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A Predictive Model for Turbulence Evolution and Mixing Using Machine Learning

Authors : Yuhang Wang, Jorg Schluter, Sergiy Shelyag

Abstract : The high cost associated with high-resolution computational fluid dynamics (CFD) is one of the main challenges that inhibit the design, development, and optimisation of new combustion systems adapted for renewable fuels. In this study, we propose a physics-guided CNN-based model to predict turbulence evolution and mixing without requiring a traditional CFD solver. The model architecture is built upon U-Net and the inception module, while a physics-guided loss function is designed by introducing two additional physical constraints to allow for the conservation of both mass and pressure over the entire predicted flow fields. Then, the model is trained on the Large Eddy Simulation (LES) results of a natural turbulent mixing layer with two different Reynolds number cases (Re = 3000 and 30000). As a result, the model prediction shows an excellent agreement with the corresponding CFD solutions in terms of both spatial distributions and temporal evolution of turbulent mixing. Such promising model prediction performance opens up the possibilities of doing accurate high-resolution manifold-based combustion simulations at a low computational cost for accelerating the iterative design process of new combustion systems.

Keywords : computational fluid dynamics, turbulence, machine learning, combustion modelling
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