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Numerical Study of a Ventilation Principle Based on Flow Pulsations

Authors : Amir Sattari, Mac Panah, Naeim Rashidfarokhi

Abstract : To enhance the mixing of fluid in a rectangular enclosure with a circular inlet and outlet, an energy-efficient approach is further investigated through computational fluid dynamics (CFD). Particle image velocimetry (PIV) measurements help confirm that the pulsation of the inflow velocity improves the mixing performance inside the enclosure considerably without increasing energy consumption. In this study, multiple CFD simulations with different turbulent models were performed. The results obtained were compared with experimental PIV results. This study investigates small-scale representations of flow patterns in a ventilated rectangular room. The objective is to validate the concept of an energy-efficient ventilation strategy with improved thermal comfort and reduction of stagnant air inside the room. Experimental and simulated results confirm that through pulsation of the inflow velocity, strong secondary vortices are generated downstream of the entrance wall-jet. The pulsatile inflow profile promotes a periodic generation of vortices with stronger eddies despite a relatively low inlet velocity, which leads to a larger boundary layer with increased kinetic energy in the occupied zone. A real-scale study was not conducted; however, it can be concluded that a constant velocity inflow profile can be replaced with a lower pulsated flow rate profile while preserving the mixing efficiency. Among the turbulent CFD models demonstrated in this study, SST-kω is most advantageous, exhibiting a similar global airflow pattern as in the experiments. The detailed near-wall velocity profile is utilized to identify the wall-jet instabilities that consist of mixing and boundary layers. The SAS method was later applied to predict the turbulent parameters in the center of the domain. In both cases, the predictions are in good agreement with the measured results.

Keywords : CFD, PIV, pulsatile inflow, ventilation, wall-jet
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