MEng Research Proposal

Numerical Optimization of Mesh-Assisted Cold Spray for Producing Patterned Coatings

1. Background and Motivation

Cold spray is a solid-state deposition process in which micron-sized particles are accelerated to high velocities through a converging–diverging nozzle and deposited onto a substrate through severe plastic deformation. Introducing a wire mesh between the nozzle and substrate can spatially control the particle flux and create patterned coatings, such as arrays of raised features or pin-fin geometries.

Previous numerical work has demonstrated that masked cold spray can be modeled in ANSYS Fluent using a three-dimensional Eulerian–Lagrangian framework. The mask geometry, nozzle operating conditions, mask position, and substrate standoff distance significantly affect particle trajectories, impact velocities, temperatures, and deposition efficiency. A subsequent study used the resulting CFD data to predict particle spatial, velocity, and temperature distributions through machine-learning methods, illustrating the value of CFD-generated particle-deposition maps for process optimization.

In the current experimental configuration, a wire mesh is placed at a controlled distance above the substrate. The mesh blocks or redirects part of the powder stream while allowing particles to pass through its openings. The mesh-to-substrate spacing is expected to influence particle spreading after the mesh, the sharpness of the resulting pattern, and the velocity of particles reaching the substrate. A numerical model is therefore required to identify operating conditions that produce a well-defined, uniform, and repeatable patterned coating and predict the powder distribution over the mesh mask at the same time.

2. Research Objective

The main objective of this project is to develop a numerical model of the mesh-assisted cold spray process in ANSYS Fluent and use it to determine the operating and geometric parameters that provide the best patterned coating on the substrate and deposition prediction on mesh.

The model will predict:

- Gas-flow behavior around the mesh and substrate.
- Particle trajectories through and around the mesh openings.
- Powder deposition and interception on the mesh.
- Particle spatial distribution on the substrate.
- Particle velocity and temperature at impact.
- Deposition efficiency and pattern quality.

3. Expected Outcomes

The project is expected to provide:

1. A validated ANSYS Fluent model of mesh-assisted cold spray.
2. Detailed gas-flow and particle-trajectory fields near the mesh and substrate.
3. Quantification of powder deposited on both the mesh and substrate.
4. Identification of the parameters controlling pattern sharpness and uniformity.
5. An optimized range of mesh-to-substrate distances and operating conditions.
6. Practical recommendations for conducting patterned cold spray experiments.
7. A numerical framework that can later be extended to different powders, meshes, nozzle conditions, or substrate geometries.

4. Project Deliverables

The student will submit:

- A literature review on masked and mesh-assisted cold spray.
- Complete ANSYS Fluent geometry, mesh, setup, and case files.
- Mesh-independence and numerical-verification results.
- Particle-distribution and deposition maps.
- Parametric-study results.
- Comparison with experimental coating patterns.
- Recommended operating conditions.
- Final MEng report and presentation.

5. Proposed Timeline

Period	Activity
Weeks 1–2	Literature review and collection of experimental parameters
Weeks 3–4	Geometry generation and computational-mesh development
Weeks 5–7	Continuous-phase model setup and verification
Weeks 8–10	Particle-phase model development and reference-case reproduction
Weeks 11–22	Parametric simulations with postprocessing

Period	Activity
Weeks 23–24	Experimental comparison and optimization
Weeks 25–27	Final report and presentation preparation

Project Summary

This project will develop a three-dimensional ANSYS Fluent model of mesh-assisted cold spraying, with primary emphasis on predicting the powder distribution at both the mesh mask and the substrate. The simulations will track particle trajectories and quantify the fractions of powder passing through the mesh openings, impacting or accumulating on the mesh, and reaching different regions of the substrate.

A parametric study will be conducted to determine how particle size distribution, mesh opening size, mesh-to-substrate distance, nozzle standoff distance, and nozzle traverse speed influence powder transmission, spatial deposition patterns, and coating uniformity. The numerical results will be used to identify operating and geometric conditions that maximize powder delivery to the intended substrate regions or mesh.