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Design and Development of Solid State Additive Manufacturing Techniques

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Aim: "*To develop a flexible additive manufacturing system using supersonic laser deposition techniques in order to allow precise manufacture and remanufacture of large scale, net-shape components.*"

Project Motivation

The manufacture of large scale metallic components poses several key problems for industry; the timescale required for manufacture, machining waste, the ability to remanufacture components and the use of materials that are difficult to process.

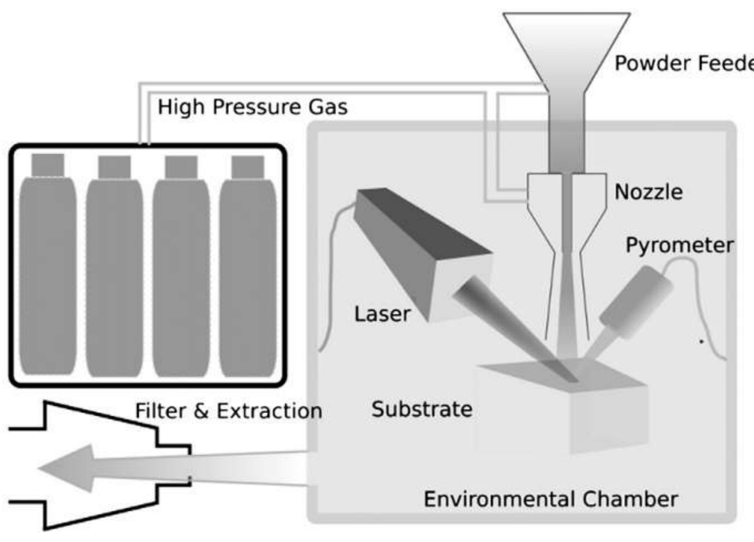
The purpose of this project is demonstrate the potential for novel manufacturing techniques to overcome these problems, and design a system that will minimise the time required and waste generated when creating or remanufacturing these components, as well as increasing design freedoms for large scale industrial components.

Supersonic Laser Deposition Overview

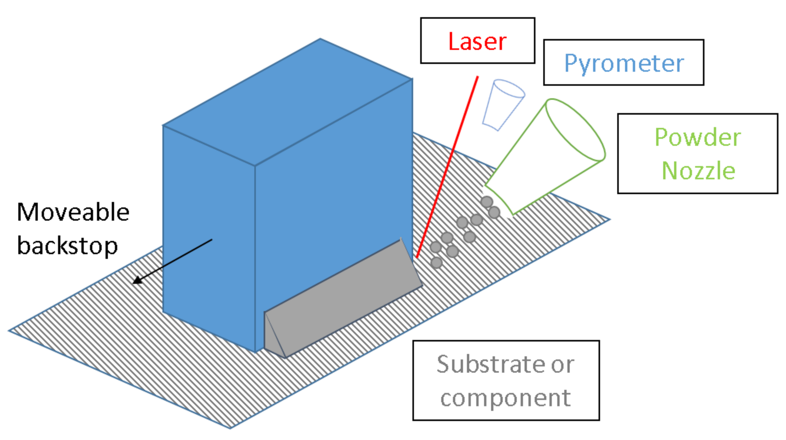
Supersonic Laser Deposition (SLD) is a solid state deposition process currently used to provide surface coatings to components, with superior metallurgical and mechanical properties and in a wider array of material than competing technologies.

In the SLD process, the powder is entrained within a jet of nitrogen carrier gas by means of a high pressure powder feeder, at 30 bar or higher, and is combined with another stream of high pressure nitrogen, before being accelerated through a converging-diverging (de Laval) nozzle. The powder within the nitrogen stream, now travelling at supersonic speeds, is directed towards the substrate which is heated to a controlled temperature by the laser and pyrometer.

