3D Laser Metal Printing in Zero Gravity Using Additive Manufacturing

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Introduction

The thirst of knowledge in the space exploration has always been the driving factor when it comes to innovation. 3D Printing in space is very different & challenging. Composition, weld quality, structure, all depends on the distribution of the molten materials, temperature in the melt pool; its very difficult to control in space. Laser deposition gives high precision control of all the parameters involved during the printing process, especially the melt pool and bead shape. It allows us to control the formation of a strong and clean deposition without using too much melted material. We can produce very precise, high quality small parts, quickly and efficiently. Once we have achieved this goal in 0g, the future of space manufacturing, space habitats looks very promising.

Research Aim & Objectives

The aim of this research is to develop experimental and numerical process to understand the affect of gravity on the metal printing.

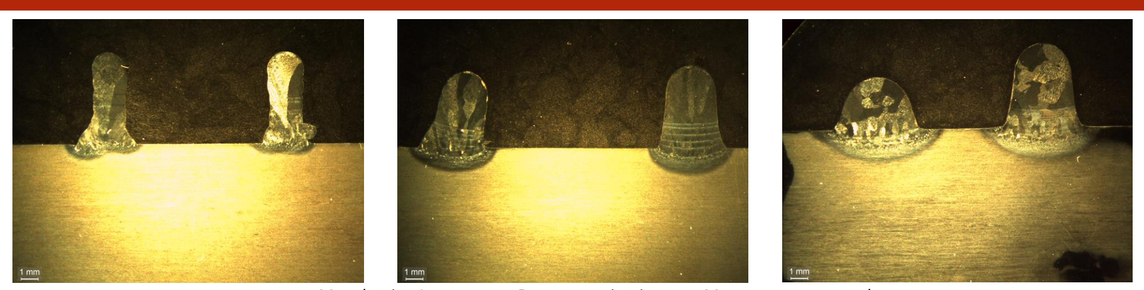
Main objectives are to:

- Study the effect of melt-pool formation under 0g conditions.
- Identify the key process parameters: forces, laser power, beam size, wire feeding speeds, material properties, travel speed, temperature and weld shape.
- Develop CFD based simulation to study these parameters
- Develop experimental setup for 0g experiment using Drop Tower or Parabolic Flight.
- Develop vertical and out of position experimental setups
- Develop and validate experimental results with simulation results.
- Create efficient technique for multilayer deposition (layers are equal and same as the base layer)

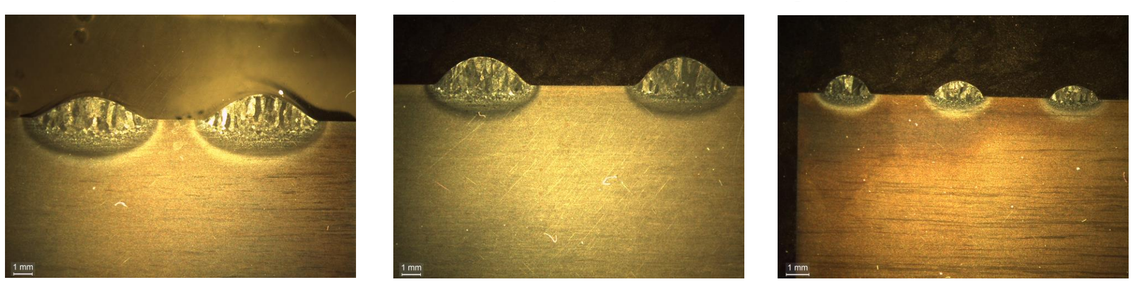
Challenges

- How to control the bead profile as its dependent on many parameters and it can vary with boundary conditions.
- Gravity plays an important role; difficult to investigate experimentally
- Precise parameters for laser deposition; to control printing in 0g
- Accurately incorporate the heat source on the surface
- Forces should be properly incorporated; considering the effects of the surface forces including surface tension, Marangoni shear stress.
- In laser processing gravity has a very minimal effect on fluid flow, therefore, we need to find perfect parameters on which the effect can be seen.
- How to compensate for gravity accurately, must be identified

