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Experimental modeling of polymer latex spray coating for producing controlled-release urea

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ABSTRACT

Spray coating of polymer latex onto fertilizer particles in a fluidized bed for producing controlled-release urea is an environment friendly technology as it does not need any toxic organic solvent. Since the spray coating process in a fluidized bed occurs in the presence of particle collisions, the coating of the particles is random, intermittent and multiple, thus making it difficult to investigate the film formation process. In this paper, an experimental model apparatus was designed and used to investigate the effects of the key factors in the spray coating process. This apparatus reasonably simplified the complex process to avoid particle collisions and randomness in the coating. The intermittent coating in the fluidized bed was modeled by periodic coating and dewatering in the experimental apparatus. A large area film was obtained, and the film permeability was measured. The effects of atomizing gas flow rate, spray rate of latex, solid content of latex and gas temperature on film structure and film permeability were investigated. It was found that water transfer played a dominant role in the spray coating process.

1. Introduction

The use of slow- and controlled-release fertilizers is an effective way to solve the problems of resource waste and environmental pollution that would be caused by indiscriminate use of huge quantities of fertilizers, especially in China. A new technology for producing slow- and controlled-release fertilizers using polymer latex as the coating material by spray coating in a fluidized bed has the advantages of simplicity, economy and not involving any organic solvent, thus making it environmentally benign (Chen, Wang, Yu, & Jin, 2002).

The effective control of the performance of slow/controlled-release fertilizers is the research focus in this field. Shaviv, Raban, and Zaidel (2003) showed that the film permeabilities of water vapor and urea were important parameters that affect the release process because they determined the release rate, release time and release pattern. Therefore, film permeability coefficients as crucial parameters in the spray coating process can be used to facilitate prediction of the release performance of the coated urea.

Existing research on the preparation of slow/controlled-release fertilizers have mostly focused on spray coating conditions. Researches on polymer latex spray coating in various fluidized beds showed that many factors such as spray rate of latex, solid content of latex, temperature of fluidizing gas, velocity of fluidizing gas, etc. affect the spray coating process and release characteristics of the coated urea (Donida & Rocha, 2002; Liu, 2009; Tzika, Alexandridou, & Kiparissides, 2003). McGinity (1997) reported that in a fluidized bed more than 20 factors can affect this process. The spray coating process in a fluidized bed occurs in the presence of particle collisions so that the surface coating is random, intermittent and multiple, thus making it very difficult to study. Moreover, since the film surface area of the coated urea is very small and the samples and sampling are affected by randomness, it is hard to characterize and compare film permeabilities and mechanical properties.

Among works on spray coating for producing slow-release medicine, Mendoza-Romero et al. (2009) modeled film coating by spraying in a rotating drum. They achieved effective control of sprayed film formation conditions such as substrate temperature, drying time, etc., and explored conditions for improving film formation. Sun, Huang, and Chang (1999) prepared films by spraying a turning table and analyzed the structural differences between sprayed films and cast films. The film permeability coefficients and the mechanical properties were measured.

In this work, an experimental model apparatus was designed to simulate the process of spray coating on particles in a fluidized bed. The proposed experimental model simplified the spray coating process by eliminating the influences of random particle collisions in the fluidized bed, to better reflect the effects of key factors in the

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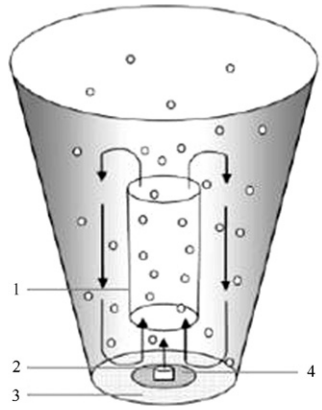

Fig. 1. Schematic of spray coating process in a Wurster fluidized bed (Tzika et al., 2003). 1, partition; 2, nozzle; 3, perforated plate area A; 4, perforated plate area B.

process. Various films were prepared under different conditions, and their film structures were characterized and their permeability coefficients were measured. The key factors in the spray coating process were analyzed, in order to more effectively design and control the film structure so as to better promote research and development of slow-release fertilizer production technology.

