

## Research Project Description

### Mathematical Modeling of Three-Dimensional Electromagnetic Shaping Mechanics to Solve the Inverse Shaping Problem for Heterogeneous Materials

The field of electromagnetic shaping seeks to understand and model the application of magnetic fields in order to shape a given material. Much of the work in this area of materials processing has focused on modeling the shaping of homogeneous fluids (e.g. molten metals) in continuous casting processes [1]. In this application, high frequency alternating currents are employed in order to limit the effect of the magnetic force to acting only on the surface of the liquid. This force, known as the magnetic pressure, is applied to shape the liquid into a desired 2D cross-section in the casting process.

To date, work in the area of electromagnetic shaping has included modeling and simulating the shaping of materials with electromagnetic fields. Significant work has also been done to solve the *inverse electromagnetic shaping problem* [2]. In the inverse problem, methods are developed that allow one to determine the placement and power of electromagnets in order to achieve a particular free boundary shape. It is the inverse problem that has more practical application to engineering. To date, this work has been focused primarily on homogenous materials such as molten metals. However, very little if any work has been focused on modeling the electromagnetic shaping of viscous heterogeneous materials. Further, the work has mainly been constrained to solving two-dimensional problems. Finally, this work has only considered the shaping of the external boundaries of a material. It has not provided solutions for shaping materials with internal features.

The goal of this research effort is to develop a stochastic math modeling approach for solving the inverse electromagnetic problem in order to shape heterogeneous materials into precise three dimensional complex shapes. Three key challenges are identified in this work:

- 1) Develop mathematical models that accurately characterize the electromagnetic shaping mechanics of heterogeneous materials.
- 2) Develop solutions to the inverse electromagnetic shaping problem for such heterogeneous materials that incorporate the influence of electromagnetic fields on the interior of the shape in order to create shapes with complex internal features.
- 3) Develop solutions to the inverse electromagnetic shaping problem for such heterogeneous materials with complex shapes (including internal features) in three-dimensions.

#### References:

1. Garnier M., "The Clifford Paterson Lecture, 1992: Magnetohydrodynamics in Material Processing, Philosophical Transactions of the Royal Society, London, 1993, **344**, pp.249-263.
2. Canelas A., Roche J.R., Herskovits J., "The Inverse Electromagnetic Shaping Problem", Structural and Multidisciplinary Optimization, Springer-Verlag, 2008