Developing a 1D Axisymmetric Flow Profile in Liquid Mercury With Eddy Current Flow Meters and Deep Neural Networks

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Motivation

Eddy Current Flow Meters (ECFMs) have been used to measure characteristics of conductive fluid flow for decades in a limited capacity. Measuring: average fluid velocity, detecting voids and/or blockages. However, with increased interest in conductive fluids for use in both fission and fusion reactors there is a need for better techniques to characterize the fluid flow in these systems.

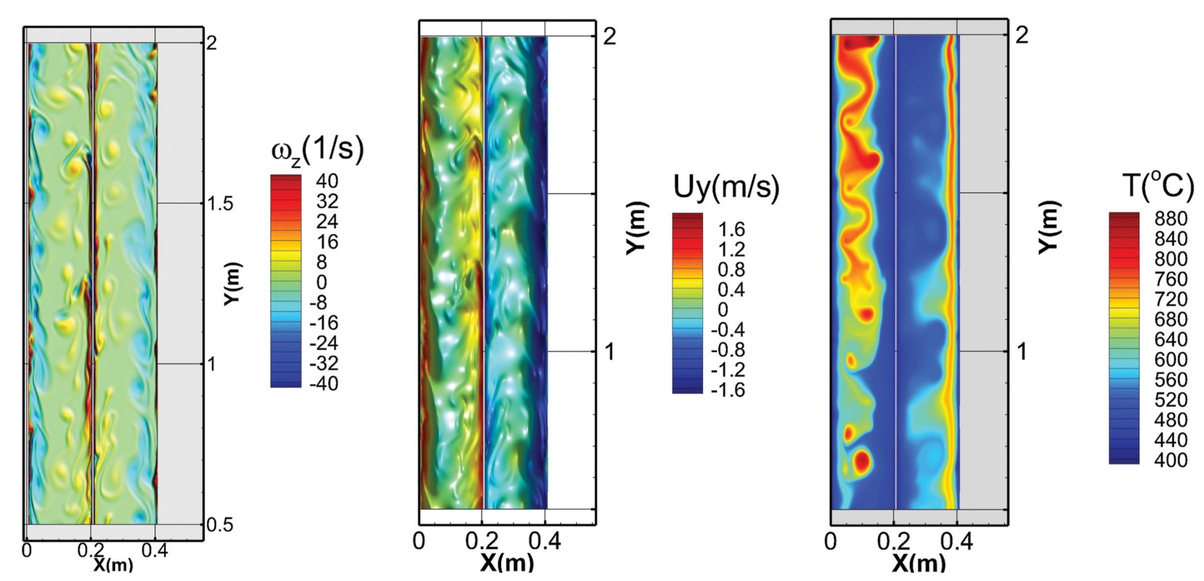


Figure 1: Fusion reactor PbLi blanket poloidal duct simulation [1]

ECFMs are particularly well suited for these applications because of their compact size, flexible geometry and their ability to characterize flows with non-invasive measurements. In this work we set out to expand the capabilities of ECFMs by measuring **fluid velocity profiles**.

