Development of an Automated Finite Element Simulation Framework for Machine Learning-Based Prediction of Electroforming Outcomes

OntarioTech Engineering & Applied Science

PRECISION MANUFACT. LABORATORY

Dr. Jana Abou Ziki's Research Team

Department of Mechanical and Manufacturing Engineering

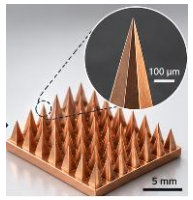
Introduction

Electroforming is an electrochemical manufacturing process in which metal is deposited onto a conductive substrate through controlled electrochemical reduction. It enables the production of complex metallic components with high dimensional precision.

The resulting deposition profile is strongly influenced by mold geometry and electrode configuration, making accurate prediction of deposition thickness essential for process optimization.

Applications

- Micro structured components
- Fine metal meshes and filters
- Watch components
- Micro needles
- Dental and medical components
- Self assembling parts



Micro needles



Self assembling parts

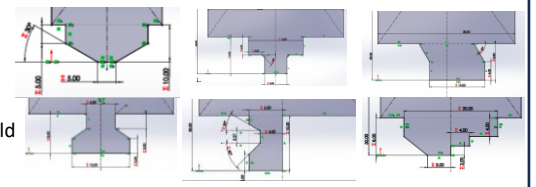
Research Focus

Developing a robust computational framework for FEM data generation through:

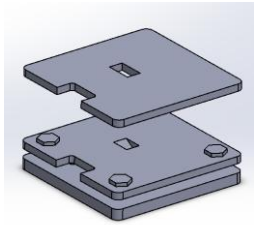
- **Parametric Geometry:** Generating diverse mold configurations.
- **Simulation Automation:** Integrating MATLAB and COMSOL for automated FEM analysis.
- **Geometrical Validation:** Detecting invalid and intersecting geometries.
- **Numerical Robustness:** Optimizing mesh configurations and solver settings.
- **Dataset Generation:** Producing reliable data for future machine learning applications.

Objectives and Methodology

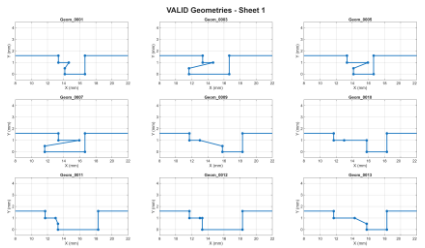
Automated Geometry Generation:
Develop a parametric framework to generate and validate diverse mold geometries.



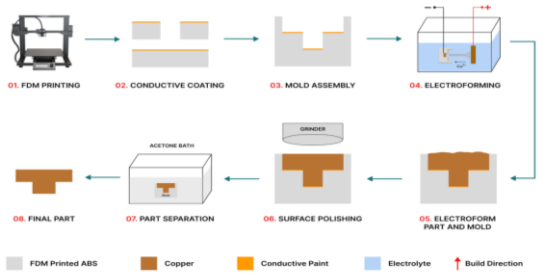
Examples of different geometry families



Exploded CAD view of the 2.5D mold assembly designed for electroforming, featuring additively manufactured ABS (acrylonitrile butadiene styrene) components and alignment features.

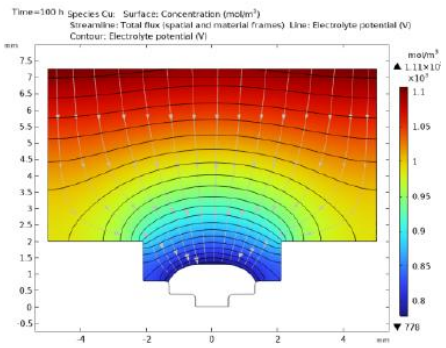


Examples of valid parameterized mold geometries generated for electroforming simulations, illustrating variations in profile shape and dimensions for systematic computational analysis.



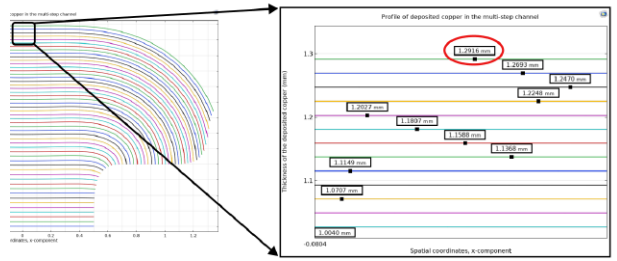
Method of electroforming of personalized miniature metal parts using additively manufactured molds

Results



A robust computational pipeline was developed to simulate all permutations of mold dimensions and cathode locations.

A machine-learning model will be trained on hundreds of thousands of simulation results to predict electroforming outcomes in seconds.



The developed mold design method for electroforming allowed manufacturing 3D parts that effectively replicated the complex **3D** mold and with high surface precision

