA (wire and powder) based on commercially available equipment for FFF (kg/hr)
- Emerging - VHP UAM – very high power ultrasonic AM of strip
Example Metals AM Processes

- Arcam EBM®
- Concept Laser DCM®
- Optomec LENS®
- EOS DMLS®
- MTT SLM® (No longer in business)
- Sciaky EBFFF
- MTS Aeromet LAM (No longer in business)
- Phenix Systems
- GTAW (Hot Wire)
Deposition Rate vs Resolution

Decreased Resolution

Increased Deposition Rate

As deposited

During machining

Finish machined

Courtesy Boeing
Overview – AM of Plastics

- The most popular AM processes include:
  - SLA
  - 3D Printing
  - FDM
- All plastic AM processes build up parts with successive layers of material
- Mathematically slices 3D models to generate finished parts from the bottom up
- Led by high demand and competition the material options, part qualities, and throughput continue to increase
Advantages

- Reduce development timeline by more efficiently moving from design to manufacturing
- Quickly evaluate real parts from CAD files
- Produce prototypes, conceptual models, manufacturing tools
- Can use various materials, two materials in one part
- Advanced prototypes with working components
- Build production parts while waiting for tooling to be completed
AM Processes for Plastics

- **Fused Deposition Modeling (FDM)**
  - Plastic is extruded from heated nozzle from the bottom up, one layer at a time.
  - A second nozzle builds support structure which must be dissolved in ultrasonic waterbath.

- **Stereolithography (SLA)**
  - A UV laser is used to cure consecutive layers of a liquid photopolymer.
  - The finished part must be cleaned in chemical bath and cured in a UV oven.
  - Fast speeds, very high resolution, and produces smooth surface finish.

- **3D Printers**
  - Printheads dispense droplets of liquid photopolymer – cured with UV lamp.
  - Support structures have to be cleaned by high-pressure water jets.
  - Fastest speeds, high resolution, and produces smooth surface finish.

- **Laser Sintering**
  - Layers of fine power are fused by CO2 laser to form a 3D part. Lose powder is blown away at the end of the cycle
Examples of Parts - Plastics

Two Materials

Soft Materials

Large Parts

Transparent Parts

Working Parts

Courtesy of Objet and 3D Systems
Personal Printers

- Small, personal 3D printers are becoming very popular
- Very popular for hobbyists and specialty shops
- Generally limited to small parts made with one material
- Complete systems are available for $15-20k
AM Benefits/Competitive Advantages

Different for each market, but in A&D/general:

- Enable new product design features - make things you can’t make any other way
- Make it cheaper (fewer operations, simplified supply chain) – consider total life cycle costs and an holistic approach
- Reduce time to innovate and launch new products
- Support lean/agile manufacturing
- Produce replacement parts for legacy systems
- Reduce material waste and energy usage
- Support environmental sustainability
AM Value Proposition

- Different for each industry but for A&D;
  - Primes want high quality cheaper parts, on shorter delivery cycles from a diverse and financially healthy supply base
  - Supply base wants revenue from Primes/OEMs based on their competitive advantage in processing/quality/consistency
  - No-one wants to pay for the $XMs to generate the required mechanical properties
  - Collaboration affords sharing costs for data development
  - Business analysis – very little data in public domain, regarding the true cost/cost reduction as very few parts are in production. EBFFF meets the cost requirements for large aerospace parts in Ti-6-4, but may be too expensive for other industries – hence the need to develop/qualify other processes
  - The ‘chicken and egg cycle’ needs to be broken for public domain data funded by government agencies
  - Europe has/is spending $56M to date since 2004
Example Aerospace Applications

- EB FFF and laser powder (DMLS) parts
- LM Aero calculate 50% cost reduction for EBFFF versus forging for JSF
Ti-6-4 Vehicle Control arm with GTAW-HW

- First layer and completed deposit
Demonstrated arc-based processes for low cost, high deposition rate Titanium additive manufacturing
- GMAW-P
- RWF-GMAW
- PAW (Cold Wire)
- PTA (Powder)
- GTAW (Hot Wire)
Ultrasonic Additive Manufacturing (UAM)

- Increases design flexibility and reduces manufacturing waste
- Enables use of internal channels, sensors, and actuators
- Very high power, large envelope, multi-material system for use in development and manufacturing
- Status: Formed Fabrisonic LLC to build/deploy systems
The Additive Manufacturing Consortium (AMC) was founded to provide a U.S. AM forum and is already attracting international interest.

