2D CFD Parametric PINN

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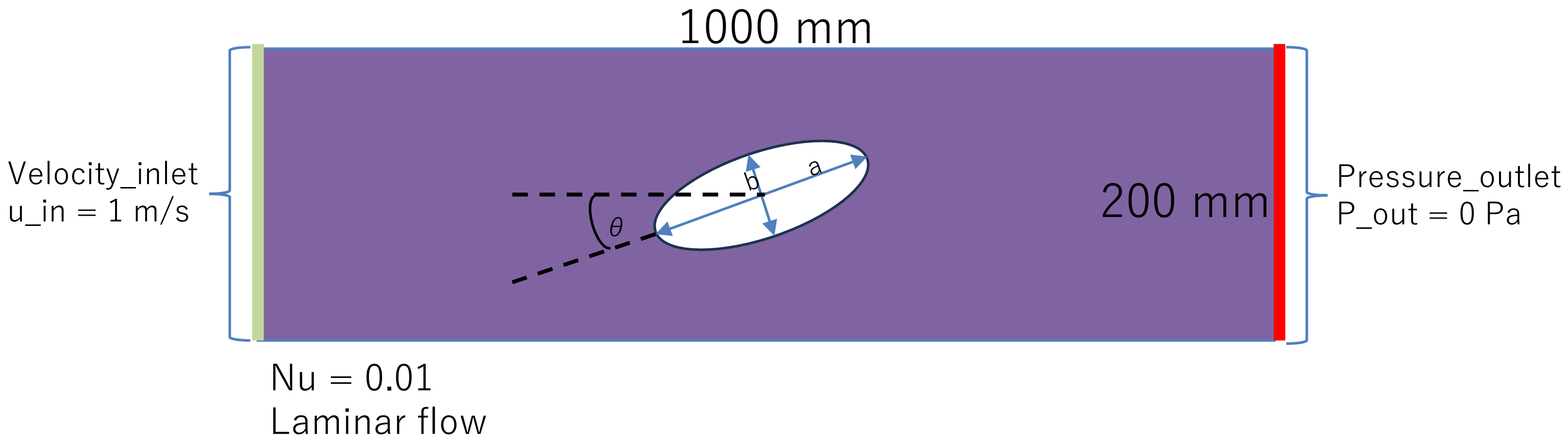
Introduction

- As part of our AI×CAE activities, we have been investigating and researching PINN (Physical Inform Neural Networks) models for CFD application. We have succeeded on 2D parametric problem for fluid dynamic case.

Implementation Details

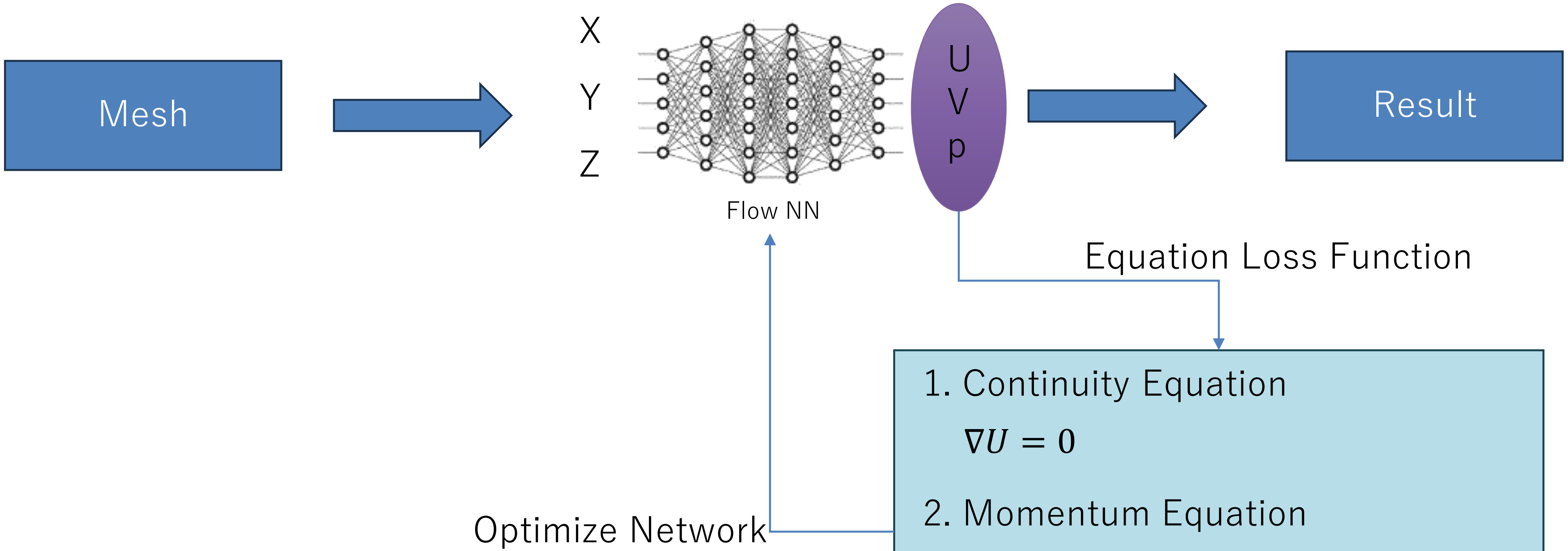
- In order to apply the PINN (Physical Inform Neural Networks) to the Fluid Dynamics problem, we verified the model with a 2D Pipe with parametric obstacle.
- This PINN (Physical Inform Neural Networks) is not using data for training but only use it for validation of the results.
- The PINN (Physical Inform Neural Networks) will not mesh to the input, only the points location is necessary. This will make the result not mesh quality dependent.
- DoE (Design of Experiment) of this parametric study is not discrete but continuous between design range.

