CHAPTER I

INTRODUCTION

Multi-phase flow with droplets or particles is encountered in almost all particulate material processing operations, including fluidized bed, spouted bed, granulation, dust collection, and so on. In the past such operations have to be investigated experimentally or semi-empirically, thus requiring lots of time, efforts and materials. During the past decade rapid advances in computer technology coupled with regular steep drops in the prices of computer hardware have rendered feasible a number of more realistic simulation approaches with a minimum number of simplifying assumptions and restrictive conditions on the mathematical model of the process of interest. One of the practical and powerful approaches is the Distinct Element Method (DEM) or Discrete Particle Simulation (DPS) pioneered in Japan by Prof. Yutaka Tsuji et al. in Osaka University. In this innovative approach, simultaneous separate movements of individual particles in a particulate system are calculated using the simple Newton's equations of motion while taking into account local particle-to-particle and particle-to-fluid interactions. Computational fluid dynamics is also used to predict the fluid movement in the presence of discrete particles, which take part in the multi-phase flow. While mathematically simple and more realistic than the conventional continuum multi-phase flow models, the DEM technique bears a heavy burden proportional to the number of individually treated particles in the system. Naturally the larger the number of particles, the longer the required computational time and the larger the computer memory becomes.

The spouted beds are widely used in industry such as drying of granular materials, granulation, tablet coating and solid blending. The conventional spouted bed is formed in conical or conical-cylindrical vessel which has a small opening for gas injection at the center of the vessel. The high gas velocity injected at the bottom lifts and carries the particles upwards through the central part of the bed. These particles, after reaching a certain height above the peripheral bed level, fall as a loosely packed bed into the annulus region between the hollowed core and the vessel wall. The overall bed is composed of a dilute phase in the central core(spout region) which the particles are lifted and moved upward by the injected gas and a dense phase(annulus region) between the spout region and the vessel wall which the particles are moved down. To improve the bed structure and stability flow, a draft tube was inserted in the core of the spouted bed to separate the spout region from the annulus region, thus stabilizing solids circulation and reducing the bed pressure drop as mentioned by T. Kudra et. al. (1992). Among the various modifications of the spouted beds proposed to overcome some of the limitations of the conventional design, the most promising appears to be Two Dimensional Spouted Bed in which the scale-up can be achieved, to some extent, by a simple multiplication of the apparatus along the bed depth.

1.1 Significance of problem

The spouted bed technique has become established as an alternative to the fluidized bed for the handling of particulates which are too coarse and monodisperse in size. Spouted beds are widely used in the industry such as drying of granular materials, granulation of powders, coating of tablets and blending of solids. The conventional spouted bed is formed in a conical or conical-cylindrical vessel having a small opening for gas injection at the center of its bottom. The injected high-velocity gas lifts and carries particles upwards through the central part of the bed. After reaching a certain height above the peripheral bed level, these particles fall as a loosely packed bed into the downcomer region between the hollowed core and the vessel wall. Therefore the overall bed is composed of a dilute phase in the central core (spout region) through which the particles are lifted and moved upwards by the injected gas and a dense phase (downcomer) between the spout region and the vessel wall through which the particles move down. The combination of these two distinct flow regimes, a pneumatic transport through the bed center (in the spout) and a falling bed in the downcomer, results in an internal circulation of the solids which is characteristic of the spouted bed. In the drying operation, this intensive particle circulation results in more nearly uniform moisture content and bed temperature while the high velocity of the injected gas allows high gas temperature without thermal degradation of the product. Although the spouted bed requires a relatively high pressure drop prior to the onset of spouting and a high inlet gas velocity (but lower volumetric flow rate than the fluidized bed), the resulting high thermal efficiency makes this technique economically feasible under numerous conditions as mentioned by L.M. Passos et. al.(1987).

The literature on conical-cylindrical spouted beds (CSBs) has shown that the continuous movement of particles has significant effect on the performance of the spouted beds in industrial applications such as drying, coal gasification, granulation and particle coating. However, the CSBs are rarely used in the post-harvest industry because of scale-up and operating problem. In an attempt to overcome some of the limitations of the CSBs, A.S. Mujumdar (1984) proposed the idea of a two dimensional spouted bed (2DSB). A typical 2DSB consists of planar walls with a slanting base and has an air entry slot at the center of the bed width. The rectangular geometry makes the 2DSB easier for scale-up than a cylindrical bed. Production can readily be scaled up by adding identical units in the orthogonal direction. Therefore a laboratory-scale apparatus can be considered to be a single unit in a complex of similar units. In order to eliminate back mixing, stabilize solids circulation and reduce the bed pressure drop, draft plates are frequently inserted in the core of the spouted bed to separate the spout region from the downcomer region as mentioned by T. Kudra et. al. (1992).

