Investigating RANS Turbulence Models for Predicting Airflow Dispersion in Enclosed Environments: Numerical Simulation and Experimental Validation

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Abstract

The dispersion of respiratory aerosol particles in enclosed environments poses a significant challenge to understanding the transmission of airborne infectious diseases, mainly due to the influence of turbulence on the propagation of aerosol particles. Turbulence, with its complex and chaotic nature, is a prevailing phenomenon in a fluid flow.

Four widely used Reynolds-Averaged Navier-Stokes (RANS) turbulence models—Standard k-epsilon, RNG k-epsilon, Realizable k-epsilon, and SST k-omega incorporate empirical relationships and assumptions to approximate turbulent quantities. This study investigates these models' applicability and limitations in airflow dispersion in an enclosed space.

The study has two parts. Firstly, Particle Image Velocimetry (PIV) analysis in an enclosed domain will be conducted across a range of velocities. Secondly, a computational fluid dynamics model based on RANS with different turbulence models will be setup for simulation. By comparing the experimental data and numerical simulations, we aim to comprehensively examine the accuracy of RANS turbulence models in capturing the behavior of turbulent flows.

This research serves as a preliminary study toward understanding the transmission dynamics of bioaerosols, such as virus-laden droplets, in ventilated indoor environments.

Fig.1. PIV experimental and computational setup

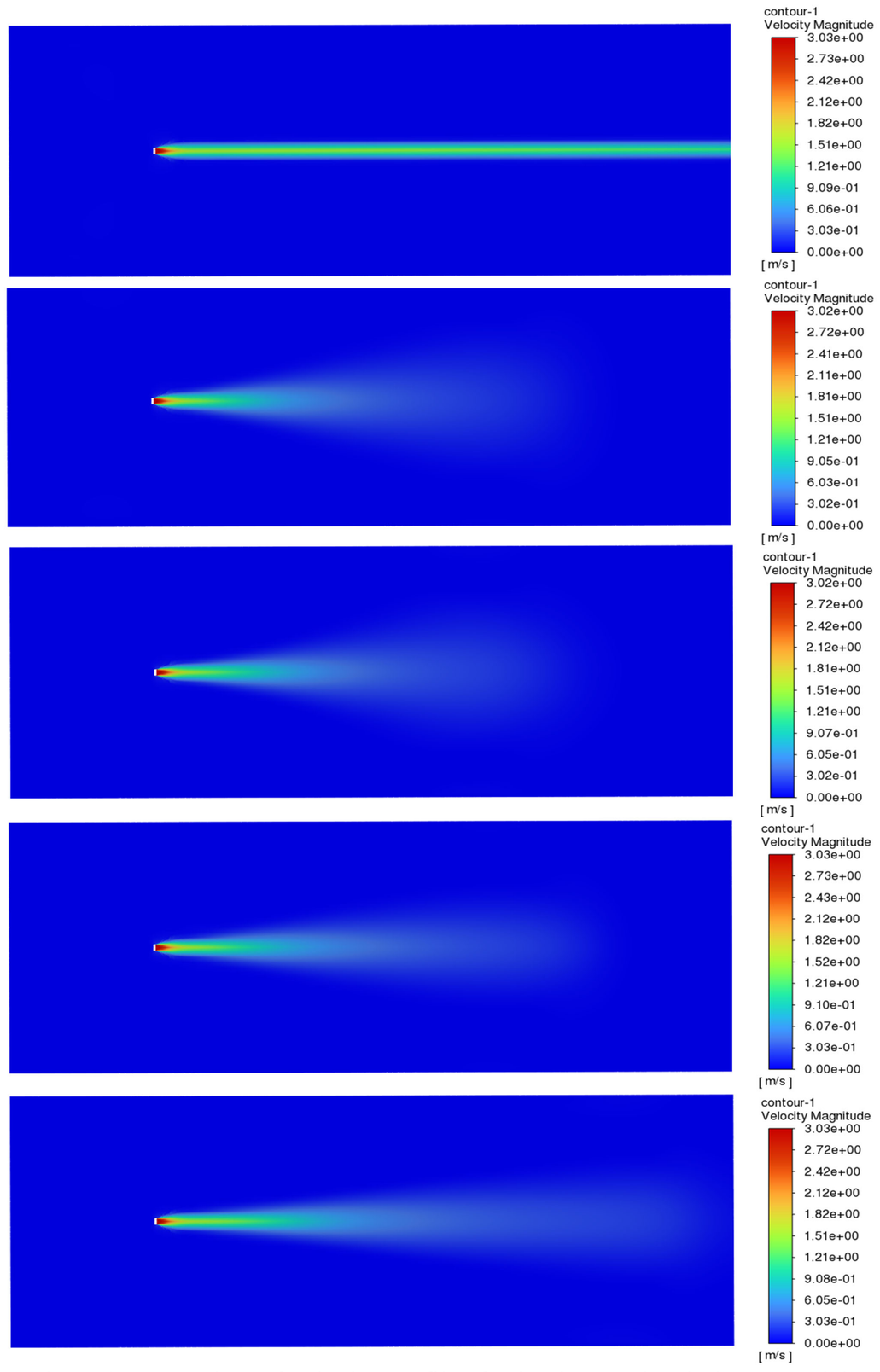

Fig.2. Contour plots of velocity profiles for laminar and turbulence models (SST k-omega, RNG, Standard, and Realizable k-epsilon) at 3 m/s Airflow

Conclusion

In conclusion, this research provides a crucial insight into the complex interplay of turbulence in fluid flow, with its inherent chaotic characteristics, which is a significant aspect of this study. By juxtaposing experimental PIV data and the four (4) prevalent RANS turbulence models — this study sheds light on the applicability and averaging limitations of these models in the context of airflow dispersion in an enclosed environment.

The study effectively assesses the accuracy of RANS turbulence models in replicating the complex behavior of turbulent flows. This research serves as an important preliminary study towards a deeper understanding of the transmission dynamics of bioaerosols, such as virus-laden droplets, in ventilated indoor settings.

Validation against the PIV results is underway.

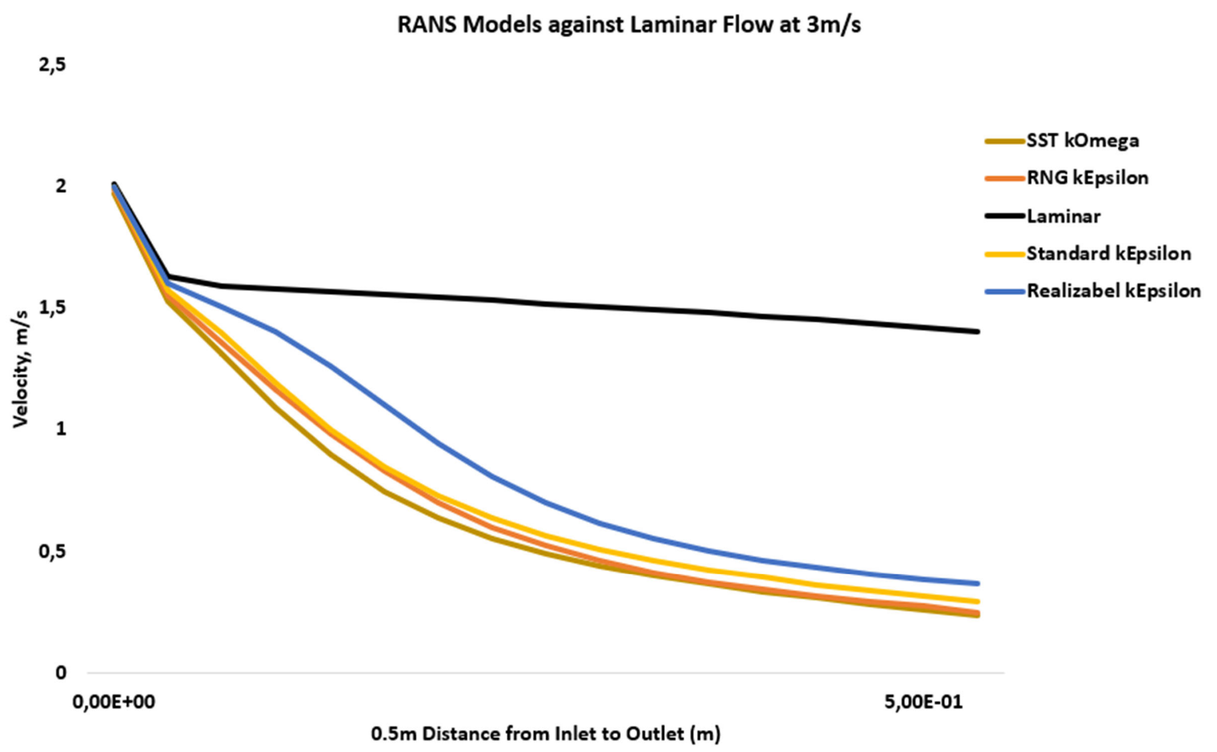

Fig.3. Velocity diffusion profile at 0.5 m distance from inlet

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