Fluid Dynamic Case



- The Design of Experiment
  - a = 20 : 140 mm
  - b = 20 : 140 mm
  - θ = -1 : 1 rad

PINNs Details



1. Continuity Equation

$$\nabla U = 0$$

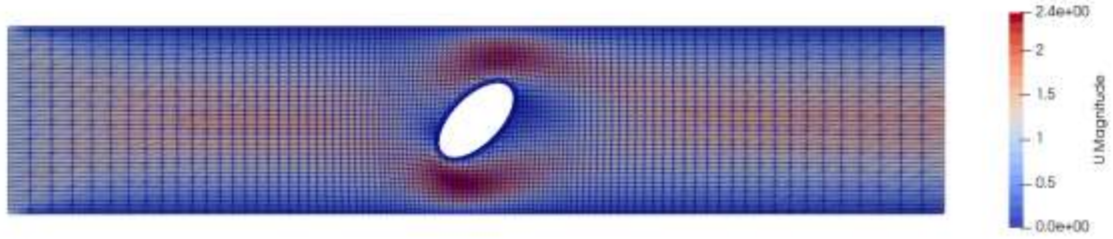
2. Momentum Equation

x: $u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + \frac{1}{\rho}\frac{\partial p}{\partial x} + \nu(\nabla^2 u) = 0$

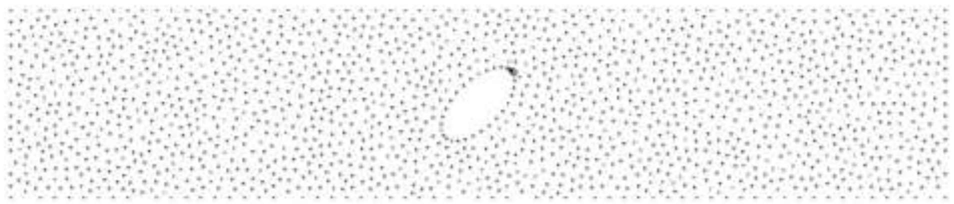
y: $u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + \frac{1}{\rho}\frac{\partial p}{\partial y} + \nu(\nabla^2 u) = 0$