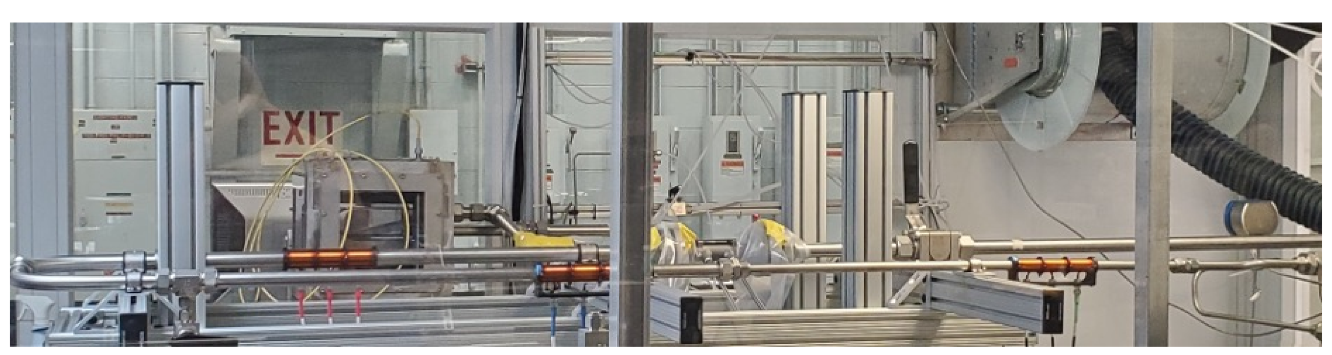
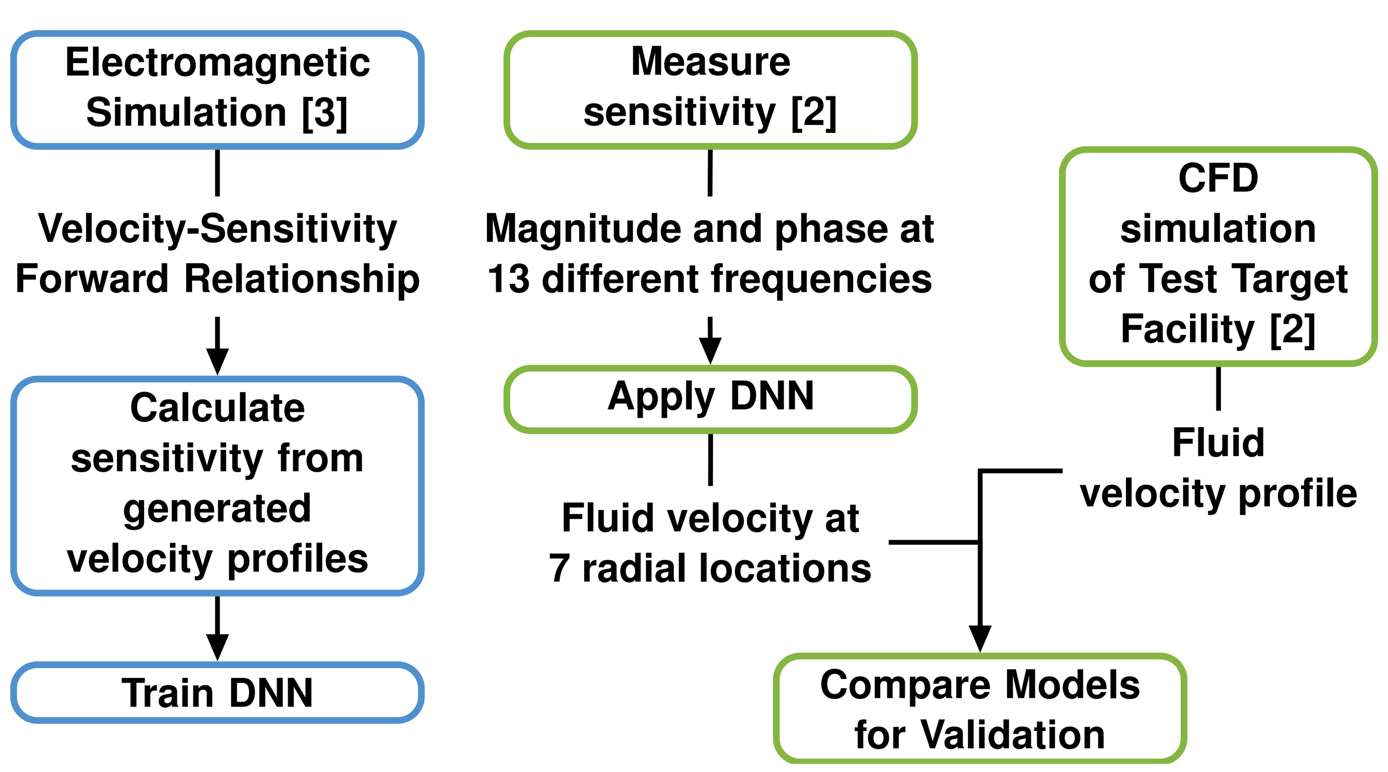


Figure 2: ECFMs on the Test Target Facility Liquid Mercury Loop [2]

