MODULAR SPACE FOUNDRY EXPERIMENTAL DESIGN FOR METAL CASTING ON THE INTERNATIONAL SPACE STATION

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Introduction: In-Space recycling of space debris opens a new opportunity to build a space-based economy where raw materials can be processed into usable products for use in LEO. Further, the relative ease with which orbital debris can be obtained provides researchers with opportunities to develop a strong foundation for space manufacturing that can be later extended to the broader category of space resources. To that end, experiments conducted on the International Space Station will demonstrate the viability of recycling and manufacturing materials in a sustained microgravity environment. The planned experiment has two parts: first, demonstrate casting of molten aluminum with a continuous chain casting system; second, demonstrate a pathway to contactless metal feed using a closed loop 3D position control using magnetic manipulation of conductive liquid metal samples.

Cast Subsystem: The Modular Space Foundry (MSF) testing that will be conducted on the ISS will focus on establishing processing parameters for CisLunar's continuous chain cast system. Chain cast consists of mold sections connected to chains arranged sequentially to continuously cast billets, ingots or propellant rods (As seen in Figure 1).

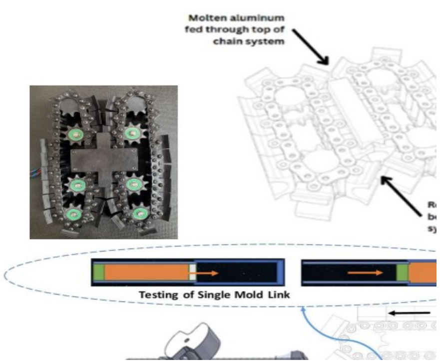

Figure 1. Chain cast system zoomed into a single link

The ISS payload will demonstrate a single mold link from the chain cast concept, the objective is to establish minimum viable process parameters for heating cooling and feed rates for the micro gravity environment.

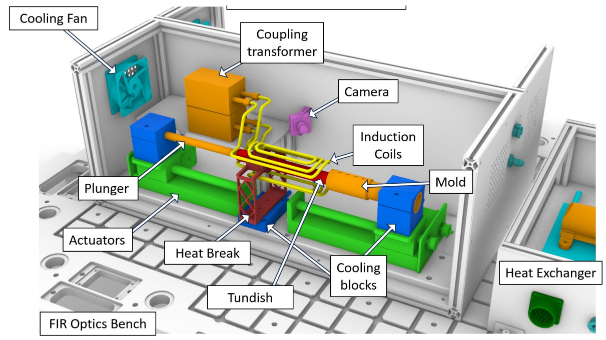

Figure 2. ISS Cast System for Fluids Integration Rack

The Cast payload consists of numerous aluminum samples heated by an induction coil in a tube that serves as a tundish. Once the aluminum reaches the casting temperature, a piston motivates the molten aluminum to into a mold which simulates chain casting. Samples will be produced on ISS under a variety of processing parameters. The cast samples will be returned to earth an analyzed to understand the affects of micro gravity on casting, and to establish minimum viable processing parameters for the MSF-2 which is planed to operated external to ISS and produces a continuously cast billet.

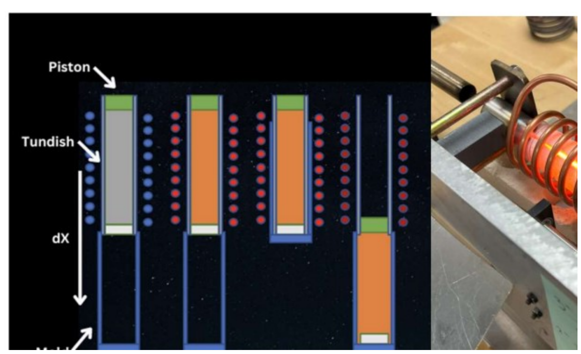

Figure 3. Testing apparatus Left is a diagram of the concept, right is an early iteration of the experiment

Steer Subsystem: Work being conducted at the Colorado School of Mines has focused on 3D position control of conductive materials within a defined magnetic workspace.

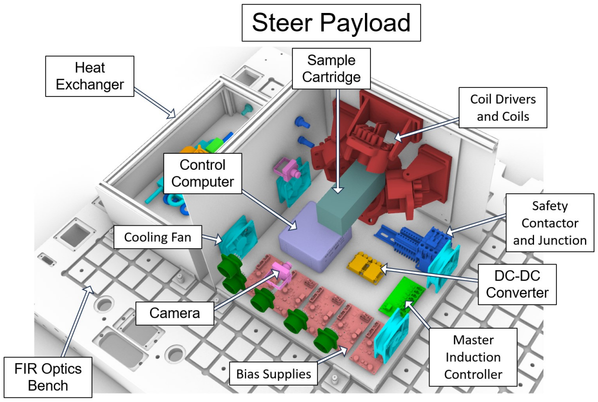

Figure 4. ISS Steer System for Fluids Integration Rack

Researchers in the M3robotrics lab have demonstrated open-loop control of an aluminum sphere by leveraging the magnetic dipole moment associated with induced eddy currents in a conductive medium. The team has demonstrated that nearly neutrally buoyant aluminum sphere can be guided to stable points in the magnetic workspace by generating a magnetic field that perfectly balances the weight of the aluminum sphere. Position control is therefore achieved not by attempting to directly move the sample, but rather the stable point in the workspace is moved and the sample follows. Figure 3 shows an aluminum sample suspended by the oscillating magnetic fields.

Currently, the team at Mines is focused on using real-time position data to create a closed loop control algorithm. Two cameras mounted around the workspace are able to triangulate the position of the sample, which is then used to correct any discrepancies between desired path and measured path (camera configuration seen in Figure 4). It is anticipated that the closed-loop control will be completed prior to Summer 2024.

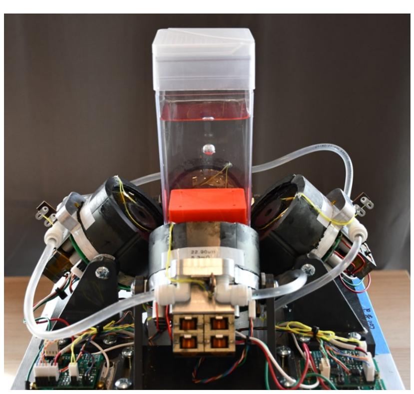

Figure 5. Buoyant aluminum sphere suspended by oscillating magnetic coil array

Preparations are currently being made to demonstrate the magnetic steering system on the international space station. The intent of the initial flight on the ISS is to gauge how well ground based position control translates to an actual microgravity environment, and to determine the behavior of liquid samples that are manipulated by the oscillating magnetic system (currently all ground based experiments are limited to solid conductive samples due to the requirement that they be made neutrally buoyant in a water bath).

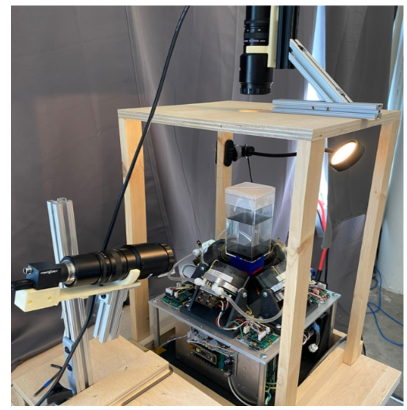

Figure 6. Dual Camera setup to triangulate position in magnetic workspace

Knowledge gained from these experiments will be used to inform future developments that aim to process not only discarded aluminum metal in LEO, but also can be extended to any non-terrestrial, conductive material. Further, a robust position control system could allow for manufacturing complex geometries through novel additive manufacturing techniques.

References:

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