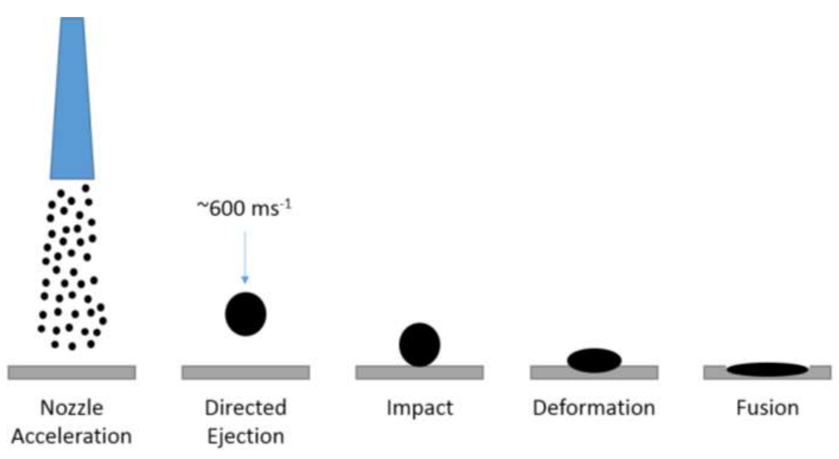
Current System

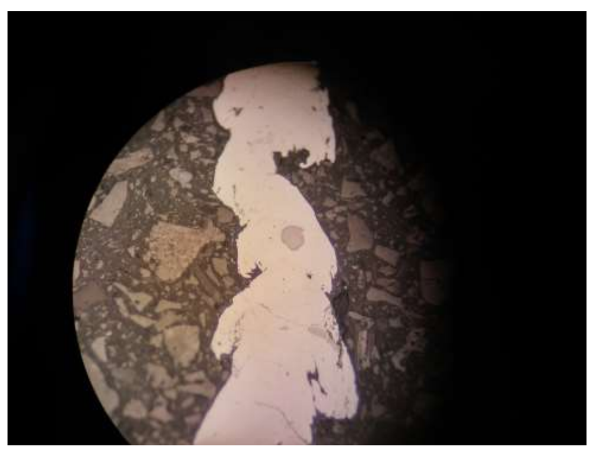


Concept System



Upon impact with the substrate, the powder particles plastically deform rapidly enough to cause localised heating, leading to flash welding at the interface between the particles and the laser heated substrate. This deposit can then be built upon with subsequent impacts.



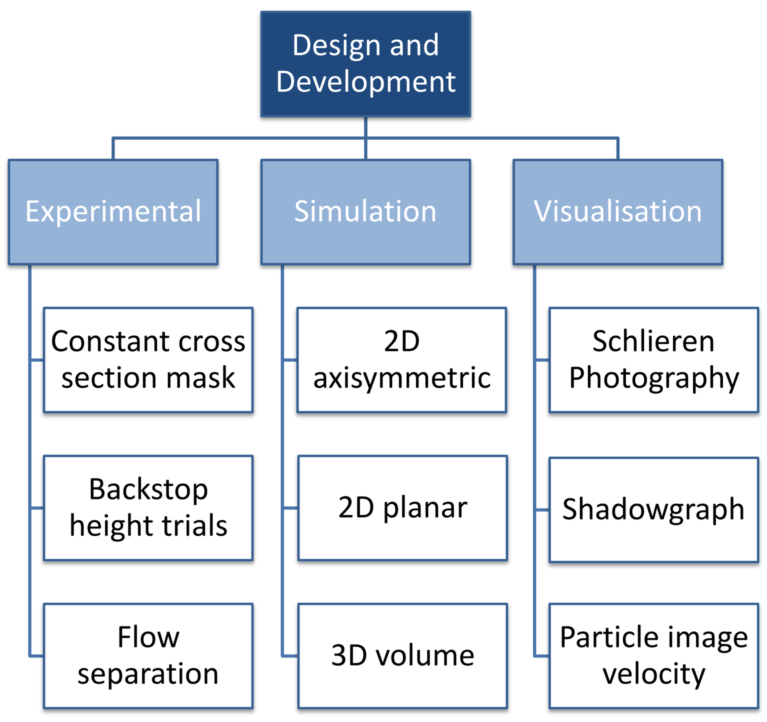


The concept being developed is to progress this technology from coating applications to the creation of 3D structures. This would be facilitated by the use of a moveable backstop at the deposition site, to provide a defined edge to the depositing material.

Benefits of using SLD

- High deposition rate
- Low cost
- Large scale
- No inert atmosphere
- CNC integration
- Controllable microstructure
- Good mechanical properties
- Multi-material and functionally graded

Workstreams



The project has been categorised into 3 areas which will inform and support each other.

Experimental

Investigations of wall fidelity, different materials backstop erosion rates, maximum height tests.

Simulation

Creation of CFD models to predict the gas and particle flows throughout the system, and inform experimental parameter choices.