Nowsaday computational techniques are popular and often used to simulate multi-phase flows, including dilute- and dense-phase gas-solid flows. The Discrete Element Method (DEM) is a powerful tool for getting detailed information on these complex phenomena without physically disturbing the flows. A distinct advantage of carrying out DEM simulation of the spouted bed over the traditional use of the two-fluid models is that the former is capable of elucidating the bed dynamics at the individual particle level (R.J. Rhodes et. al. (2001)). Tsuji et al. (1992,1993,1998,2000) successfully applied the DEM to plug flows in a horizontal pipe, two-dimensional fluidized bed and a cylindrical spouted bed with slanting base. They found that the calculated results on the formation of bubbles, slugs, particle mixing and velocity profiles of the particles agreed well with experimental observations. Horio et al. (1999, 2000, 2001, 2002) successfully applied DEM to the investigation of the hot-spot formation on the distributor near the wall of a fluidizing column in which polymerization reaction is taking place, the behavior of particles and bubbles around immersed tubes in a fluidized bed at high temperature and pressure, and the mechanism of agglomeration in a fluidized bed. M.A. Van Nierop

(2001) used DEM to investigate charge motion of a mill found that the simulation results predicted well the power draft and the charge motion of the mill at speeds below the critical value. R.J. Rhodes (2001) applied DEM to the investigation of mixing in a gas-fluidized beds. The results indicated that the rate of solids mixing increased as the gas velocity increased but the degree of mixing achievable was unaffected. While the initial rate of mixing was found to be insensitive to the particle size, the overall rate of mixing and the resulting degree of mixing were found to decrease as the particle size increased. Although 2DSBs with draft plates is expected to be useful to the post-harvest industry, there has been little detailed information on particles dynamics and gas flow, and their measurements without causing undesirable disturbances in 2DSBs are experimentally difficult.

Corn is an important economic agricultural produce for Thailand and many other countries. The demand for corn is high, especially in the feed milling and food industries. Modern agricultural technology has been developed to solve the problem of shortage of corn. Consequently, a huge quantity of corn is often produced within a short period of time, thus resulting in poor corn quality and infection with aflatoxin B-1 in corn with high moisture content. In this situation, sun drying is generally unsuitable because it depends on weather conditions. Therefore the fluidized bed and spouted bed dryers are often employed because of the small area required for installation.

In this work, DEM is used to investigate the aerodynamics of coarse particles in a 2DSB with draft plates. The properties of the particles are set as the corn particles. As explained above, the 2DSB is selected because it is suitable for coarse heat-sensitive particles. Detailed information such as minimum spouting velocity, pressure drop, spatial distributions of particle velocity and particle circulation rate, is analyzed and presented. The effects of the draft plates and the separation height are also investigated. Such information will be useful for the design of a 2DSB dryer in the post-harvest industry.

1.2 Objectives of research

The main objectives of this research are as follows:

1.2.1 To develop the mathematical model for investigating the aerodynamics of 2DSB with draft plates.

1.2.2 To develop the heat transfer model for 2DSB with draft plates

1.2.3 To validate the model by comparing the simulated results with available experimental and published results.

1.3 Scope of research

1.3.1 Discrete or distinct element method(DEM) is employed in this work.

1.3.2 Investigate the aerodynamics of monodisperse particles and fluid flow in 2DSBs with draft plates.

1.3.3 Investigate the heat transfer phenomena in 2DSB with draft plates.

1.3.4 Test the validity of the model by comparing the simulated results with available experimental and published results.

1.4 Obtained benefits

1.4.1 Understanding the aerodynamics such as minimum spouting velocity, particle velocity, fluid velocity and particle circulation rate of non-isothermal multi-phase flow in 2DSB with draft plates

1.4.2 Understanding the behavior of the particle and fluid in 2DSB with draft plates

1.4.3 Understanding gas-to-particle heat transfer in 2DSB with draft plates

1.4.4 Obtaining a new tool for the design and simulation 2DSB without disturbing the system