SUCCESS STORY

Pushing the boundaries of AM using a Multi^{3D} system to manufacture complex geometric dielectric structures

Increasing Capability & Reducing Cost of Fully Commercializable Hybrid Platform

A five-axis motion system, collectively referred to as Multi^{3D} manufacturing, provides spatial control of material and functionality within a single enclosure containing a suite of complementary additive and subtractive manufacturing processes.

PROBLEM

Current Multi^{3D} technology is cost and space restrictive for multifunctional aerospace component fabrications that require both additive and subtractive technologies (hybrid manufacturing). A system that provides spatial control of material and functionality as structures are created layer-by-layer with a suite of complementary manufacturing processes blended together was successfully demonstrated at the University of Texas El Paso (UTEP) under a previous America Makes program (Project 4030: 3D Printing Multifunctionality in Additive Manufacturing for Aerospace Applications). The developed system configuration, however, provides a production-level system with a footprint size and cost that is prohibitive for small to medium-sized enterprises (SMEs).

OBJECTIVE

The goal of this project was to develop a low cost industrial system for hybrid manufacturing that is housed within a single enclosure. The system includes embedding tools for wire and foil applications and toolpath generation software to enhance commercialization efforts particularly among SMEs and for applications requiring high quality complex parts.

TECHNICAL APPROACH

To develop a low cost system that integrates additive and subtractive technologies for fabricating state-of-the-art thermoplastic structures with intricate detail and embedded metallic traces and surfaces serving as conductors, the project team performed the following tasks:

- Worked with an El Paso-based engineering design firm to develop all elements of the structural and electrical functionality of a system
- Incorporated machine vision, a tool rack, and automatic tool change plates into a gantry system with a machining spindle
- Designed and incorporated wire and metal foil embedding capabilities
- Incorporated pellet-fed extrusion via a Strangpresse extruder
- Developed toolpath planning software for use with the Multi^{3D} system, concurrent with the machine design
- Produced and evaluated industry relevant parts against functional requirements to demonstrate the system capabilities

AMERICA MAKES TECHNOLOGY DEVELOPMENT ROADMAP

This project aligns to: PROCESS

ASTM PROCESS CATEGORY: Material Extrusion

MATERIAL: Polymers (with wire and foil embedding)

ACCOMPLISHMENTS

The Multi^{3D} system was designed and assembled with a five-axis motion platform to accommodate additive manufacturing, subtractive manufacturing, and foil/wire embedding processes with the capability to design and manufacture multifunctional components within a single enclosed unit. The system offers hybrid capabilities at a fraction of the cost of a commercial AM system. In addition, the footprint size was reduced from 307 to 84 square feet, when compared to its predecessor (the foundry Multi^{3D} system).

The ability to alternate between developed tools was crucial to the success of the overall system. A tool changing subsystem was developed that contained a master tool plate mounted on a gantry. The tool heads included a pellet-fed and filament extrusion tool with multilateral dual extrusion capabilities, a tangential wire embedding tool, and a foil application tool. An integrated camera provided precise tool-to-substrate calibration and placement.

Software was developed to read CAD models with incorporated toolpaths for wire embedding, foil embedding, machine vision, and robotic component placement. The software processes the CAD model to generate code that enables the specific functions required to produce the build. This allows the user to freely design a part that contains material extrusion with any of the supporting processes, which the system can interpret and perform. To gather CAD information and interface with toolpath generation software, SolidWorks macros were developed to work seamlessly with Cura and UTEP's custom add-ins to produce G-codes. A graphical user interface (GUI) utilizing Autodesk Fusion 360 and Python programming language simplified repetitive tasks in the user's active design such as the creation of component cavities within a build.

The integration of the machine vision system (MVS) for quality control and pick and place optimized the registration process between the various technologies of both additive manufacturing and subtractive machining within the system which simultaneously improved the part build quality and accuracy.

Testing was performed and each of the system's tools (wire embedding, foil embedding, machine vision, and robotic component placement) were successfully demonstrated. The design of a propulsion device was completed and iteratively fabricated showing the capability to embed wire in thermoplastic material while placing a thruster component (designed by Busek) within the build. Another device was designed to perform as a thermal panel for the Air Force Research Laboratory (AFRL) illustrating the wire and multiple electronics embedding approach to manufacturing. A final demonstration was a 2.4GHz patch antenna for AFRL to show the added functionality offered by patterned embedded copper foils.

PROJECT END DATE

July 2017

DELIVERABLES

- Low cost Multi^{3D} system design
- Low cost Multi^{3D} system assembly report
- Report on wire embedding head design
- Report on foil embedding head design
- Complete Multi^{3D} hardware report
- Toolpath generation software report
- Complete system control architecture report
- Industry relevant demonstrations and test pieces fabricated
- Train-the-trainer educator 3D printing boot camps

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

FUNDING

$2M total project budget
($1M public funding/$1M private funding)

PROJECT PARTICIPANTS

Project Principal:
University of Texas at El Paso

Other Project Participants:
Northrop Grumman
Strangepresse
AST2
Draper Laboratory

Public Participants:
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U.S. Department of Energy

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