Workflow



Deep Neural Network (DNN) Parameters

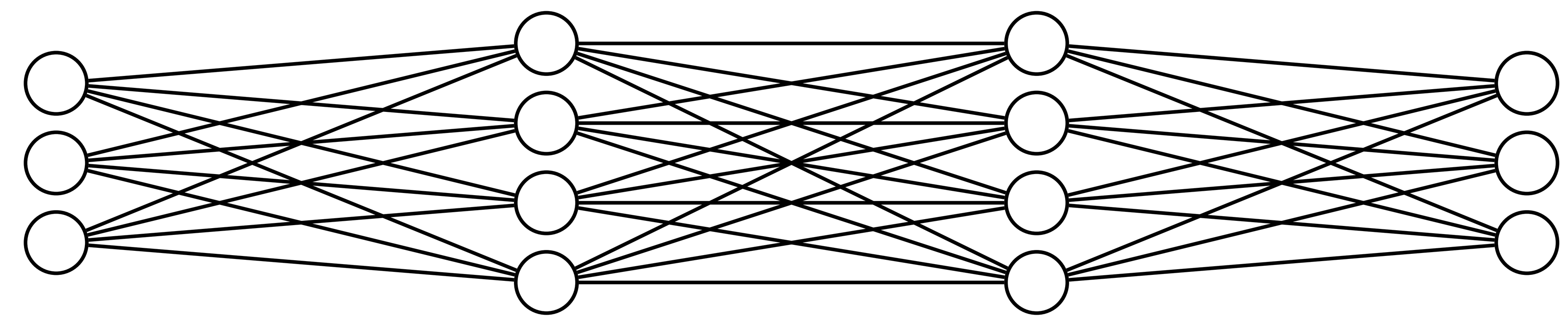
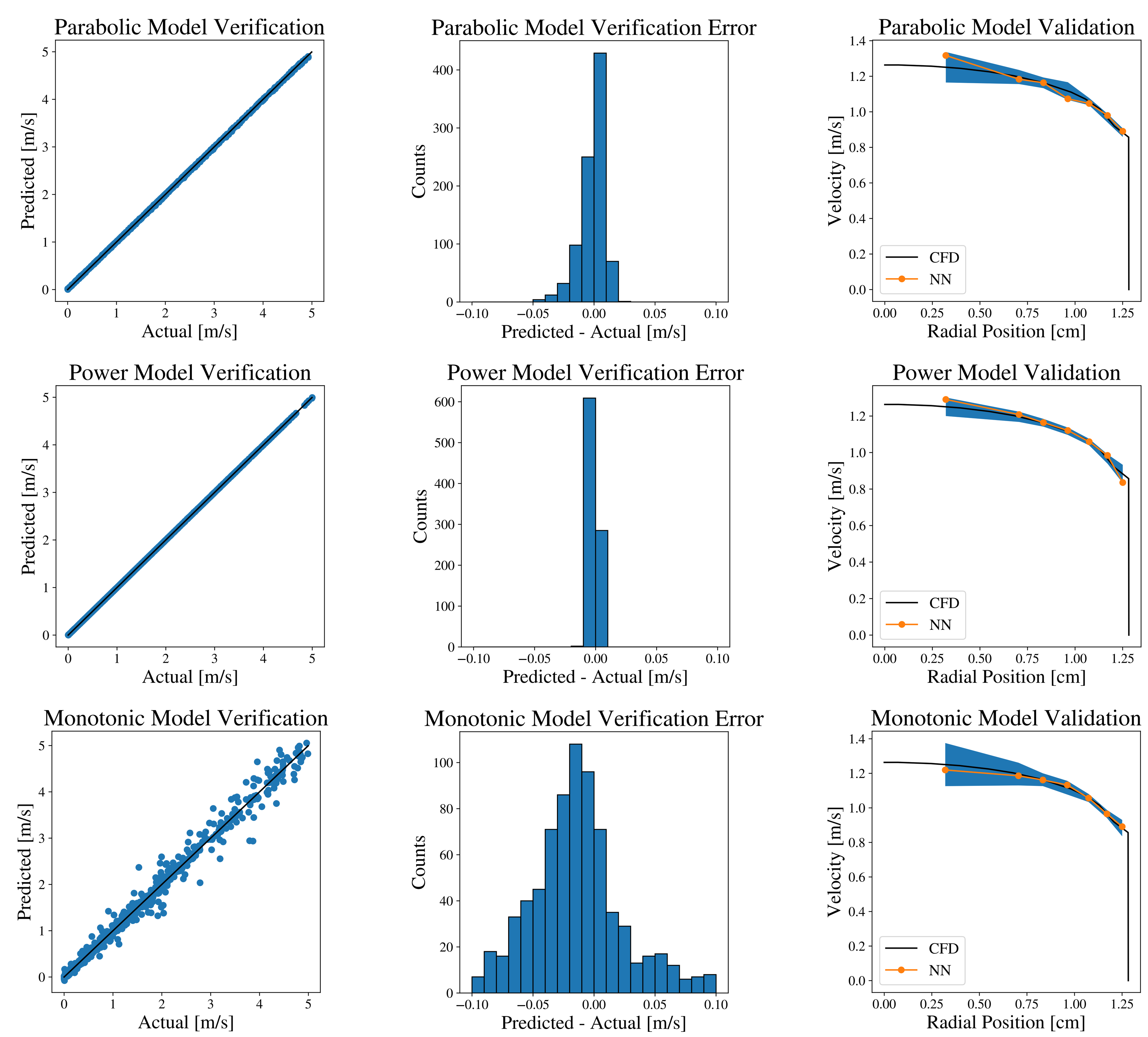


Figure 3: Cartoon of the DNN Used

Training Velocity Conditions	Inputs	Hidden Layers	Nodes per Layer	Outputs
Parabolic (Laminar)	26	2	100	7
Power Law (Turbulent)	26	2	100	7
Monotonically Decreasing (General)	26	3	100	7

Table 1: DNN Model Parameters

Results



The left column shows verification using 128 randomly generated profiles. The center column shows the error in verification set. The right column shows validation, comparing predictions made with experimentally measured data to computational fluid dynamics (CFD) simulation. The error bands represent the error in 1000 predictions using measured data with 5% random noise on the sensitivity magnitude.

Results Cont.

Flow Conditions	Max Error [m/s]	Max Error [%]
Parabolic	0.07	5
Power Law	0.05	5
Monotonically Decreasing	0.03	2

Table 2: Maximum Error between DNN model and CFD model

Flow Conditions	Max RMSE [m/s]	Max NRMSE [%]
Parabolic	0.08	7
Power Law	0.05	4
Monotonically Decreasing	0.13	10

Table 3: Maximum Error between DNN model with noise and CFD model

Conclusions

- ECFMs can provide an accurate and efficient measurement of fluid flow profiles in conductive fluids.
- Deep Neural Networks can provide an efficient and numerically stable general relationship between ECFM sensitivity and the fluid velocity profile.
- Inclusion of phase can increase stability and accuracy of velocity profile calculations. While also decreasing the number of layers, training time and optimization required.

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References

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