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Storage Strategy in Granular Silos: Heat and Mass Transfer Analysis

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ABSTRACT

This study delves into the investigation of heat and mass transfer within a vertical silo, specifically focusing on the dynamics of stationary two-dimensional forced or mixed convection within a cylinder entirely filled with a porous medium, represented by the granular product. The cylinder, maintained at a constant temperature T0, facilitates the transfer processes. The fluid flow is characterized by employing Darcy's model, while the chemical reaction aspect is incorporated through the Frank-Kamenetskii term. Notably, depending on the Reynolds number and Rayleigh number values, the findings unveil two distinct types of flow patterns: one marked by a chimney-type flow without recirculation, and another characterized by recirculation in the system. This delineation highlights the influence of key parameters on the flow dynamics within the studied vertical silo.

Keywords: Porous medium, Darcy model, Granular silo, Forced and mixed convection.

1 Introduction

This paper encompasses a comprehensive examination of existing studies on convection, specifically in the context of storage silos and vertical cylinders filled with a porous medium, incorporating both natural and mixed convection phenomena. The literature on this subject is extensive and diverse, spanning experimental investigations [1], analytical approaches, and numerical simulations [2]. Within the realm of this research, key parameters that significantly influence the analysis of heat and mass transfers include opening dimensions, thermal boundary conditions, and permeability [3-5]. The exploration of these parameters contributes to a nuanced understanding of convection dynamics within the examined domains.

2 Results and Discussion

Figures 1 and 2 present the average Nusselt number (Nu) for scenarios involving constant wall temperature with N values of 0 and 1, respectively. The plots depict Nu as a function of the Rayleigh number (Ra) and Reynolds number (Re) across different Darcy numbers (Da), namely 10^{-6}, 10^{-2}, 1, and 100. These visual representations clearly showcase the escalation of average heat transfer with increasing Ra, attributed to the amplified fluid flow rates resulting from heightened buoyancy forces. It is noteworthy that the augmentation in Re contributes to an intensified average heat transfer, with a more pronounced effect observed in Da values of 1 and 100, where the medium is fluid, making the impact of the fresh air flow rate more discernible. Notably, the influence of Darcy's number becomes evident in the evolution of Nu. The transfer rate is particularly conspicuous at higher Da values (i.e., 1 and 100, indicating a fluid medium), while it remains constant for $Da=10^{-6}$, denoting a solid medium. This observation underscores the substantial impact of Darcy's number on the heat transfer dynamics in the examined system.

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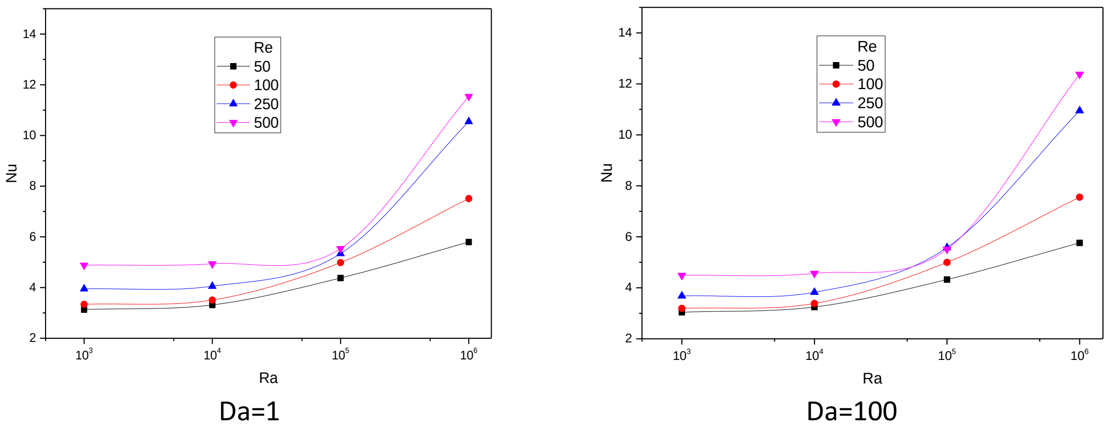

Figure1: Evolution of the average Nusselt number Nu as a function of the different parameters considered for N=0

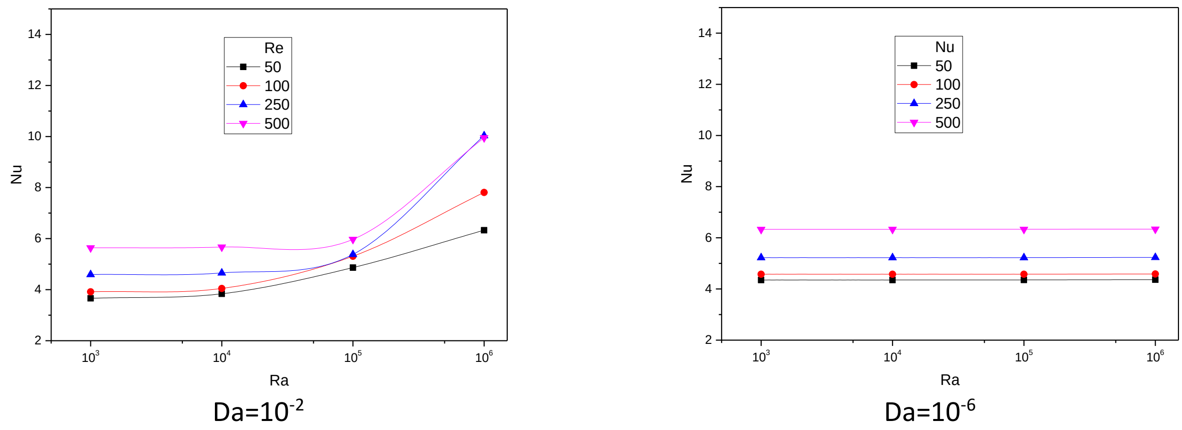

Figure2: Evolution of the average Nusselt number Nu as a function of the different parameters considered for N=1

3 Conclusions

An analysis of heat transfer reveals a notable augmentation as the Rayleigh number escalates. The average Nusselt number exhibits sensitivity to variations in both Reynolds and Darcy numbers. Generally, an upsurge in the Rayleigh number corresponds to an increase in the overall fluid flow rate, while the recirculation flow rate appears particularly contingent on the heating parameter (Ra), irrespective of the values of N (0 and -1). As the Rayleigh number increases, the boundary layer constricts, facilitating a greater influx of ambient fluid through the upper face. This phenomenon underscores the intricate interplay between heat transfer, fluid dynamics, and boundary layer characteristics in the studied system.

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