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Thermo-Solutal Convection in Ventilated Cavity with a Reactive Porous Separation: Case of Depollution

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ABSTRACT

In order to improve the depollution rate and therefore the air quality in premises, which have different uses by the occupants, the effect of eliminating pollutants by chemical reaction was added to ventilation by displacement. In this study, a numerical simulation of a mixed, double diffusive convection in a contaminant rectangular cavity with an aspect ratio equal to two, ventilated with fresh air by two diagonally opposite openings, with a reactive porous partition, fixed in the center of the lower wall. The right-side wall is brought to a constant hot temperature while the other walls are adiabatic. The momentum, heat and mass transfer equations were modeled by the Darcy-Brinkman-Forchheimer flow model. The reaction term in the mass transfer equation is translated by the Arrhenius model. The Lattice Boltzmann method with a multiple relaxation time (LBM-MRT) is used to resolve the obtained system of equations. The results are illustrated in terms of streamlines, isotherms and iso-concentrations according to the different control parameters (Ri, Da). The results of ventilation efficiency indices and the transfer rate are also presented. It was concluded that the optimal pollution control rate efficiency was obtained when the reaction was present

Keywords: Air quality, Displacement ventilationn, LB-MRT method, porous separation, Thermo-solutal convection, Depollution.

1 Introduction

The study of ventilation has received particular attention by several researchers, due to its wide range of applications related to heat and mass transfer in ventilated cavities. Indoor air quality (IAQ) is one of the interesting applications in recent times, which presents a priority for the health of individuals. A healthy indoor environment is one that contributes to the productivity, comfort, health and well-being of occupants. Good IAQ will include an atmosphere free from unacceptable levels of contamination and ensure a comfortable indoor environment, in terms of temperature, air circulation, etc. Renewing the air in premises has become a necessity given, that many people spend most of their time in enclosed spaces. As a result, a lot of research works has focused on cavities ventilated by displacement, treating the IAQ in different situations of space occupation by individuals, in educational buildings [1] in ventilated open space involved with indoor comfort [2,3], in train station waiting hall [4], and in transport ways as passenger aircraft cabins [5,6]. In the present paper, the cavity ventilated by air displacement is used to remove heat and pollutants, for two cases of permeabilities (low and high values), the reaction coefficient and the height of the porous partition are kept at fixed values equal to 1 and 0.6 respectively, the value of 0.6 represents sitting position in the premises.

2 Mathematical formulations

Mixed convection with double diffusion in a rectangular cavity of aspect ratio L/H=2, ventilated by air (Pr=0.71). The opposed diagonal openings of value H/10 and all walls are kept adiabatic and impermeable at exception of the right wall which minted at a constant temperature as shown in Figure 1. A reactive porous separation height Hp=0.6, whose thickness is H/5 and with a reaction rate a_k=1, placed in the middle of the lower wall.

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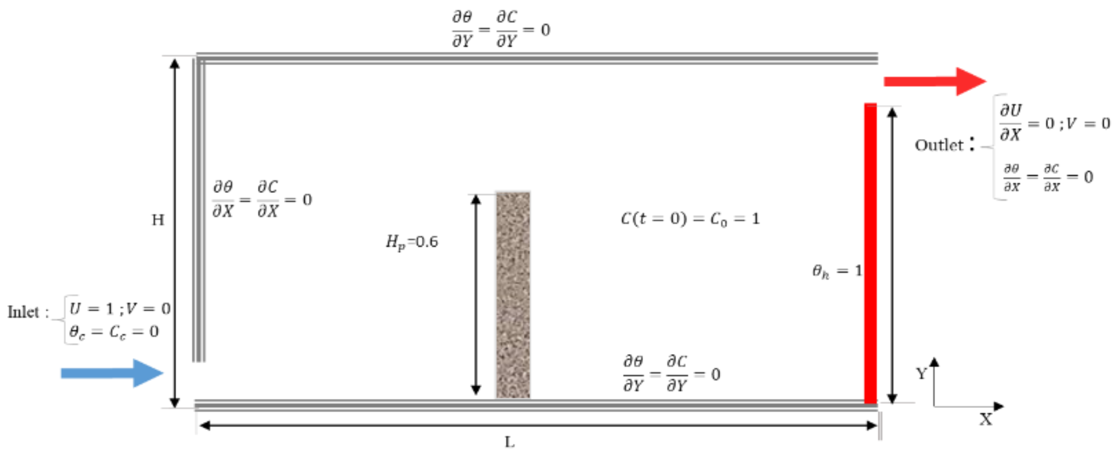

