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LBM Simulation of the Time for Removal of Pollutant Particles in a Ventilated Enclosure

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ABSTRACT

The adverse impact of poor indoor air quality on the health and well-being of occupants is undeniable. Research into the elimination of contaminants is a major current topic, illustrating the growing importance attached to this issue. This study aims to improve indoor air quality in enclosed spaces such as homes, workplaces, and schools. This investigation aims to numerically study the removal time of pollutant particles in a chamber ventilated from the bottom of the active wall at a velocity represented by the Reynolds number ($10 \leq Re \leq 10^3$). The exhaust is located at the top of the right-hand wall. A porous partition is placed in the middle of the lower wall and is characterized by a permeability defined by the Darcy number ($10^{-6} \leq Da \leq 10^2$). Simulation results were calculated with Fortran code using the lattice Boltzmann method with multiple relaxation time (LB-MRT). The results show the evolution of different contours of the stream function, isotherms, and iso-concentrations, as well as the displacement efficiency.

Keywords: Air quality, Displacement efficiency, LB-MRT method, porous separation, ventilated cavity.

1 Introduction

Industrial activities such as energy production, agriculture, waste production, and transport also produce pollutants, which can be very harmful to our health and the environment. It's important to understand the impact of our daily activities on the environment and find solutions to reduce them. Several internal sources, such as occupants' activities, building equipment, construction materials, and so on, can pollute indoor air. The study of heat and mass transfer by forced, natural, and mixed convection in ventilated cavities has been the subject of several theoretical and experimental works that include mathematical modeling of the cavity and numerical analysis of the convection equations [1, 2]. Our work aims to investigate numerically the removal time of pollutant particles in a vented enclosure in the presence of a porous separation. This study is of interest for thermal comfort in general and mainly for decontamination and indoor air quality in buildings.

2 Numerical method and Mathematical formulation

Our physical problem, which is based on the formulation of the Navier-Stokes equations, was simulated using Lattice Boltzmann's MRT (multiple relaxation time) meth. This mesoscopic approach has proven its efficiency and accuracy in several fields of research. The fundamental equations used to solve our physical problem are the conservation equations of mass, momentum, energy, and concentration. [2].

$$\nabla . u = 0 \quad (1)$$

$$\partial_t u + (u.\nabla)\left(\frac{u}{\varepsilon}\right) = -\frac{1}{\rho}(\varepsilon) + v_e + \nabla^2 u + F \quad (2)$$

$$\partial_t T + \nabla.(Tu) = \alpha \nabla^2 T \quad (3)$$

$$\partial_t C + \nabla.(Cu) = D \nabla^2 C \quad (4)$$

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In addition, the expression used to calculate the displacement efficiency is [1]:

$$\eta d = \frac{C\,(t) - C_0}{C_c - C_0} \tag{5}$$

3 Results and discussion

Figure 1 illustrates the evolution of the displacement efficiency and average concentration as a function of dimensionless time (τ), Rayleigh (Ra), and for Reynolds ($Re = 100$), Darcy ($Da = 10^{-2}$), Hight of porous separation ($Hp = 0.6$) and buoyancy ratio ($N = 0$). The displacement efficiency curve follows a distinctly exponential trend, reaching its maximum value of one. The average concentration curve asymptotically approaches zero. When the effect of the porous partition is negligible ($Da = 10^{-2}$) and for low Reynolds values ($Re = 100$), with Rayleigh number equal of 10^5, better efficiency is observed.

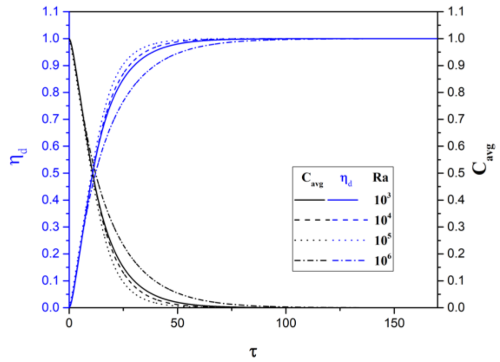

Figure1 : The displacement efficiency and average concentration as a function of dimensionless time (τ), Rayleigh (Ra), and for Reynolds ($Re = 100$), Darcy ($Da = 10^{-2}$), height of porous separation ($Hp = 0.6$) and buoyancy ratio ($N = 0$).

3 Conclusion

When the effect of the porous partition is minimal and for low Reynolds values and high Rayleigh values, better removal efficiency of pollutant particles is observed.

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