National Institute of Technology Rourkela

Defence Seminar

Seminar Title	: Hydrodynamic Investigation of Flow Through Pipe Bends Assisted by Artificial Intelligence
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Venue	: ME-001 (Mechanical Seminar Room)
Date and Time	: 30 May 2025 (9.30 am)

Abstract

: A computational fluid flow investigation of a 90-degree and 180-degree bend pipe has been undertaken in this study for varying Reynolds number and curvature ratio. The Reynolds averaged Navier-Stoke&rsquos equations have been solved for a steady incompressible flow in a smooth circular bend in the finite volume framework of ANSYS Fluent. The Reynolds stress model has been adopted for closure of turbulence quantities. The parameters that have been taken here are curvature ratios from 0.01 to 0.2 and Reynolds numbers up to 0.1 million. Firstly, a quasi-universal correlation for the friction factor has been performed using the ensemble of metamodels. Secondly, a detailed exploration of the flow, turbulence, and the vortex structures in the mean turbulent flow field has been undertaken using the paradigm based on the complex conjugate eigenvalues of the velocity gradient tensor. Furthermore, a parametric analysis is performed. Moreover, an artificial neural network model has been constructed considering the heterogeneity of friction factor data over laminar and turbulent flow regimes. In the friction factor analysis using the ensemble of metamodels, the ensemble has been trained and validated with simulation data to develop the required correlation. The k-fold cross-validation technique has been employed to the ensemble to optimize the model&rsquos predictive capabilities over the changing flow regimes, thus generating a large database of values. Furthermore, identification of vortex structures through the eigenvalue-based vortex defining paradigm has shown that the convex contour of the inner side of the bend is the key vortex-generating surface. The vortices have been found to start gaining swirling strength just after entering the bend. The strength further decays within the remaining part of the bend. The outer side of the bend appears to maintain a straining flow regime. The vortex-induced turbulence has been found to suffer significant dissipation within the bend region. The vortices transported downstream help in generating turbulence. Additionally, in the parametric study of vortex structures, with increase in curvature swirling strength maxima shifts away from the bend inlet to the vortex arms but significantly dissipates beyond a certain curvature. In the spanwise direction, vortex structures have been densely distributed in the inner bend and have been propagated to the center at bend exit. It has also been found that the turbulent kinetic energy is less at the inner bend section, which shows shifting of perturbations to the outer section of the bend. Additionally, an artificial neural network is designed for prediction, inverse modeling, and velocity field reconstruction of vortex structures. With this, the two-fold hydrodynamic analysis of flow through pipe bends has been performed, leveraging machine learning and artificial intelligence, to enhance the investigation, and present a comprehensive understanding of the same.