PennState Applied Research Laboratory

Project Report

Acoustic Materials Additive Manufacturing System

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This project completed the acquisition and assembly of a system for additively manufacturing advanced viscoelastic materials for undersea applications. A large scale system (with a build area of 3 ft x 3 ft x 1 ft) was designed and built in order to enable the production of undersea parts. Material deposition is done using a two-part mixing extruder that enables the printing of standard existing resin materials as well as the ability to extrude novel materials that are tailored for specific material properties and processing requirements. This machine is controlled using standard 3D printing gcode for motion control, allowing for both the use of open-source machine motion control generation and/or custom control that allows for process and geometry optimization.

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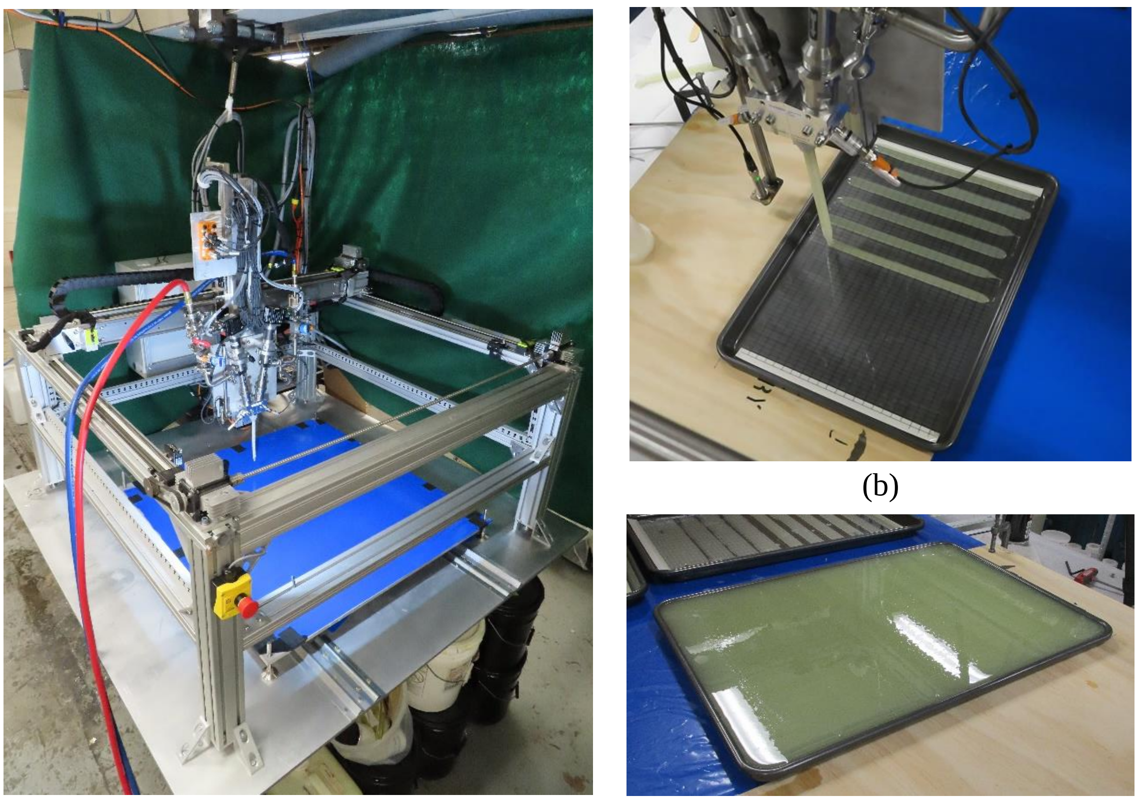
1 Project Summary

This project completed the acquisition and assembly of a system for additively manufacturing advanced viscoelastic materials for undersea applications. A large scale system (with a build area of 3 ft x 3 ft x 1 ft) was designed and built in order to enable the production of undersea parts. Material deposition is done using a two-part mixing extruder that enables the printing of standard existing resin materials as well as the ability to extrude novel materials that are tailored for specific material properties and processing requirements. This machine is controlled using standard 3D printing gcode for motion control, allowing for both the use of open-source machine motion control generation and/or custom control that allows for process and geometry optimization.



(a) (b) (c)

Figure 1: The additive manufacturing extrusion system that dispenses two-part resin materials in 3D space, where (a) shows the system, (b) shows printing of singular roads, and (c) shows a part.