Visualisation

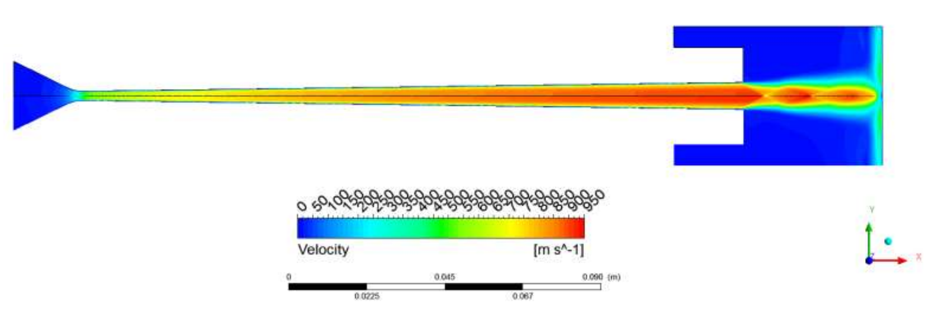
Several techniques are being investigated to visualise the flow of the gas and powder through the system, to validate the models.

Simulation

The simulation of this system is conducted in Ansys Fluent.

2D Axisymmetric

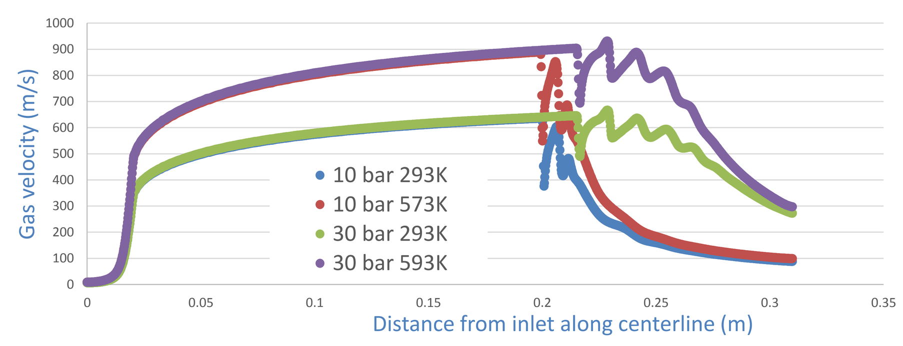
Simulations have been completed for a range of temperatures and pressures, to provide data for validation of initial Schlieren images.



Model with substrate at 40 mm offset, 3 MPa inlet pressure and 573 K.

3D Volume

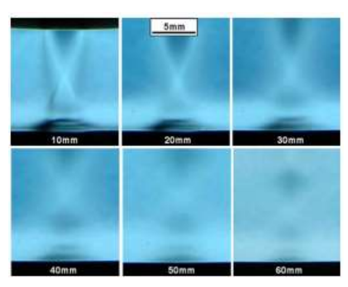
As 2D models require less processing power, 3D simulations are being conducted to validate the 2D process as an approximation for real events.



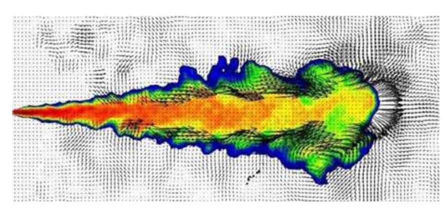
Particle Tracking

The next stage of simulation is the addition of individual particle tracking, with custom capture algorithms needed to be written for FLUENT, to account for adhesion.

Visualisation



Shockwaves at nozzle exit [1]



Spray particulate tracking with PIV [2]

Schlieren Photography

Schlieren photography will allow the investigation of shockwave profiles generated by the gas, and any obstacles such as backstops. This will allow validation of the simulation models, but is unfeasible with powder in the jet.

Particle Image Velocimetry

PIV measures three velocity components in a volume using 3 or more cameras, in order to track particle movement. This will allow validation of the simulated particle tracking.

Short Term Targets

- Begin testing of masks and backstops for surface generation
- Identify best materials for deposition
- Progress the CFD simulation to include particle tracking
- Identify the highest value opportunities

[1] Image by Krste Pangovski, http://www.ifm.eng.cam.ac.uk/research/cip/completed/coldgas/
[2] Image of spray particulate tracking in spray combustion, from IFP Energies Nouvelles http://www.ifpenergiesnouvelles.com/

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