Intensified gas-solids contact and separation and solids-solids segregation in a high-G rotating fluidized bed in a vortex chamber

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Long Abstract

Introduction

The potential of combining high-G intensified gas-solids contact, gas-solids separation and solids-solids segregation in a rotating fluidized bed in a vortex chamber is numerically and experimentally studied. For the numerical study, CFD-DPM simulations with the MFiX-DPM code were carried out (Figure 1) with a vortex chamber of given dimensions equipped with 4 or 8 evenly or 7 non-evenly distributed gas inlet slots and focusing on binary particle mixtures, varying the density or size ratio. The rate and quality of segregation were studied as well as the solids retention and the bed density and uniformity. For the experimental investigation, a 43 cm diameter, 2.5 cm long vortex chamber with 38 x 381 µm wide gas inlet slots has been designed and 3D printed from nylon. Experiments were carried out with different binary particle mixtures and with varying solids loading and gas flow rate (Figure 2).

Main findings

The simulations show that within a relatively wide particle size or density ratio, efficient segregation takes place within a couple of centimeters thick rotating fluidized bed. The inner bed of lighter particles is somewhat less dense and slower rotating than the outer bed of heavier particles, but bubble formation is minimal and only observed in the inner bed and with the lightest particles that were considered. Within a given range, the rotation speed of the outer bed increases and that of the inner bed decreases with increasing particle size or density ratio. The effect is somewhat more pronounced with varying particle diameter ratio than with varying particle density ratio. The bed expansion with the lighter particles in the inner bed reduces the strength of the central vortex. The bubbling observed with the lightest particles in the inner bed increases the inner bed rotation speed again and causes some back-mixing of light particles into the outer bed, so that from the viewpoint of quality of segregation an optimum size or density ratio exists for a given vortex chamber design. In general, the outer bed is more easily contaminated with lighter particles than the inner bed with heavier particles. At the highest particle diameter ratios studied (> 3), some losses of mainly small particles via the chimney are predicted. The simulations showed that the number of gas inlet slots and the gas flow rate have to be sufficiently high to guarantee uniform gas distribution and a uniform and stable particle bed, which was accounted for in the design of the experimental set-up. The flexibility of the technology with respect to the gas flow rate was confirmed, the solids retention, bed density and uniformity as well as the solids-solids segregation hardly being affected when increasing the gas flow rate.

The experiments confirm that within a given range of operating conditions, combining intensified gas-solids contact, gas-solids separation and solids-solids segregation is possible. Sufficiently high gas flow rates and solids loadings are required to obtain a stable, dense and uniform outer and inner rotating fluidized beds. Slugging is observed otherwise, initially and mainly in the inner bed of the lighter particles. The experiments also confirm a somewhat more pronounced contamination of the outer bed with lighter particles than of the inner bed with heavier particles. With the lighter particles used, losses of almost exclusively light particles via the chimney could not be prevented with the applied vortex chamber design. Further optimization of the design is possible.

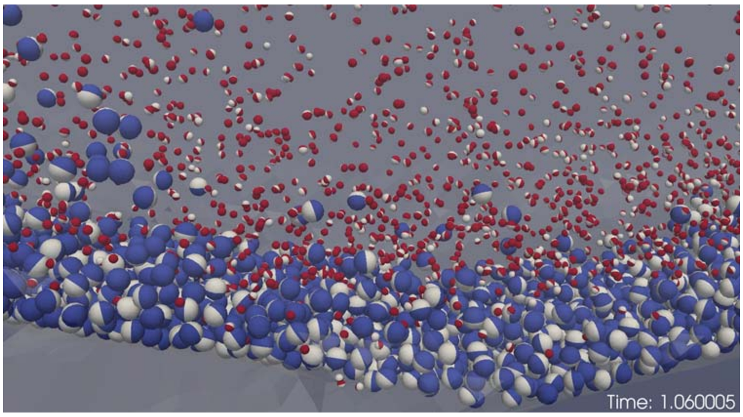

Figure 1. CFD-DPM simulation of a bidisperse rotating fluidized bed in a vortex chamber.

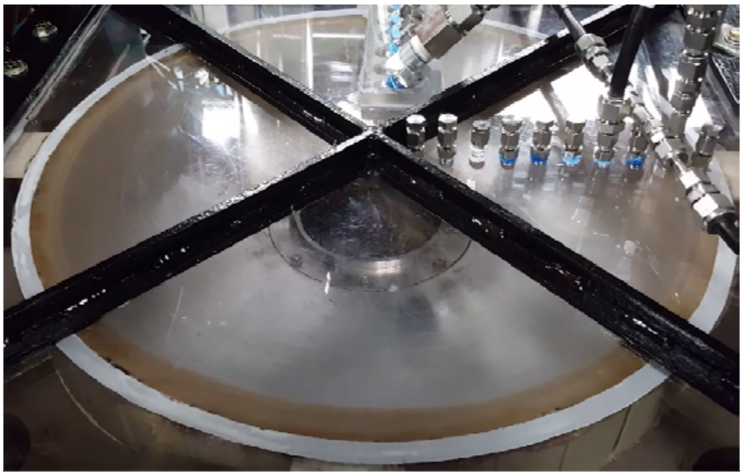

Figure 2. Picture of the experimental set-up at NETL.