2 System

2.1 Large-scale 3-axis motion

2.1.1 Mechanical

A Cartesian movement frame was constructed with aluminum structural framing and linear slides to a floor anchored platform over a rail system to load and unload printed components to a lift cart for processing. Axis motion is along precision linear rails along primary coordinate system with corner origin. Y-axis is dual stepper motor contained belt driven slide with ~50lb working capacity and stable translation speed of >3ft/min. X-axis is a stepper motor contained belt driven slide linked to a heavy duty linear slide to accommodate overhung z-axis load. The Z-axis is a direct drive ball screw stepper motor driven slide.

2.1.2 Electrical

The electrical heart of this gantry system is a RepRap Arduino-Due Driver Shield (RADDS V1.5) 32bit RepRap compatible controller. For this specific installation, stepper expansion board to increase possible extruders and LCD interface was added to the RADDS 1.5 board. The supporting electrical system was designed such the central controller can be changed with any controller with discrete stepper driver modules to prevent rapid obsolesce. Discrete stepper motor drivers were removed and custom circuit boards were installed that provide a connector for direct connection from each RADDS motor control sockets. Direction, enable, and step connections are sent to custom circuitry to increase voltage and current to power industrial sized stepper controllers. This unification of control signal allows controller replacement with any size stepper drive and motor. A Total of 10 stepper drivers with adjustable micro stepping were installed for X, Y1, Y2, Z and 6 possible extruders into a Full ATX computer case with 1,400W of power supplies as shown in Figure 2. For this installation stepper drives were 24-50VDC at 4.5A with 8 bit microstepping. Selected motors for this installation were bipolar 4.2A per phase 36VDC Nema 23 with greater than 17 lb*in torque in the optimal rpm for the mechanical slides. Additional electrical enclosures were added to provide industrial level protection of; over travel prevention, multiple emergency stops, and extruder connection isolation.

Figure 2 Electrical controller enclosure

2.2 Large-scale rapid deposition

Design requirements for the deposition system included the ability to hold large quantities of material, accurately meter and mix our chosen acoustic material, and deposit material rapidly for large-scale printing. Large external reservoirs were used for holding the resin material. The reservoirs were filled with the resin and an inert gas to protect the material from reacting. A steady state pressure was used to help push the material to the deposition head. Metering was done using a screw-pump system to enable the pumping of viscous resins and precise metering of the material. The material was mixed using a disposable plastic static mixer which provides thorough mixing of the material and simple clean up that prevents material build up and clogging maintenance issues. The pumps chosen could provide up to 650 ml/min flow rate resulting in a maximum flow rate of 1300 ml/min for rapid deposition for printing large scale parts.

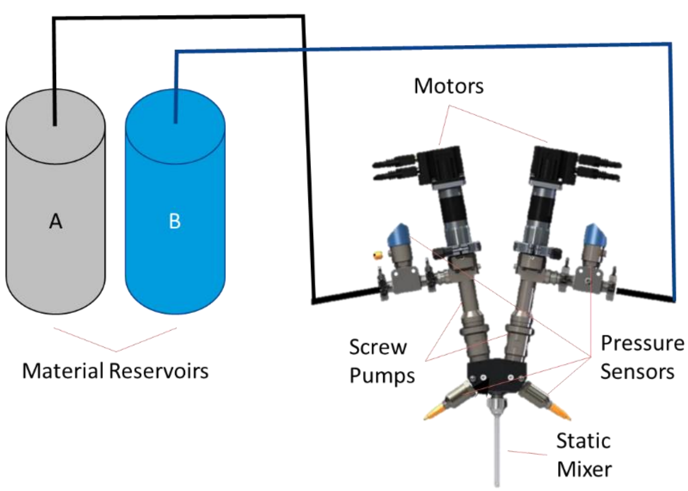


Figure 3: Shows a schematic of the two-part resin material reservoirs connected to the screw-pump system.

2.3 Acquired equipment

Bag dump station	$29,586
Volumetric Feeder	$ 13,378
Reaction vessels and controllers 10 gallon and 15 gallon	$15,255
Circulation pumps	$7,000
Reaction vessel 10 gallon with circulation and heat	$17,160
Work tables	$1,500
ViscoTec Duo-VM system and controller	$54,529
Small parts - mechanical and electrical components for control system	$19,831
Small parts – material handling systems	$10,301
TOTAL:	$168,540

2.4 Labor costs

Total engineering and assembly labor: $194,467