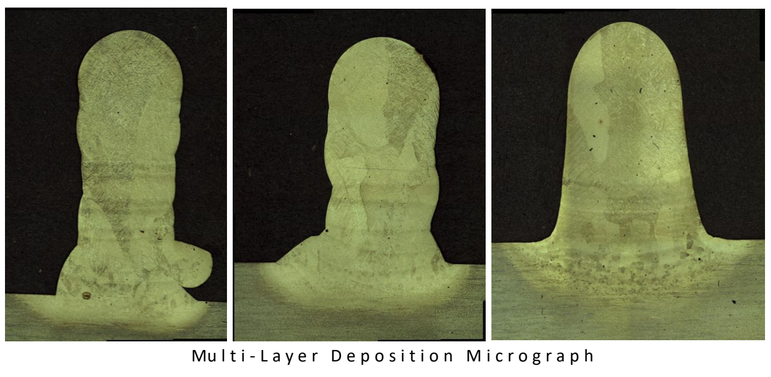
Results



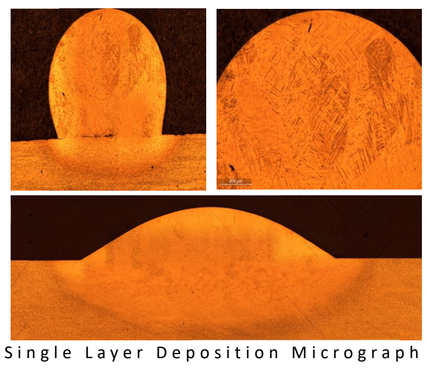
Multi-Layer Deposition Macrograph



Single Layer Deposition Macrograph

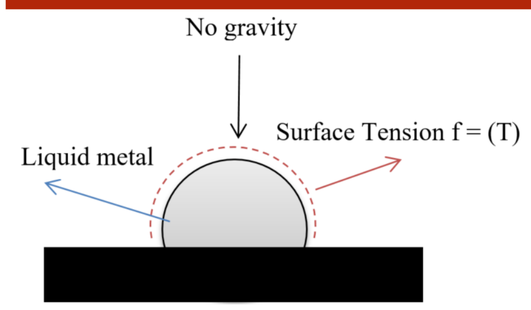


Multi-Layer Deposition Micrograph



Single Layer Deposition Micrograph

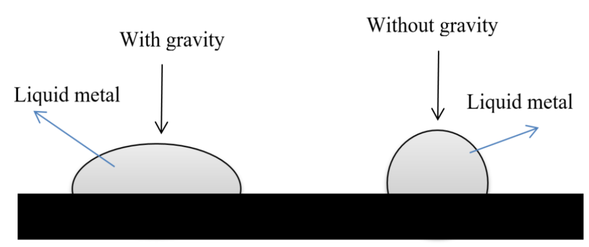
Research Methodology



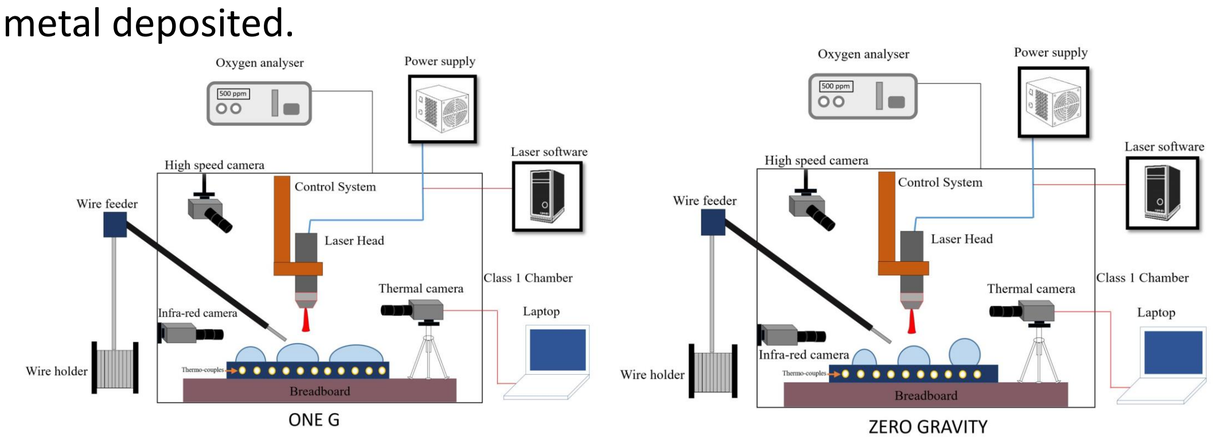
G acting in the downwards direction which is opposed by the σ; σ is trying to achieve a round shape of the liquid metal. σ depends on the T & O_2 level; different bead shapes can be achieved for the same volume of metal deposited.

The control of bead profile is very important & we rely on it immensely.

$$\delta = f\,(T, e)$$



There should be a threshold, at which the effect of gravity would be minimal on the melt pool.



The experimental setup of 0g & g experiment

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