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PINN Approximation of Steady 2D Flow Past a Square Cylinder

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ABSTRACT

The objective of the present work is to develop and validate a Physics-Informed Neural Network (PINN) framework for predicting two-dimensional steady incompressible flow past a square cylinder at low Reynolds numbers. Flow past bluff bodies such as square cylinders is a classical benchmark problem in fluid mechanics due to the presence of flow separation, wake formation, and strong velocity and pressure gradients. In the present study, numerical simulations are first carried out using the open-source CFD solver OpenFOAM to generate reference solutions for Reynolds numbers 10, 20, and 30. A structured computational mesh is employed, and steady laminar flow is solved using a SIMPLE-based solver, and the resulting velocity and pressure fields are used for validation.

A hybrid PINN model is then formulated by embedding the incompressible Navier–Stokes equations and continuity constraint directly into the loss function, along with boundary condition enforcement and supervised data loss derived from OpenFOAM solutions

This study bridges machine learning and CFD, laying the foundation for mesh-free flow prediction using Physics-Informed Neural Networks. Details regarding geometry and flow have been listed in Table-1.

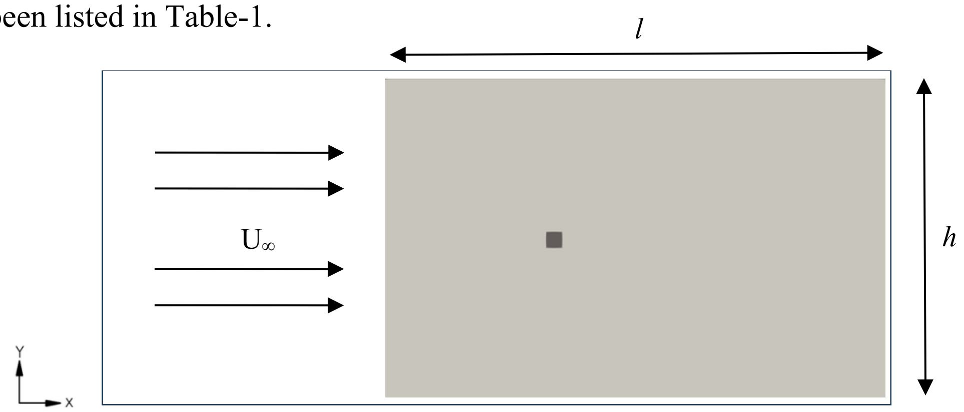

Figure 1: Geometry

Table-1: Details of geometry and flow conditions

Geometry details	Length of the domain (*l*) = 31m
	Height of the domain (*h*) = 21m
	Characteristic length (L) = 1m
	Obstacle center position (x, y) = (10.5, 10.5)
Fluid Property	Inlet Velocity (U_∞) = 1m/s
	Kinematic viscosity = 0.1, 0.05, 0.033 m^2/s
Reynolds number	Re = 10, 20 and 30