Additive Manufacturing Repair and Feature Addition for Metallic Components

Michael Tims, Kenneth Sabo

Concurrent Technologies Corporation
Johnstown, PA

Digital Bridge 2018

01 November 2018

This presentation was prepared by Concurrent Technologies Corporation and is approved for public release; distribution is unlimited.

Background

- Additive manufacturing (AM) is a viable method for producing metallic components, especially for parts less than ~12″ × 12″ × 12″ on a powder bed system – the most common AM hardware
  - Powder bed systems are extremely limited in repair functionality
  - Directed energy deposition (DED) and cold spray (CS) are more amenable for part repair via metal addition
- Hybrid systems are emerging that couple AM and machining (i.e., subtractive manufacturing) in single machine setup resulting in:
  - Improved surface finish
  - Better geometric tolerances

  } Relative to as-built AM
- Focus of presentation: DED-hybrid as a potential repair or feature addition technology for metallic components

Directed Energy Deposition (DED)

- Metal powder carried to melt pool via protective carrier gas
- Additional protective gas forms shield around weld pool
- Energy source (laser or electron beam) melts metal
  - Wire-based systems also available
- Material deposition efficiency: ~80–98%
- Relative motion between deposition head and workpiece
  - Deposition head and/or workpiece may move

Hybrid DED Systems

- Several systems exist on market
- Discussion focus: Ambit® from Hybrid Manufacturing Technologies
  - Incorporated into existing CNC machining center
  - DED head selected like machine tool in carousal
    - Requires docking station to supply gas, powder and laser
  - Weld pool protected by shielding gas
  - Deposition rates: 0.1–2.5 kg/hr
  - Uneven surface: usually needs to be machined
- Standard G or M code used
  - Well known by machinists
- Bond strength similar to weldment

Photos courtesy of Hybrid Manufacturing Technologies

CTC's Ambit System

- Integrated into Haas VF11 vertical machining center
- Maximum working envelope
  - 120″ × 40″ × 30″ for 3-axis applications
  - 120″ × 40″ × ~20″ for 4-/5-axis applications
- Currently 2 separate powder hoppers
  - Allows for transition in allow type; functional graded build
  - Expandable to 4 or more separate powder hoppers

Benefits of Hybrid DED

- Single machine tool setup
  - Chuck Part → Prepare Surface → Confirm Geometry → Add Metal → Machine → Inspect → Finished Part
    - Repeat Add Metal → Machine several times during “typical” build
    - May also require subsequent thermal treatment and final machining
  - Reduced turnaround time
  - Improved tolerances
  - Improved part-to-part consistency
- Allows for repair of existing parts, reducing impact to environment
- Machining center remains available as a machining center
- Ambit may be used for laser welding or laser etching

Component Build with DED

- Not restricted to flat planer addition of metal
- Incorporate substrate into final part
  - Substrate (e.g., wrought or cast) unit cost << powder
    - Titanium plate ~$90/kg
    - AM titanium powder ~$240/kg + ~$220/kg for AM machine use
  - Allows for more rapid part production
  - In some circles, more accepted product form

Build features on large tube*

*Photo courtesy of Hybrid Manufacturing Technologies in collaboration with Mazak

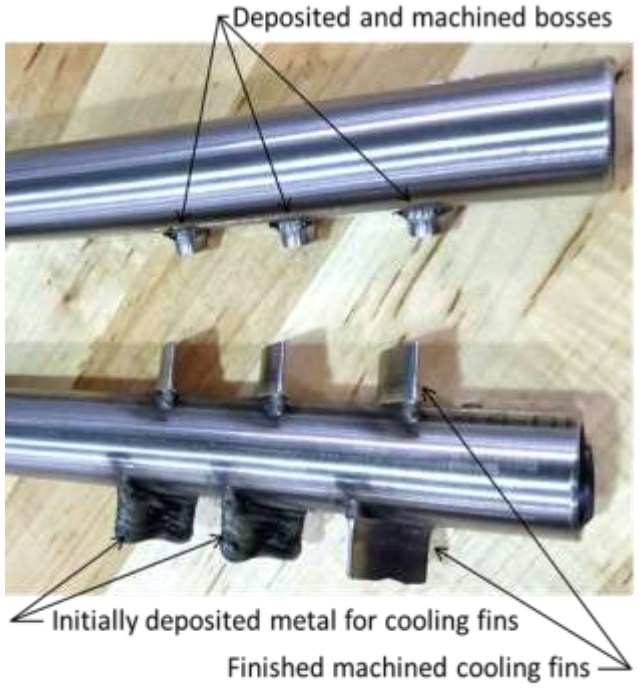
Properties of Inconel® 718 DED AM Builds

