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Large Scale Metal Additive Manufacturing with Wolf Robotics

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June 2017

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OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

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Advanced Manufacturing Office
Energy and Transportation Science Division

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ABSTRACT

Large Scale Metal Additive Manufacturing (LSMAM) is a new additive manufacturing (AM) technology based on the metal arc welding process. A continuously fed metal wire is melted by an electric arc that forms between the wire and the substrate and is deposited in the form of a bead of molten metal along the predetermined path. Objects are manufactured one layer at a time starting from the base plate. The final properties of the manufactured object are dependent on its geometry and the metal deposition path, in addition to depending on the basic welding process parameters. The focus of the first phase of this two-phase program was the installation, initial operation and development of processing parameters to demonstrate the ability to manufacture metal large scale parts. The second phase of the project will focus on the development, and validation, of process models for the system.

1. Wolf Robotics Workstation

This phase 1 technical collaboration project (MDF-TC-2016-093) was begun on July 20, 2016 and was completed on May 31, 2017. The collaboration partner Wolf Robotics is a large business.

1.1 System installation

The Oak Ridge National Laboratory (ORNL) Manufacturing Demonstration Facility (MDF) took delivery of the new Wolf Robotics (WR) Wolfpack system with a Metal Inert Gas (MIG) welder on June 23, 2016 (Figure 1). The Wolfpack system includes a safety enclosure for both optical (welding) and physical (robot) hazards.

Figure 1: Wolfpack installation

Initial efforts were focused on getting all research safety summaries and procedures approved, all utilities installed and the system operational. The system was operational by August 16, 2016 (Figure 2). For remote viewing, the system has thermal imaging, a welding camera and a nest camera (Figure 3).

Figure 2: Operational system

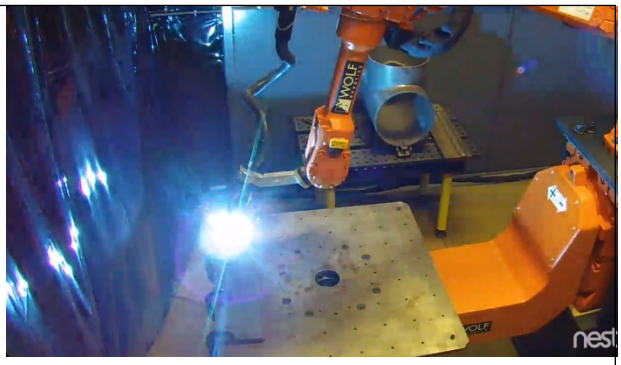

Figure 3: Nest camera view

1.2 CAD TO PART

Once the Wolfpack system was in place at the MDF the next step was to integrate software controls between the Wolfpack and the slicing software that controls the layer toolpath for each printed object. To integrate the software, ORNL worked with Wolf to develop a translator for the existing ORNL Slicer software (see Figure 4). The Slicer software now has a Wolf Robotics printer with a Wolf material selection option. The software uses the exact same interface and has a translator to transform the standard g-Code output to the required Wolf Robotics input commands.

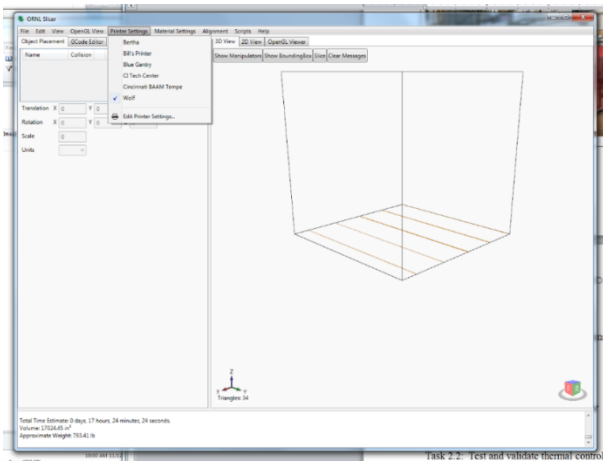

Figure 4: Wolf printer setting

The team then successfully demonstrated the ability to print large objects with complex geometries. The part shown in Figure 5 required no modification to the output file of the Slicer. The part took approximately 18 hours to print and weighs 48 pounds. The mild steel printed part was a test piece designed to validate process parameters. The team identified current angle limitations (15 degrees), feed rates and robot speeds. This part is a generic complex geometry that captures many of the basic complexities in additive manufacturing (varying cross section, overhanging structures…).

Figure 5: CAD to part demonstration

1.3 MECHANICAL PROPERTIES

In terms of mechanical testing, Figure 6 shows the stress/strain curves for mild steel (ER70S-6) in the x (bead direction), y (bead to bead) and z (layer to layer) directions. For this work walls were printed that were useful to provide test samples. These results are preliminary and can be improved with refinement of the processing parameters. However, the results are encouraging. The resultant properties are within 5% of the bulk material properties. The degradation in the z direction is expected due to small amounts of porosity. Further work will continue to refine the processing parameters and improve on the material properties.