Figure1 : physical model

3 Results and Discussion

Figure 7 illustrates the evolution of the mean Nusselt number as a function of Ra for different Reynolds, Darcy and Hp equals 0.6. For Da=10-2 we note that for low Rayleigh values, heat transfer intensifies with increasing Reynolds number and forced convection dominates, so the value of the Nusselt number depends solely on the value of the Reynolds number. However, as Ra increases, the evolution of the Nusselt number tends towards natural convection. The maximum transfer rate is obtained for Re=1000 and Ra=106, the maximum deviation calculated is 17% for the range of Reynolds variation (500≤Re≤1000) with Ra=106. For Da=10-6, the same applies to low values of Rayleigh. For moderate values of Ra and Re, we see a remarkable decrease in Nu, reflecting the competition between natural and forced convection. For large values of Ra, the rate of heat transfer increases due to increased buoyancy forces at low values of Re. At maximum Re, there is always competition between the thermal gradient (natural convection) and the ventilation jet (forced convection). For this permeability value, the maximum Nu value was obtained for 200≤Re≤500 and Ra=106. A maximum deviation of 9.4% was calculated for a range of parameter variations: 200≤Re≤500 and 10^5≤Ra≤10^6.

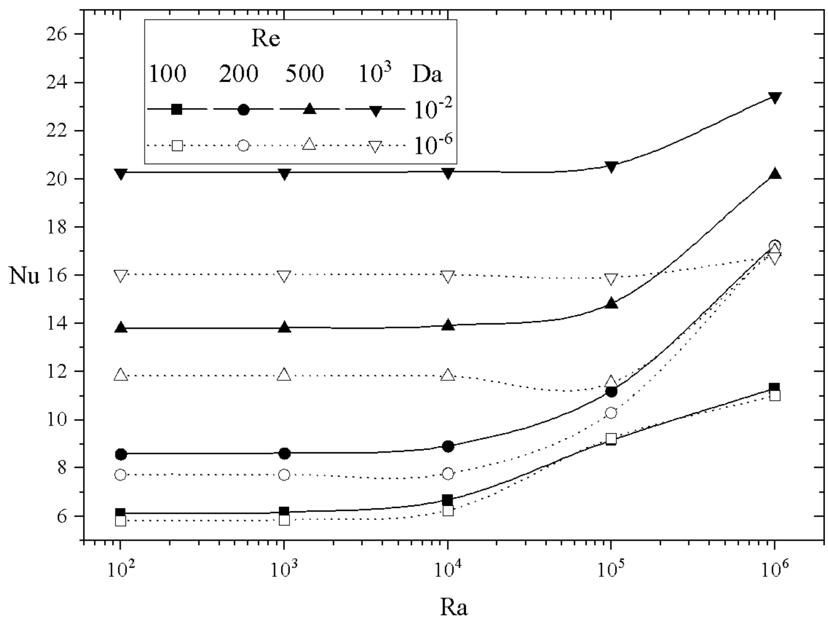

Figure2: Evolution of the mean Nusselt number as a function of Ra for different Reynolds number, two values of Darcy number (Da=10-2, Da=10-2) and Hp= 0.6

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4 Conclusions

The effectiveness of displacement ventilation in a rectangular cavity with a porous partition in the presence of a chemical reaction has been numerically investigated The main findings are:

- Analysis of the thermal fields shows that heat transfer is most intense in the right-hand side of the cavity. For high permeability, the increase in the Richardson number results in a narrowing and flattening of the vertical lines, and a development of the thermal boundary layer at the hot wall.
- The overall heat removal efficiency is acceptable for high permeability; however, it is very efficient for Re=500 and a maximum Rayleigh number value. On the other hand, at low permeability, thermal efficiency is good for an intermediate Reynolds value and a high Rayleigh number.
- The optimum value of air change time for high permeability (Da=10-2) is τ_c=63 with for Re=100, Ri=1.4·10-2 in the presence of the reaction, whereas the optimum value is τ_c=47 for Da=10-6, with Re=100 and Ri=14.

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