DEPARTMENT OF MECHANICAL ENGINEERING

ME Spring Seminar 01

Physics-Aware AI Modeling of Urban Wind for Urban Air Mobility Safety Assessment

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Accurate prediction of urban wind conditions is important for many applications, including urban climate studies, infrastructure planning, and the emerging field of urban air mobility (UAM). However, high-fidelity computational fluid dynamics methods, such as large-eddy simulation (LES), remain too expensive to be used routinely for large urban domains or long-term analyses. This lecture introduces a physics-aware artificial intelligence framework that combines high-performance CFD with deep-learning-based surrogate modeling to enable efficient urban wind prediction. The first part of the talk presents a surrogate modeling approach based on the POD-Transformer architecture. High-resolution, building-resolved LES simulations are performed using a multi-GPU solver to generate a database of transient urban flow fields. Proper orthogonal decomposition (POD) is used to extract dominant flow structures, and a Transformer network is trained to learn the relationship between meteorological inputs and the corresponding reduced-order flow representation. The resulting surrogate model reconstructs urban wind fields with good fidelity while reducing the computational cost by several orders of magnitude compared with conventional LES. The second part focuses on long-term wind reconstruction using the trained surrogate model together with year-long meteorological observations. This approach enables analysis of minute-scale urban wind variability across a dense, high-rise district in Seoul. The reconstructed fields reveal clear morphology-dependent flow features, including channeling effects and strong rooftop shear within the urban canopy. Probabilistic analyses also show that mean-based indicators often fail to capture transient wind events that may affect UAM operations. Overall, the framework illustrates how high-performance computing and physics-based machine learning can be combined to extend high-fidelity CFD toward long-term urban wind assessment.

Bldg.110 #N105

16:00 - 17:15

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