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Effect of particle size in fluidization of polyethylene particle mixtures on the extent of bed electrification and wall coating

Y. Tian, P. Mehrani*

Chemical and Biological Engineering Department, University of Ottawa, 161 Louis-Pasteur St., Ottawa, Ontario, K1N-6N5, Canada

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ABSTRACT

In this work the effects of polyethylene fluidizing particle size (smaller than 400 μm) on the degree of fluidized bed electrification and wall coating formation was studied. Experiments were conducted in a stainless steel, 0.15 m diameter column, under ambient conditions. Polyethylene resin as received (20–1500 μm) as well as mono-sized and binary mixture of large (600–710 μm) and small (212–300 & 300–425 μm) polyethylene particles were fluidized while their mass, net specific charge and size distribution in the bulk of the bed and the wall coating were measured. For the binary mixture the fraction of the small particles examined were 5%–10% and 20%. The extent of wall coating varied between different cases tested with the mono-sized large particles resulting in the most amount coating. It was found that as the fraction of the small particles in the binary mixture was increased, these particles formed majority of the wall coating. At the mass fraction of 20%, the extent of wall coating and its net specific charge were similar to that of resin as received. Overall results implied that the magnitude of the smaller sized particles within the resin played an important role in the degree of particles electrostatic charging and the extent of the particles adhesion to the column wall. Small particles were found to generate a much larger net specific charge which although resulted in them coating the column wall but prevented the coating layer growth.

1. Introduction

Gas-solid fluidized bed reactors are widely used in chemical, petrochemical and food industries, among others. An example of a process where such reactors are employed is the catalytic polymerization of ethylene to produce polyethylene. A major nuisance in some gas–solid fluidized beds is the generation of electrostatic charges which could cause particle agglomeration impacting the fluidized bed hydrodynamics, as well as the adhesion of particles to the reactor wall imposing reactor shutdown for clean-up. The generation of electrostatic charges is due to the continuous contacts amongst the fluidizing particles and between the particles and the fluidized bed reactor wall. An industry that has suffered from the challenges resulted from electrostatic charging is the petrochemical industry and specifically in the production of polyethylene. In such reactors, electrostatic charging of the catalyst and polyethylene resin often results in the particles coating the reactor wall, a problem known as “sheeting” [5,6,8,18].

The first references identifying the electrostatic charging of fluidizing particles as a problem date back to 1940s and 1950s [9,12,14]. Although since then much research has focused on understanding the electrostatic charging in gas–solid fluidized beds, but the problem still persist. This is due to the fact that factors that influence the extent of charging and reactor coating are still not well understood. Thus, it is essential to evaluate the impact of fluidized bed operating conditions including parameters such as fluidizing particles properties on the degree of bed electrification. One parameter that has been the subject of previous research is the fluidizing particle size. Boland and Geldart (1971/72); Gajewski (1985); Guardiola (1996), [3,4,7] conducted tests with mono-sized particles of various type (e.g., glass beads and polyethylene) and size (200–4000 μm) and found that the degree of fluidized bed electrification increases with the increase in fluidizing particles size. Sowinski et al. (2012) [19] investigated the effects of fluidizing polyethylene particle size on charge generation and reactor wall fouling where the particles as received from commercial reactors (i.e., with a wide particles size distribution of 20–1500 μm) and those sieved into narrow sized ranges (300–425 μm, 500–600 μm, 600–710 μm and 710–1000 μm) were tested. Their results indicated that the smaller particles had a higher frequency of building

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* Corresponding author.
E-mail address: poupak.mehrani@uottawa.ca (P. Mehrani).

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up on the column wall. In addition, for the non-sieved resin with a size range of 20–1500 μm, particles which attached to the column wall were found to be of similar size to the smallest narrowed size fraction tested (300–425 μm) and smaller. Their results also indicated that for all size ranges of sieved particles, the net charge-to-mass ratio (q/m) of particles forming the wall coating almost remained the same. However, the net q/m of non-sieved particles was twice larger than that of sieved particles. Moreover, they found that the larger particle size ranges of 600–710 μm formed an unstable wall coating and particles larger than 710 μm had difficulty to adhere to the column wall altogether. Mehrani et al. (2007) [11] fluidized mono-size and binary mixture of glass bead particles consisting of relatively large and fine particles in a Faraday cup fluidized bed. They concluded that the entrained fines transported a net charge out of the fluidized bed, leaving a net charge of opposite polarity behind. Yu et al. (2010) [21] examined mixtures of different sizes of granular polyethylene particles (185–855 μm mixed with larger 1275 μm particles) and concluded that the net bed electrostatic potential augmented by increasing the fraction of the small particles. This observation was more obvious for smaller particles tested. Moughrabiah et al. (2012) [13] employed binary mixture of small (45–90 μm) and large (600–850 μm) glass beads and experiments were conducted at elevated pressures of up to 1000 kPa. In their work, electrostatics was detected by electrostatic probes and was found to increase as the proportion of small particles in the mixture increased. It is also important to note that in fluidizing different sized particles, some researchers have found that the large and small particles become charged oppositely, a phenomenon called “bipolar charging” [1,2,10,20,22]. Overall previous research indicates that fluidizing particles size could have a profound effect on the electrostatic charging behavior of gas–solid fluidized beds. However, these works did not comment on the effects particle mixtures of various size on the extent of fluidized bed column wall coating, a serious industrial operational challenge. Commercial processes such as those of gas-phase ethylene polymerization involve particles of a wide size distribution inside the reactor. Thus it is important to better understand the impacts of particles size, especially those of smaller nature, on reactor electrification and wall coating. The aim of this work is to evaluate the effects of particle size on the fluidized bed charging behavior and the extent of wall coating through fluidization of mixture of small and large polyethylene particles.

