2D and 3D Simulation on Thermal Flow Around the Human Body

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Abstract

Indoor thermal comfort has become a hot topic as energy saving raises the public attention. Accurate thermal flow prediction in an indoor environment and its influence on human provides a critical background to the development of comfort-providing yet energy-saving solutions. This study focuses on establishing a benchmark to simulate thermal flow between human and indoor environment.

Firstly, only air flow in indoor environment was simulated for the environment fidelity check. A 3D chamber model was built as a copy of a physical climatic chamber with a thermal manikin inside (Fig.1 (a)). A 2D chamber model was acquired from the cross-section plane at the center of 3D model. The air flow simulation for the 2D chamber model was compared to the 3D chamber model. Then, the 3D chamber model was complemented with a human body model to investigate heat flow at the body surface. To figure out the balance between computational cost and accuracy, two simplified nude human body models were built. One is a "cylinder man" model (Fig.1 (b)), which composes of one cylinder with three divisions representing head, torso and leg segments. The other one is a "tin man" model (Fig.1 (b)), which composes of several cylinders and one sphere. COMSOL Multiphysics® was employed for the simulation. Turbulent Flow, Low Re k-ε and Heat Transfer in Fluids interfaces were used for air flow and heat transfer simulation respectively. Radiative heat transfer was simulated with S2S model. Air velocity in the physical chamber and heat flux at the manikin surface were measured for model validation.

As a result, the greateset discrepancy between 2D simulation and measurements was observed at waist level, where a wind speed of 0.24 m/s was measured while the simulated value was close to 0 m/s. This could be explained by the incompletely developed flow in the 2D chamber model, which limites the air flow to a single plane. In spite of the discrepancy, 2D simulation, which took approximate one third of the time needed for 3D simulation, has helped with the determination of the boundary conditions and mesh size for 3D simulation and, thus, helped save computational cost. 3D simulation with full scale chamber model showed a better agreement with measurements than 2D simulation. The

greatest discrepancy of air velocity between simulation and measurements at waist level was reduced to 0.11 m/s. Regarding the heat flux at human body surface (ΔT=10.5 °C), for the "cylinder man", both local and total heat flux agreed well with the measurements. For the "tin man", which has a more realistic but complex body structure, the simulated heat loss agreed with measured data at head and torso and was larger at the legs by 27.5%. Coarse mesh between two legs in the "tin man" model might be the reason for the discrepancy.

As a conclusion, 2D model is able to predict the approximate air flow distribution in an indoor environment, while 3D model predicts the air flow even closer to the real condition. The body structure simplification shows a few influences on the total heat transfer from the human body. Locally, complex body structure requies denser mesh for more accurate heat transfer prediction.

Figures used in the abstract

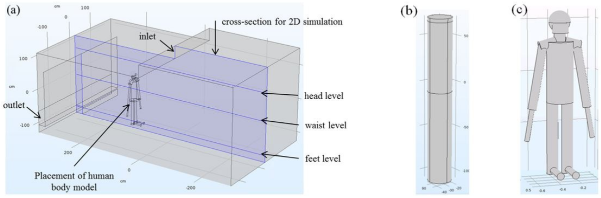

Figure 1: Fig.1 Climatic chamber used for validation (a) and “cylinder man” model (b) and “tin man” model (c).