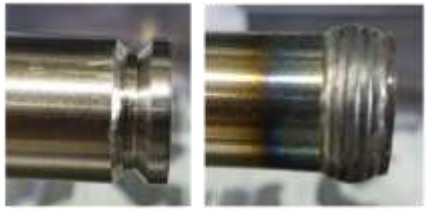
	As-Deposited Reference [1]	As-Deposited Testing at CTC	As-Hot-Rolled Bar [1]
Yield Stress, N/mm² (ksi)	587 (85)	768 (111)	591 (86)
Ultimate Tensile Strength, N/mm² (ksi)	931 (135)	990 (144)	965 (140)
Elongation, %	31.7	14	46
Reduction of Area, %	31.2	20	58
Hardness, HRC	23	N/A	23

- Thermal processing may be used to modify final properties
  - Homogenization – improve chemical uniformity
  - Hot isostatic pressing – eliminate/reduce porosity

[1] Yamazaki, T. (2106), "Development of a Hybrid Multi-Tasking Machine Tool: Integration of Additive Manufacturing Technology with CNC Machining," Proceedings of the 18th CIRP Conference on Electro Physical and Chemical Machining, pp. 81–86.

Examples of DED Builds/Repairs

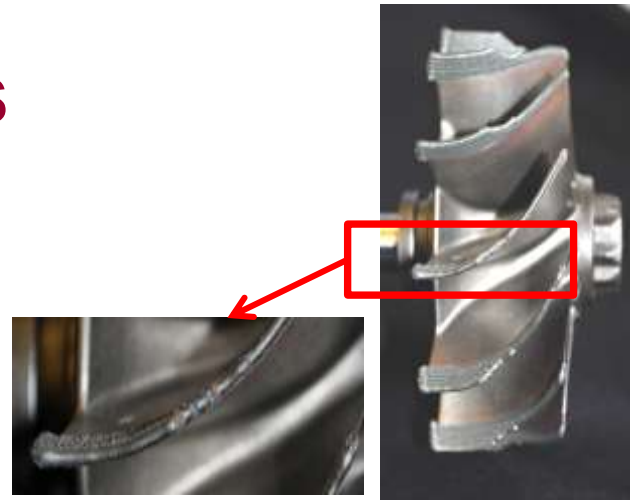




Initial plug insert and as-deposited material for end cap

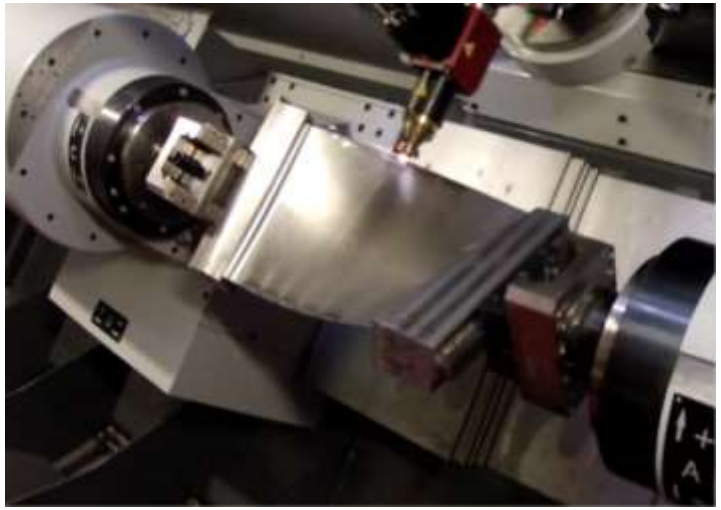
Flange with die penetrant showing no surface-connected voids

Construction of high-temperature heat exchanger tubes at CTC



Pre-machined re-tipped turbocharger impeller*

Hybrid Manufacturing Technologies now qualified by GE to repair tips on large class of turbine blades



Repair of a gas turbine blade edge*

*Photo courtesy of Hybrid Manufacturing Technologies

Other Considerations for DED

- DED amenable for wide variety of metallic and metallic/ceramic materials
  - Ambit system used with nickel, stainless steel, cobalt, bronze, tool steel, copper and MMC alloys
  - Ambit system can also be used with aluminum and titanium alloys
    - Requires separate glovebox flooded with argon
    - Other DED/hybrid systems currently designed within sealed chamber allowing for immediate application of aluminum or titanium alloys

Conclusions

- Hybrid DED AM is useful for:
  - Repair of metallic components
  - Build up of features on commonly shaped, lower-cost substrates
- Cold spray has been successfully applied to the repair of several metallic components
- L-PBF has limited practical use for repair of metallic components
- Prior to wider application of AM repair technologies, qualification for specific alloys, and in some instances for specific components, must be completed
- As AM processes continue to mature, expect an increase in the number of parts repaired by AM processes

digitalbridge 2018

PITTSBURGH'S INDUSTRY 4.0 CONFERENCE

Bank of America Merrill Lynch

COMCAST BUSINESS

ARM ADVANCED ROBOTICS FOR MANUFACTURING

ectobox

America Makes

RiverPoint TECHNOLOGY

INTERSTACKS

datanomix

PA MEP PENNSYLVANIA MANUFACTURING EXTENSION PARTNERSHIP

CATALYST CONNECTION
Your Strategic Partner for Manufacturing Growth