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Short Paper

Visualization of Powder Mixing in a High Shear Mixer using Positron Emission Particle Tracking

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1. Introduction

Powder mixing is a fundamental technology used in many industries, including the production of pharmaceuticals, clay and ceramic detergents, and agricultural chemicals. The quality of the product depends on the degree of mixing of the constituent materials. The homogeneity of the resulting mixture depends on the nature of the mixing procedure. In reality, the design of the mixer depends on the physical properties of the processed materials. The flow pattern in the mixer can also be affected by the properties of the source materials. Compared to conventional mixing methods such as a fluidized bed, a high shear mixer has the advantages of being able to handle fine cohesive powders as well as high viscosity binder liquids. Further, high shear mixer granulation usually results in more spherical, better-compacted granules with a wider particle size distribution than does fluid bed granulation. A complex mechanism dominates high shear mixer granulation because there is an enormous range of geometries and designs for the mixer, with a very wide range of agitation intensities (i.e. shear rates). The mechanisms for powder flow behavior within a high shear mixer are still poorly understood because mixers are considered to be the most complicated of all granulators for analyzing product attributes (Litster and Ennis, 2003). Positron Emission Particle Tracking (PEPT) can provide quantitative information for particle motion in a mixer, and is a powerful tool for non-invasively exploring the dynamic behavior of a single particle in an opaque system. However, no PEPT measurements for high shear mixer have been carried out because no suitably small tracer particles have been available. In recent years, however, finer resin tracer particles have been developed, which has made it possible to mimic the fine cohesive particles used in a high shear mixer. The purpose of this paper is to demonstrate the use of positron emission particle tracking in order to visualize the particulate motion in a high shear mixer.

2. Experimental Method

Microcrystalline cellulose powder (hereinafter abbreviated as MCC, AVICEL PH102, Merck, UK) was used as a starting material. The high shear mixer used in this study was fitted with a stainless steel bowl with an internal diameter of 160mm and vertical side height of 200mm, which was attached by using a centrally mounted impeller rotating around the vertical axis (Figure 1). Three beveled blades with a length of 66 mm, a thickness of 10 mm and an angle of the leading edge of 13° were used in the granulation, with a rotational speed of 150 rpm.

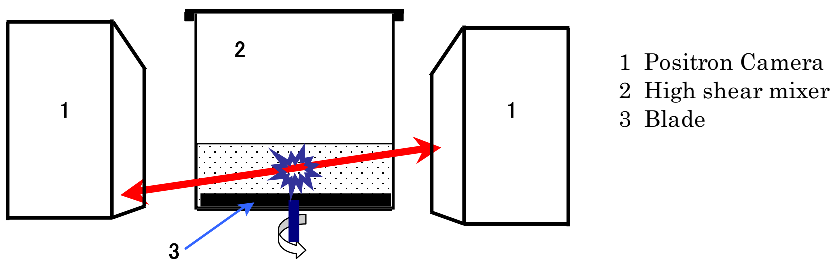

Fig. 1. Experimental apparatus.

PEPT is a method in which a single labeled radioactive tracer is tracked in three dimensions with granulation time, in which the tracer mixes with a bed of particulate and granules. In this technique, a single tracer particle is labeled with a radioisotope. The radionuclide in the tracer undergoes $\beta +$ decay, that is, a proton is converted to a neutron, accompanied by the release of a positron (Feliu, 1988). Following its emission, the positron will slow down over a small stopping distance and will subsequently annihilate with a neighboring electron. Each annihilation results in a pair of 511keV γ-rays which, in order to conserve momentum, are emitted back-to back, 180° apart (to within approximately 0.3°) (Parker and McNeil, 1996). Detection of coincident pairs of gamma photons on the two camera detectors provides a straight line along which the particle lies, and lines generated from subsequent pairs will intercept at the source, enabling determination of the particle positrons by geometric triangulation. It is necessary for the size and density of the tracer to be close to that of the bed materials, and in this study, a resin particle (strong base anion ion exchanger), with a diameter of 200 μm and a density of 1100 $kg \cdot m^{-3}$, was used as the tracer particle in order to match the diameter and density of the MCC powder.

The tracer particles were labeled using a radioisotope 18F via the ion exchange technique. During the mixing, the tracer particle rapidly stuck to finer MCC particles. Therefore, the movement of the tracer will be identical to that of the bulk of the particles.

3. Results and Discussions

Figures 2 and 3 show the movement of the particles within the mixer during powder mixing at a speed of 150 rpm. The pink region indicates the region of flow showing satisfactory mixing, while the length of the arrows corresponds to velocity of the flow. The X-Y plane is horizontal and the X-Z plane is parallel to the blades. It is clear that, while the majority of the region within the mixer will show good mixing behavior, there are regions at the boundaries of the mixture that will show poor mixing.

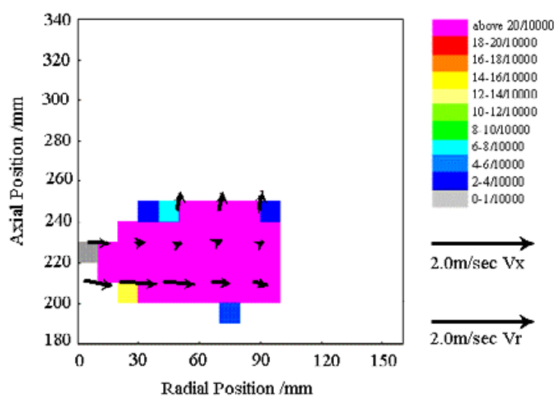

Fig. 2. Particulate and granular motion with a mixer (side view)

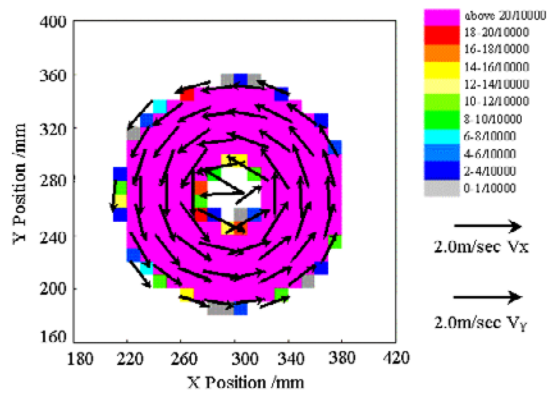

Fig. 3. Particulate and granular motion with a mixer (top view)

These PEPT visualization studies provided some useful information on powder flow in mixers beneath the powder surface, which will be helpful in more accurately modeling high shear mixer. For the first time, it has been possible to clarify the flow patterns of the particle in three dimensions. This study indicated that, within the mixer, there are a number of different regions with size-dependent flow between each one, which makes it possible to account for the varying frequency and velocity of collisions between different-sized particles directly in the kernel when segregation occurs in the mixer. It is clear that there will be different characteristic impact velocities in each region depending on the location within the mixer. Three-dimensional imaging for high-shear mixers, which has been impossible to perform with CCD cameras and PIV, has been realized by using PEPT. The new findings should prove extremely useful for the design, the operation and the scale-up of high-shear mixers, although similar experiments should be performed using different powders and different types of mixer designs in order to obtain additional corroborative data.

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