Example of Input Data and Reference Data

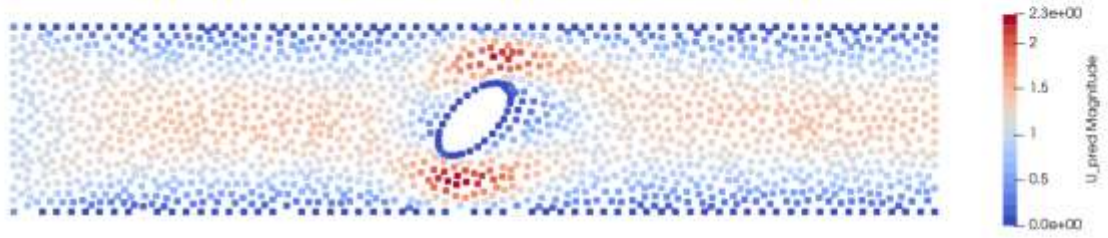
OpenFOAM Reference data for Validation



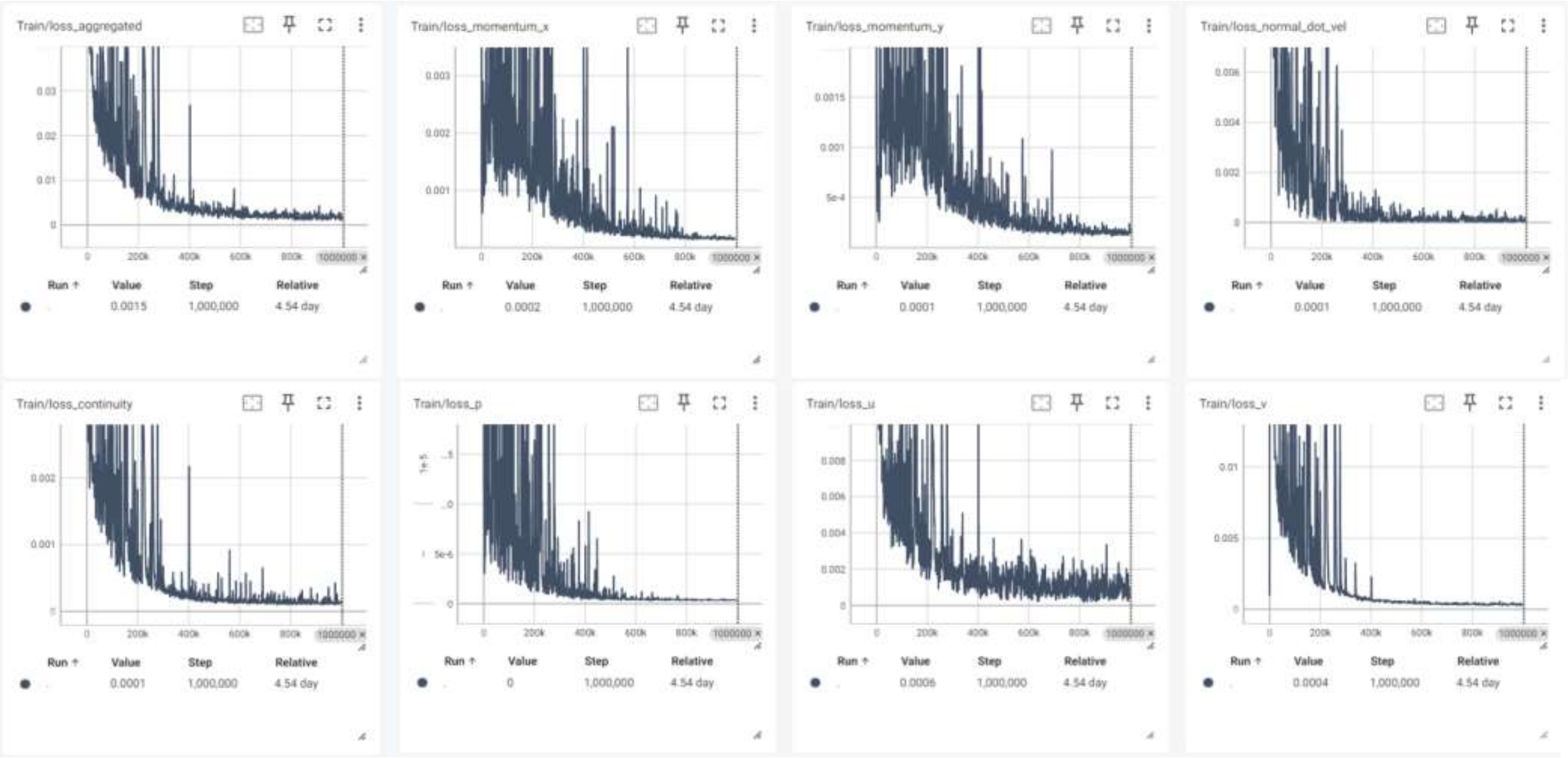
PINN input data for Network



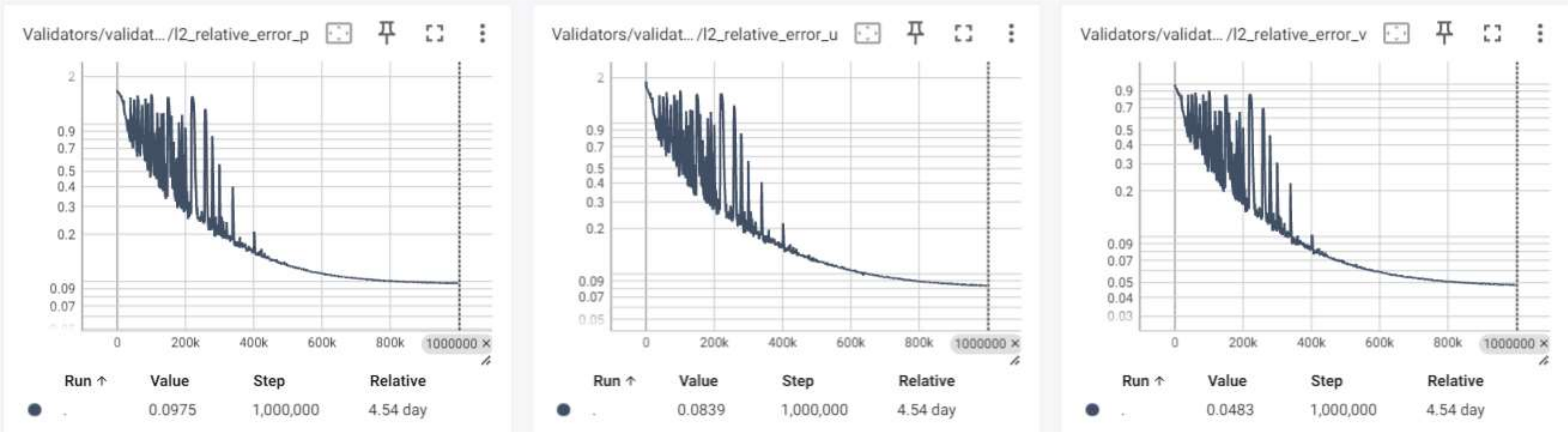
PINN output data from Network