- Consortium of industry, government, and research organizations.
- Mission: Advance the manufacturing readiness of metal AM technologies to benefit consortium members.
- Goal: Collaboration to generate needed precompetitive data, design allowables data.
Advancing Manufacturing Readiness – Crossing Valley of Death

- MRL 8-10
  - Incremental improvements and implementation
  - Short time horizon

- Additive Manufacturing Consortium
  - MRL 3-7
    - Significant commercial impacts in 2-5 years

- University & Federal Labs
  - MRL <3
    - High-risk basic research and education
    - Long time horizon
EWI Supporting Activities

- Attended RAPID 2010, Amerimold, and the Loughborough 2010 AM conference and F42 meeting
- EWI serves on ASTM F42 Materials and Processes Working Group establishing standards for metals AM
- Gained interest/traction in the ground vehicle market in addition to aerospace
- Recently installed a large new machine for VHP UAM (based on Ohio DOD Third Frontier funding)
- ODOD award just announced for $2.5M for laser-assisted VHP UAM
- Started a new AF HMI project with a $200K scope for AM - active heat sink using VHP UAM
- ODOD Advanced Energy project on AM Landscape and supplier base completed
EWI Supporting Activities

- Presented AM and AMC at AeroMat, Bellevue, June 2010
- Presented Ti AM and AMC at ITA Conference, Orlando, 2010, and San Diego in 2011
- Presented at NDIA meeting in D.C. in October, 2010
- Presented LAM and AMC at LAM 2011, Houston
- Chairing and presenting at an AM session at Aeromat 2011
- Presented AM and AMC at Deep Offshore Technology, New Orleans, Oct 2011
- Organized (jointly with OSU, NCSU, UL and Arcam) an AM of Metals Symposium for MS&T Columbus, in October 2011—50 papers in 6 sessions over 4 days
AMC

- Rapidly growing network of 26 industry members, government, and university partners – more welcome
- Launched Feb. 2010
- First Members Meeting Dec. 7, 2010
- Recognized AM Aerospace and Defense consortium – *Aviation Week* article Nov. 2010, Financial Times, Dec 2011
- Common voice for coordinated advocacy toward government agency funding of critical needs
- AMC voted to expand to all materials Dec. 2011 - now seeking to add members and serve needs in polymers
- Defining JIP for Arcam EBM
Goal – Advance the manufacturing readiness of additive manufacturing for the Nation

Government Agencies
- Air Force (Steve Szaruga)
- Army (Stacey Kerwien)
- NASA (Craig Brice)
- NAVAIR (Bill Frazier)
- NIST (Kevin Jurrens)

Industrial Members
- GE
- R-R
- Boeing
- Lockheed Martin
- Northrop Grumman
- General Dynamics
- Goodrich
- Honeywell
- Sciaky
- EOS
- Morris Technologies
- Applied Optimization
- B6Sigma

Universities/National Labs and Other Invited Partners
- EWI
- The Ohio State University
- University of Louisville
- University of Texas
- North Carolina State University
- South Dakota School of Mines
- Lawrence Livermore National Lab
- TechSolve
- NCMS
- Wohlers Associates
AMC - Proposed 1st Year Goals Achieved

◆ Obtain broad industry and government support – achieved for A&D, reaching out to power, energy, and heavy fabrication community
◆ Organize “National Test Bed Center” research partners network – in place with extensive equipment and staff resource capabilities
◆ Identify technology priorities and create development plan – priorities identified for Ti and Ni-based alloys.
◆ Conduct state-of-the-art review of metal AM technology – complete (EWI - Herderick, Kapustka, Harris)
◆ Establish a database for collecting metal AM property information – will use MMPDS – decided at 6.7.2011 mtg
AM Part Fabrication

- Ultimately from machine directly to part – but must meet cost requirements for paradigm considered
- Many processes, many materials, many potential solutions, for many markets – a viable and exciting industry in formation

reduces handling, logistics, capital equipment, time, material waste – need an holistic approach to cost – often not taken
AM is rapidly developing with technologies providing both complementary and competing attributes in metals and plastics – may the best process win, for the paradigm in question!

For metals, Develop, optimize and inspect as a weldment!

A whole new industry and supply chain is in formation for this exciting field

The Additive Manufacturing Consortium (AMC) offers precompetitive collaboration - Join us!

Europe has spent $56M and the US needs coordinated government funding to quickly advance technology here
Questions?

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Since the early 1980s, EWI has helped manufacturers in the energy, defense, transportation, construction, and consumer goods industries improve their productivity, time to market, and profitability through innovative materials joining and allied technologies. Today, we also operate a variety of centers and consortia to advance U.S. manufacturing through public/private cooperation.