Mechanical Engineering Doctoral Defense

Potential of data-driven approaches for modeling heat and mass convection processes

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Abstract

In convective heat transfer processes, heat transfer rate increases generally with a large fluid velocity, which leads to complex flow patterns. However, numerically analyzing the complex transport process and conjugated heat transfer requires extensive time and computing resources. Recently, deep learning has risen as an alternative method to solve physical problems in a computational efficient manner by omitting to solve the governing physical equations. However, research on convective heat transfer is still in its early stage.

This study aims to introduce data-driven approaches for modeling heat and mass convection phenomena. As the first step, this research explores a deep learning approach for modeling the internal forced convection heat transfer problems. Conditional generative adversarial networks (cGAN) are trained to predict the solution based on a graphical input describing fluid channel geometries and initial flow conditions. A trained cGAN model rapidly approximates the flow temperature, Nusselt number (Nu) and friction factor (f) of a flow in a heated channel over Reynolds number (Re) ranging from 100 to 27750. The optimized cGAN model exhibited an accuracy up to 97.6% when predicting the local distributions of Nu and f.

Next, this research introduces a deep learning based surrogate model for three-dimensional (3D) transient mixed convention in a horizontal channel with a heated bottom surface to check potential of a deep learning model in complex convection phenomena. cGAN are trained to approximate the temperature maps at arbitrary channel locations and time steps. The model is developed for a mixed convection occurring at the Re of 100, Rayleigh number of 3.9×106, and Richardson number of 88.8. The cGAN with the PatchGAN based classifier without the strided convolutions infers the temperature map with the best clarity and accuracy.

Finally, this study investigates how machine learning analyzes mass transfer in 3D printed fluidic devices. Random forests algorithm is hired to classify the flow images taken from 3D printed tubes. Particularly, this work focuses on laminar-turbulent transition process occurring in a 3D wavy tube and a straight tube, which is visualized by dye injection. The machine learning model automatically classifies experimentally obtained flow images with an accuracy > 0.95.

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Zoom Link: https://asu.zoom.us/j/81795828281