SUCCESS STORY

Establish Laser Hot Wire (LHW) process as a reliable and robust solution for heavy fabrication applications for aerospace and energy sectors

LHW creates quality metal parts using less energy

Typical welding wire in spool form such as shown was used in these experiments.

A FANUC welding robot was used in creating test parts by LHW process.

PROBLEM

Direct additive manufacturing of metal parts is limited by cost and availability of consumables, build times, and steep temporal and spatial thermal gradients which compromise metallurgical/microstructural control.

OBJECTIVE

The overall objective of this project was to assess the relative strengths of laser hot wire (LHW) deposition of nickel and titanium alloys as the basis of high-rate deposition methods simultaneously capable of low net heat input such that metallurgical control can be demonstrated.

An additional objective was to assess the feasibility of LHW to be a potential alternative process in the additive manufacturing (AM) industry.

TECHNICAL APPROACH

Energy efficiency, material characterization, and mechanical properties testing analyses were conducted through several shapes and features of specimens fabricated by the LHW process. In addition, these results were benchmarked against specimens created by a laser powder-based additive manufacturing process in the case of a titanium alloy.

There were two different metal materials systems used for this project: the nickel-based superalloy 625 and Ti-6Al-4V. For nickel alloy 625 the targeted application was creating corrosion resistant properties for extension of life cycles for complex steel substrates used in oil and gas applications. Ti-6Al-4V with its key properties of high strength-to-weight ratio compared to iron-based alloys, high melting point (roughly at 1670°C, or 3035°F), and high corrosion resistance particularly oxidizing and chloride-containing process streams, making it desirable for aerospace applications. These two alloys systems were selected with an intention to assist the extension of AM to corrosion sensitive application areas and demonstrate AM as an alternative to forgings of important lightweight structural alloys.

Lincoln Electric, the integrator and manufacturer of the patented LHW machinery, supplied the feedstock of filler metal wire that is used in the LHW experiments for nickel alloy 625 (sold commercially under the name Techalloy® 625). Arconic supplied the Ti-6Al-4V wire. Both are commercially available as products of the respective companies. In all experiments the wire size used was 0.045 inch (1.14 mm) in diameter.

AMERICA MAKES TECHNOLOGY DEVELOPMENT ROADMAP

This project aligns to:

PROCESS

ASTM PROCESS CATEGORY:
Directed Energy Deposition

EQUIPMENT:
Laser Hot Wire

MATERIAL:
Techalloy® 625
Ti-6Al-4V

ACCOMPLISHMENTS

LWH was demonstrated to operate with low-net heat input with melt superheats of less than 200°C. Two materials were used in the demonstrations for this project — Titanium (Ti-6Al-4V) and nickel alloy 625.

Comparisons to powder-bed technology were made to the efficacy of building parts using the same CAD model. Both processes produce near-net shape and while powder bed generates a nearer approximation to final shape, LHW shows improved thermal management resulting in less distortion overall. Both processes require additional finishing operations. Following machining, the LHW parts were inspected with ultrasound.

The following applications have been identified by industry sector:

Oil and Gas: Nickel alloys as a cladding for caster rolls, chocks, and housings that are subject to harsh environments and corrosion.

Aerospace: Titanium forgings for structural airframe components are driven by mechanical properties such as durability and damage tolerance.

A number of LHW systems are now operational at customer locations at the conclusion of the project with many engaged and potential customers anticipated.

Case Western Reserve University offers a graduate and undergraduate-level course "Additive Manufacturing of Metals, Polymers & Ceramics" that features this project and its results. Select lectures are available to America Makes members.

Several presentations have been made at trade organization events and for private companies.

PROJECT END DATE

March 2016

DELIVERABLES

- Material supply established thru delivery of substrate material on-site
- Process optimization/ arc suppression validated thru parametric analysis with samples for property assessment
- Property characterization, Initial assessment of structure
- Characterization of critical properties/ modeling assessment of properties in harsh environments report finalized and compared against benchmarks
- Comparative assessment of AM processes
- Course Lectures/Modules

All downloadable deliverables are available to America Makes members via the Digital Storefront

FUNDING

$702K total project budget
($341K public funding/$361K private funding)

PROJECT PARTICIPANTS

Project Principal:
Case Western Reserve University

Other Project Participants:
The Lincoln Electric Company
Arconic Titanium Engineering Products
RP+M
AZZ / WSI, LLC
DNV-GL USA

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U.S. Department of Energy

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