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Large Scale Metal Additive Manufacturing with Wolf Robotics Phase 1

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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

LARGE SCALE METAL ADDITIVE MANUFACTURING WITH WOLF ROBOTICS

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Prepared by
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ABSTRACT

Large Scale Metal Additive Manufacturing (LSMAM) is a new additive manufacturing (AM) technology based on the metal arc welding. 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.

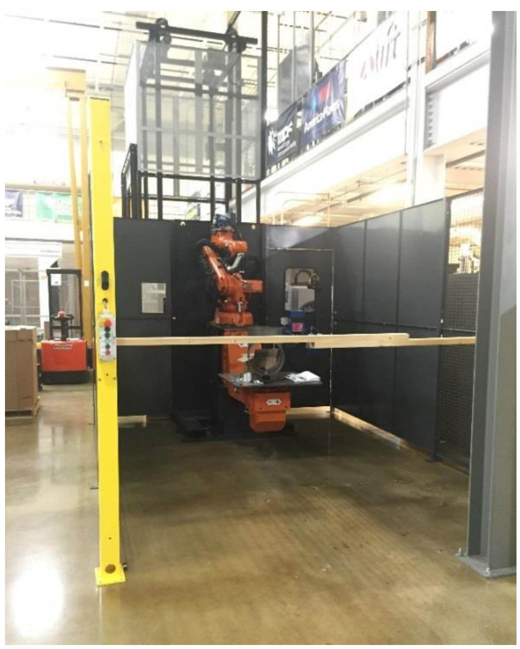

Figure 1: Wolfpack installation

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.

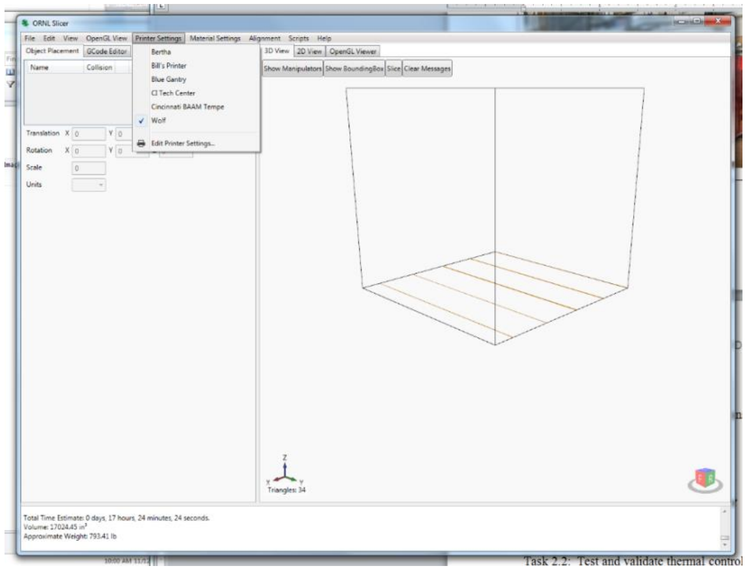

Figure 4: Wolf printer setting

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 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 steel in the x (bead direction), y (bead to bead) and z (layer to layer) directions. Coupons were cut from hexagons manufactured on the system. 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.

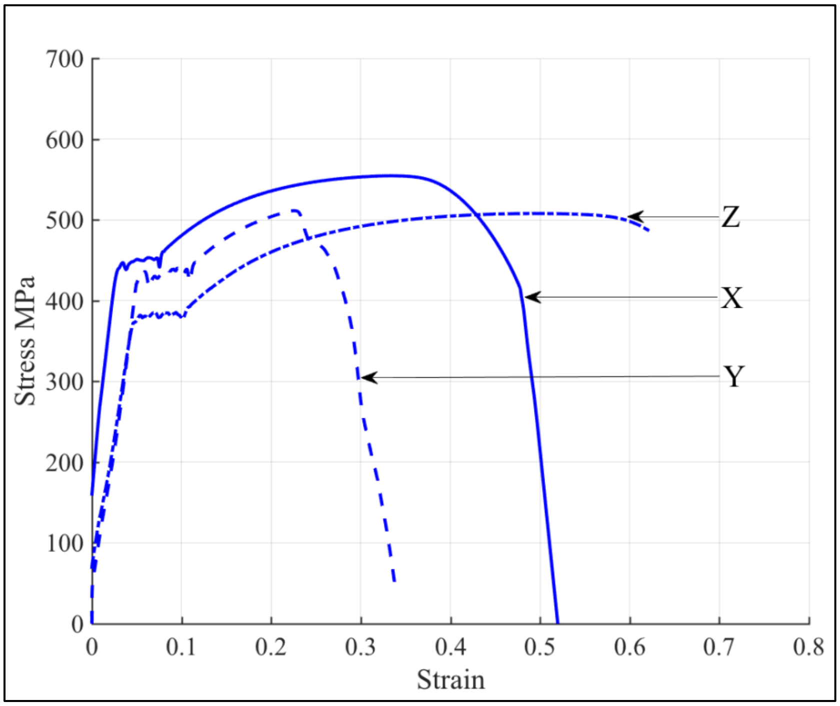

Figure 6: Tensile properties in X, Y, Z direction

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

2. Proposed Phase 2 Efforts

The primary focus of Phase 2 will be to develop and validate thermal modeling of the process and incorporate thermal behavior of the process in the toolpath generation software. Below is a high level description of proposed activities.

> Task 2.1 (ORNL): Month 4 –ORNL will develop a simplified thermomechanical model, leveraging prior work on FDM modeling, to predict the thermal center of mass and plane for a geometry.
>
> Task 2.2 (ORNL): Month 5 –ORNL working with Wolf, will modify the current slicing software to bisect the geometry, based on the thermal center of mass, and develop toolpaths including base rotation for manufacturing geometries. Wolf, working with ORNL, will incorporate the slicing software, process monitoring, and thermal process management tools into their proprietary control system.
>
> Task 2.3 (ORNL/WR): Month 6 – ORNL and WR will manufacture simplified test articles (cylinders and boxes), validating the hypothesis with thermal imaging and residual stress measurements. If successful, the team will explore non-symmetric geometries with the goal of printing an organic structure with an internal lattice structure.
>
> Task 2.4 (ORNL/WR): Month 8 - ORNL and WR will write a CRADA final report covering the results of the program and demonstration of baseline system capabilities for a Robotic MMAAM system.

Deliverables: D2 – end of phase 1 (12 Months from start of project) ORNL and WR will deliver a CRADA final report to DOE.

3. 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.