2. Experimental model

2.1. Analysis of spray coating process in a fluidized bed

Fig. 1 shows a typical spray coating process in a Wurster fluidized bed (Tzika et al., 2003). Urea particles are coated in a spray region near the nozzle at the bottom, after which the particles are carried by the fluidizing gas along the partition to the top of the fluidized bed. Latex sprayed onto the particle surface was dewatered in the gas flow, and then the particles moved down in the annular region to the spray region to be coated again. The coating and dewatering processes were repeated many times in the fluidized bed, and spray coating was complete when a film of specified thickness was formed.

During the multiple coating and dewatering processes the fluidizing gas was humidified while the latex was dewatered, and subsequently a coated film was formed. The spray coating process occurs with water input and output, to promote a random-intermittent-multiple film formation process on the particles.

The particles pass through the spray region intermittently as they move alternately through the spray region and the annular region. The circulation times of the particles vary, even for the same particle, under different circulation actions. In addition, the process occurs with particle collisions in the fluidized bed. All these cause differences in the film on the particles, thus making it difficult to characterize the film properties.

2.2. Design of experimental apparatus to model spray coating

As shown in Fig. 2, an experimental apparatus was designed to simulate the characteristics of the spray coating process described above. A rotating inner cylinder was used to simulate the continuous spraying on a moving particle in the spray region, in order to overcome the limitations of a small spray area and non-uniformity of droplet distribution due to the nozzle. In this experimental apparatus, fluidized coating of the surface of urea particles was modeled by first coating a layer of urea of about 1 mm thick on the inner cylinder as substrate.

The system shown in Fig. 2 includes a motor, a nozzle and two cylinders with the inner cylinder 100 mm in diameter and the outer cylinder 150 mm in diameter. There was an opening of 80 mm in width on the outer cylinder that was used for latex spraying onto the inner cylinder. Compressed gas at a set temperature was supplied to the inner cylinder and the gap between the inner and outer cylinders. The gas temperature and flow rate were controlled to model the temperature field and dewatering process in the fluidized bed. During coating, latex fed at a controlled rate by a peristaltic pump, was atomized by pressurized gas through the nozzle and sprayed onto the inner cylinder through the opening, and, as the inner cylinder rotated, this spray area was moved away from the opening and the latex on the cylinder surface was dewatered by the gas flow.

In order to simplify the random, intermittent and multiple coating process, periodic spraying was used. The spray time and interval were controlled by a solenoid valve which controlled the peristaltic pump.

3. Experimental

3.1. Material

The materials used in the experiments were large granular urea (China Blue Chemical Ltd.) and polyacrylic acid latex (40% solid content, Department of Chemical Engineering, Tsinghua University).

For characterizing film permeability, analytical grade urea (Fine Chemicals Co., Ltd., China) was used to prepare the urea solution, the concentration of which was first measured. 4-Dimethylaminobenzaldehyde (Analytical Grade, Sinopharm Chemical Reagent Co., Ltd., China), absolute ethyl alcohol (Analytical Grade, Moderneastern Fine Chemicals Co., Ltd., China), and hydrochloric acid (Analytical Grade, Moderneastern Fine Chemicals

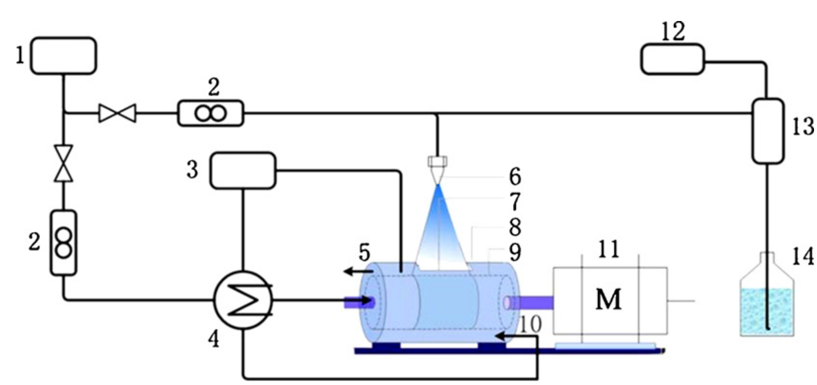

Fig. 2. Experimental apparatus to model spray coating. 1, gas compressor; 2, flow meter; 3, gas temperature controller; 4, heater; 5, gas outlet; 6, nozzle; 7, opening; 8, outer cylinder; 9, inner cylinder; 10, gas inlet; 11, motor; 12, time controller (solenoid valve); 13, peristaltic pump; 14, latex vessel.