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Modelling and Simulation of Momentum, Heat, and Mass Transfer in a Deep-Bed Grain Dryer

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ABSTRACT

This article concerns the modelling and simulation of a deep-bed grain dryer in a large diameter-column. Two-dimensional (2D) models of deep-bed grain dryers were built by considering simultaneously momentum, heat, and mass transfer in the drying phase together with coupled heat and mass balance in the grain phase. The dynamic equations are solved numerically by using finite difference method. The momentum equations are applied to simulate pressure drop and velocity field of the drying air across the bed. The mass and heat balance in the two phases determine the profile of temperature and moisture content in both phases. Further, drying rate curves for

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various temperature of inlet drying gas together with moisture content of grain were simulated. The simulated profiles are in close agreement with experimental data.

Key Words: Deep bed drying; Coupled momentum mass heat transfer; Navier-Stokes equation.

INTRODUCTION

Deep bed dryers, also known as fixed bed dryers, are one of the most common types of industrial dryers. Transport phenomena of grain drying are complex due to coupling of momentum, heat and mass transfers phenomena. The pressure of the drying air decreases due to friction between the gas and the walls as well as due to momentum losses caused by interaction of particles. The slip velocity between the particles and the gas is controlled by the interfacial drag and friction between the particles and the walls. The temperature of the gas phase is affected by heat transfer to the particles (drying process) and heat transfer at the wall and also affected by moisture (mass) transfer from the particles/grains.

Mathematical modelling and computer simulation of grain drying are now widely used in research by considering coupled momentum, heat and mass transfer for some features of dryers. Several models have been proposed to describe the heat and mass transfer processes in the types of convective grain dryer, such as Thompson et al.,[13] Palancz,[8] Franca et al.,[2] Lopez et al.,[6] Sitompul et al.[12] However, they did not consider the effect of momentum transfer in the drying process. In this article, a more comprehensive model for the drying process in a deep-bed grain dryer is proposed. Furthermore, simulated profiles are then compared with experimental data for a grain dryer with a large-diameter column.

MATHEMATICAL MODELLING AND NUMERICAL SOLUTION

Modelling of a Deep Bed Grain Dryer

In this article, we proposed a two-phase mathematical model for deep bed drying by taking into account the conservation of momentum, mass and energy within the bed and the conservation of heat and mass in the spherical grains. Average transfer coefficient between the bulk gas stream and the grain surface can be correlated in terms of dimensionless groups