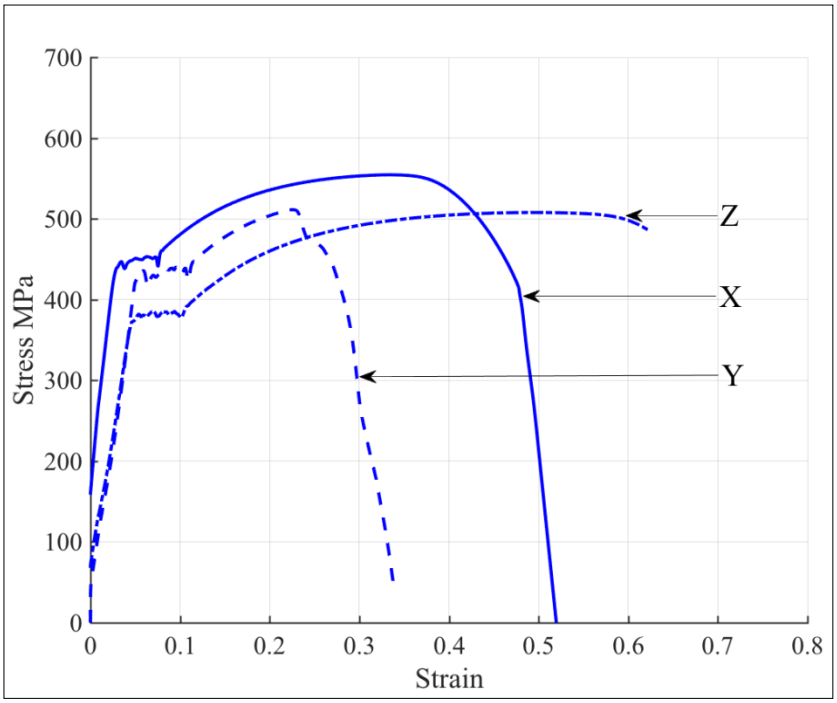

Figure 6: Tensile properties in X, Y, Z direction

The work with Wolf was displayed at FabTech and named the best new technology for the show.

1.4 IMPACTS

1.4.1 Subject Inventions

There are no subject inventions associated with this CRADA.

1.4.2 Publications

The following publications involve the DOE AOP in large scale metals but were completed using the Wolf Wire Arc System and are therefore related.

The Role of Robotics in Large Scale Metal Arc Additive Manufacturing, Andrzej Nycz, Mark Noakes, Bradley Richardson, Suresh Babu, Lonnie Love, Fabtech 2017, Chicago, November 6-9, 2017, Conference presentation. Resolution ID: 73741

N. Sridharan, Mark W. Noakes, Andrzej Nycz, Lonnie J. Love, Ryan R. Dehoff, Sudarsanam S. Babu, "On the Toughness Scatter in Low Allow C-Mn Steel Samples Fabricated Using Wire Arc Additive Manufacturing," Materials Science and Engineering: A, Vol 713, pp 18 - 27, Elsevier, January 2018.

Srdjan Simunovic, Andrzej Nycz, Mark W. Noakes, Charlie Chin, and Victor Oancea. "Modeling and Validation of Metal Big Area Additive Manufacturing," International Conference on Plasticity, Damage, and Fracture 2018. San Juan, Puerto Rico. January 3-9, 2018.

Andrzej Nycz, Mark Noakes, Lonnie Love. "Metal Big Area Additive Manufacturing - A New Emerging Technology," Design and Manufacturing-3D Printing Innovation Summit. Anaheim, CA. February 6-8, 2018.

Mark Noakes, Andrzej Nycz, Bradley Richardson, Rodrigo Rimando, "Additive Manufacturing Advances to Facilitate Novel Robot and Remote System Construction," 2018 WM Symposia: Nuclear and Industrial Robotics, Remote Systems and Other Emerging Technologies, Phoenix, Arizona, March 18 – 22, 2018.

Andrzej Nycz, Mark Noakes, Maciej Cader, "Additive Manufacturing - A New Challenge for Automation and Robotics," Automation-Innovations and Future Perspective Conference. Plenary talk. Warsaw, Poland March 21-23, 2018.

2. WOLF ROBOTICS BACKGROUND

Wolf Robotics has been delivering advanced automation solutions to some of the toughest production challenges globally since 1978. With over 8,400 installations worldwide, Wolf Robotics' expert staff designs manufacturing systems that result in faster, safer and higher-quality production.

Wolf Robotics, LLC is a member and participant in various industry organizations including: The American Welding Society, Fabricators & Manufacturers Association, Association of Equipment Manufacturers, Edison Welding Institute and Robotic Industries Association. We are also members of AmericaMakes, LIFT, and DMDII. Wolf Robotics was one of the first companies to be named a "Certified Robotic Integrator" by the Robotic Industry Association in 2012, and achieved re-certification in 2014. Wolf continuously trains and certifies personnel in assorted techniques and processes that benefit customer support services, such as 6 Sigma, CWI (Certified Welding Inspector) and CRAW-T (Certified Robotic Arc Welding Technician). In August of 2015, welding equipment and consumable manufacturer Lincoln Electric acquired Wolf Robotics due to their expertise in robotic welding.