Training Curve Result

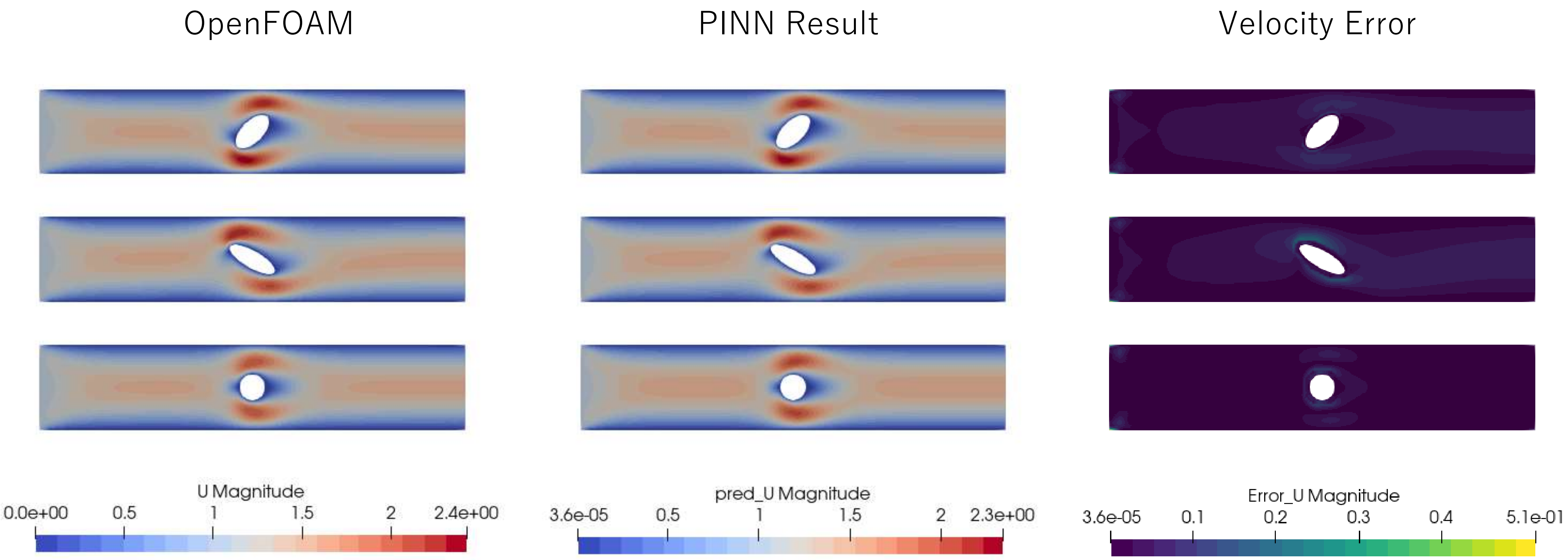


Training Validation Curve

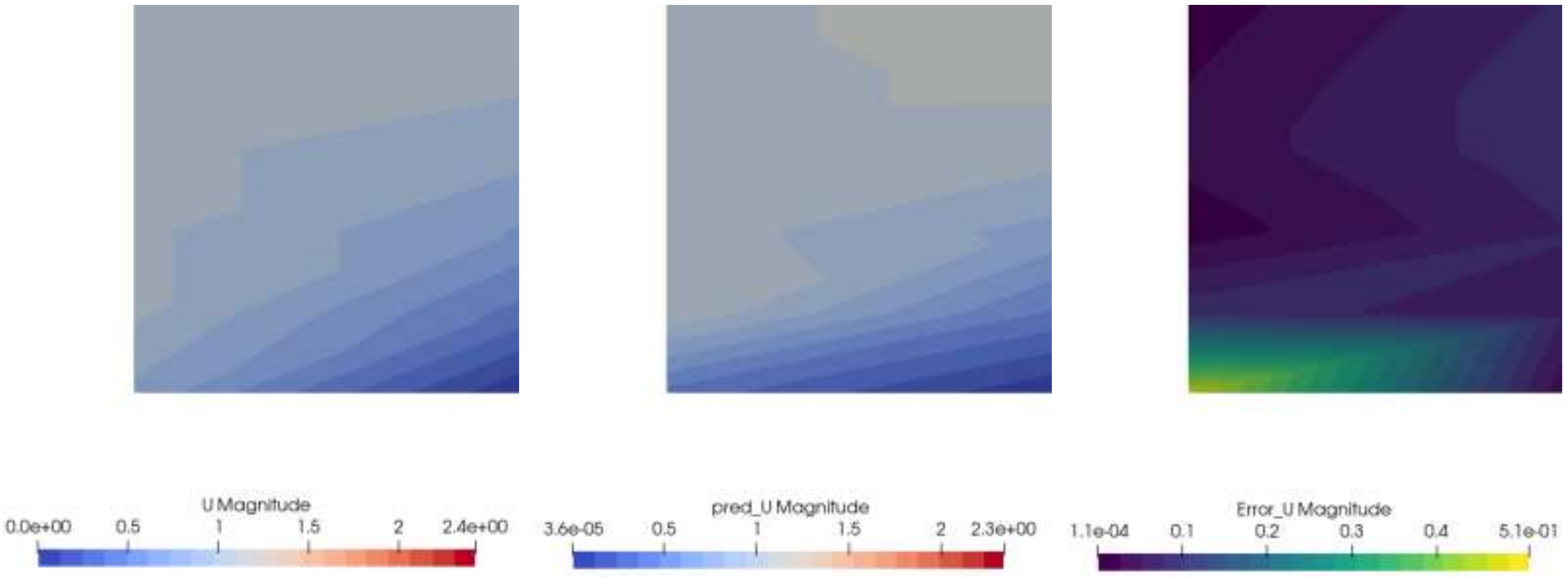


The relative error between Neural Network Prediction and OpenFOAM ground truth is small, which means PINN prediction result is match.

Comparison Example



Highest Error



- Highest error is located in inlet corner. This phenomena is explained by result on OpenFOAM point is treated as half between inlet value (1 m/s) and wall value (0 m/s). While in the PINN, that corner point is treated as an inlet value (1 m/s).

End