2. Experimental apparatus and material

The schematic diagram of the fluidization system utilized in this work is presented in Fig. 1. The details of system and operating procedures are explained elsewhere [15,16]. The fluidization column was made of stainless steel and consisted of 3 sections with a total height of 4.5 m. The fluidization section was 0.15 m in diameter and 2.5 m in height, while the top and bottom expanded sections were each 0.36 m in diameter and 1 m in height. The system was operated under ambient temperature and pressure. The fluidization column housed 2 Faraday cups, one located in the windbox and the second located at the top of the column with a filter bag inside, both connected through low noise triaxial cables to digital electrometers (Keithley model 6514). By employing this system, particle mass percentage (mass%), net specific charge (q/m), size distribution and mean diameter (dp_{50}) were determined in various regions of the fluidization column. The regions included the bulk of the bed (Bulk), particles that adhered to the column wall (Wall) and those entrained (Fines). The fines were collected throughout the fluidization runs by the filter bag inside the top Faraday cup while the bulk and wall particles were collected at the end of each fluidization period with the aid of the bottom Faraday cup. After the removal of the bulk particles, the wall particles were removed by injecting a small stream of compressed air into the column from the top which assisted in dislodging the particles from

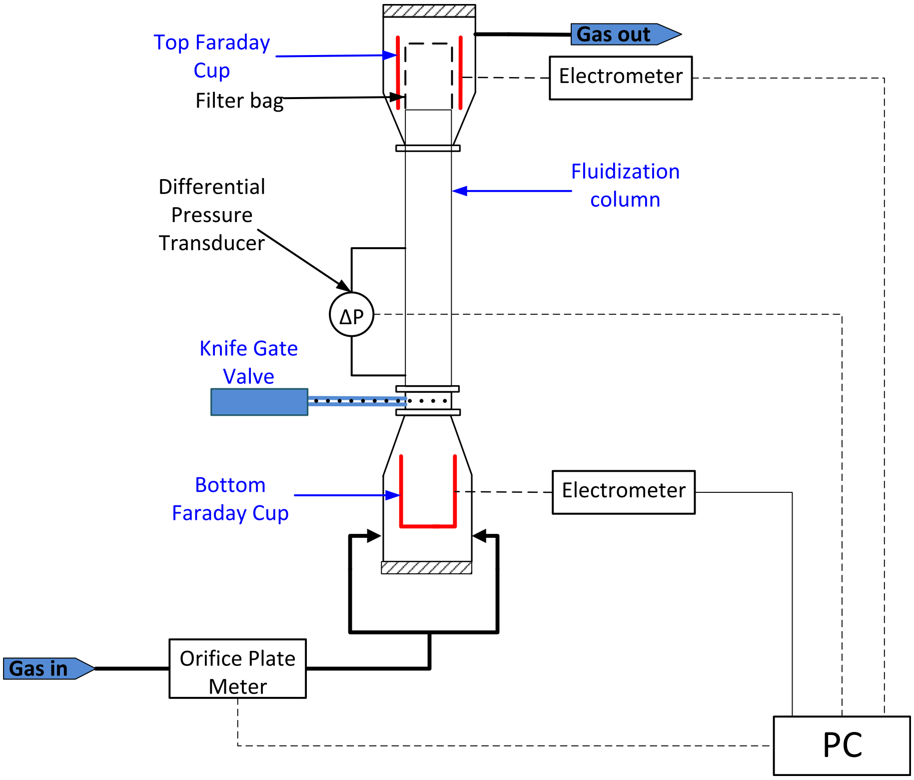

Fig. 1. Schematic diagram of the fluidization system.