Comparison of the effect of grounding the column wall in gas-solid fluidized beds on electrostatic charge generation

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Abstract. In gas-solid fluidized beds as particles are fluidized, they continuously come into contact with other particles, as well as the fluidization column wall. This generates electrostatic charges by means of triboelectrification and frictional charging, leading to particle agglomeration, reactor wall fouling, and eventually process downtime and large financial losses. Grounding the fluidization column has been considered as a means of helping electrostatic charge dissipation within fluidized beds; however, in industrial applications despite the process vessels being grounded, the electrostatic problem still persists. This work focused on the effect of fluidization column grounding on particle wall fouling. Experiments were conducted in an atmospheric system consist of a 0.1 m in diameter carbon steel fluidization column. The mass and charge-to-mass ratio (q/m) of the particles that remained adhered to the column wall upon the completion of one hour fluidization period were measured in an electrically isolated and grounded columns to quantitatively determine the amount of reactor wall fouling. Polyethylene particles with different particle size ranges (300-1000 μm) were fluidized with extra dry air at 1.5 times their respective minimum fluidization velocity (u_{mf}). Results obtained in the grounded fluidization column were not significantly different from those in the isolated column for all particle size ranges tested where the particles mass collected and q/m and were found to be generally similar.

1. Introduction
Gas-solid fluidization is a process where gas travels through a bed of particles at a high enough velocity such that the solid particles behave as a fluid and are subjected to particle motion within the bed. Gas-solid fluidization is a common process with a variety of applications such as drying, coating, and gas-solid reactions. In such reactors, particles are subsequently introduced to a significant number of particle-particle and particle-column wall interactions, which ultimately generate electrostatic charges due to triboelectrification and frictional charging. Generally, these electrostatic charges are not desired as they cause particle agglomeration, particle build-up on reactor walls, and electrical discharge which could potentially result in fires and explosions. In poly-olefin production, the formation of a particle layer on the reactor wall due to bed electrification has been reported as a significant problem for many years [1]. The particle layers tend to form sheets on reactor walls that can become large enough to dislodge and plug the gas distributor plate causing immediate reactor shut-down, reduction in reactor operation and ultimately production.

It is generally believed that grounding the reactor wall is an effective method for reducing electrostatic charges within a gas solid fluidized bed [2]. However, the majority of academic works on
electrostatic charge generation have focused primarily on fluidized beds composed of transparent plastic. Only a handful of works [3-8] have conducted studies in metallic fluidization columns, some of which utilized a grounded unit [7-11]. However, the differences of electrostatic charge generation between grounded and electrically isolated columns have not been exclusively investigated.

The objective of this work was to examine the effect fluidization column grounding on particle wall fouling, and to determine its application as a charge reduction technique.

2. Experimental Setup and Methodology
The experimental apparatus and methodology used for this work has been described elsewhere [2]; with the exception that this work focuses solely on the wall fouling of the fluidized bed. The fluidization column, fabricated out carbon steel, was 0.1 m in diameter. The column was normally electrically isolated from the rest of the system (i.e., distributed plate and top section of the column). For the grounding experiments, a grounding wire was attached to the column. The fluidizing particles were polyethylene resin, produced using a metallocene based catalyst in an industrial gas-phase fluidized bed reactor. The received resin was sieved into five different particle size ranges (300-425 μm, 425-500 μm, 500-600 μm, 600-710 μm, and 710-1000 μm), with a constant density of 918 kg/m³. The bed height to column diameter ratio (L/D) was maintained at 4 for all trials. The particles were fluidized for 60 minutes and the fluidizing gas velocity was maintained at 1.5 times the minimum fluidization velocity (u_mf) of each particle size range. The fluidizing gas was at 23 ± 0.6 °C, and was dried to 0 ± 0.02 % relative humidity.

After the fluidization period (60 min) was completed, the fluidizing gas was turned off and the bottom of the column was opened to remove the majority of the particles [2-4]. The particles that were remained adhered to the column wall denoted wall fouling. Pictures of the wall fouling were taken from the bottom of the column. Next, a Faraday cup was placed below the column and the column wall was lightly tapped to remove as many particles as possible from the wall and to record their charge. The mass of the collected particles was then recorded and the charge-to-mass ratio (q/m) was calculated. The mass percent (m%) was calculated from the mass of the particles collected in the Faraday cup divided by the initial mass of particles placed into the fluidization column. Each experiment was repeated at least three times to ensure reproducibility of the data.

3. Results and Discussion
Figure 1 shows the m% and q/m of particles that were adhered to the column wall for all particle size ranges under electrically isolated and grounded column conditions. Results clearly indicate that regardless of the particle size, a grounded column wall was not significantly different from that of the isolated column. The collected m% remained relatively constant within each particle size range with the exception of the 600-710 μm. With this range, the opposite of the general perception that column wall grounding reduces electrostatic charges was observed since more particles were adhered to the grounded column. For all particle ranges, a similar q/m was obtained for both the isolate and grounded column. At a particle size range greater than 710 μm, the gravitational force on the particles dominated electrostatic forces causing for the least amount of mass collected from the column wall. Figure 2 shows typical images taken from the bottom of the fluidization column showing particle-reactor wall fouling. From these images, it is clear that grounding the column wall did not reduce the amount of wall coating. Grounding the column wall is believed to be a method for reducing bed electrification and column wall fouling because as particles come into contact with the grounded wall, electrons can be easily exchanged while keeping the column wall neutral and thus aid in dissipating particles charge. However, in most cases the fluidizing particles are insulators where they have less of a tendency to give up their electrostatic charge. Additionally, at any given time, only a small fraction of particles within the fluidized bed will have the opportunity to come into contact with the column wall for some of their charge to be dissipated. In the meantime, the rest of the particles will continue to generate electrostatic charge through triboelectrification by particle-particle contacts, which would result in bi-polar charging. Moreover, even if the layer of particles adhered to the column wall were able to
dissipate their charge, the particles that come into contact with these adhered particles would not lose any charge due to the restricted electron flow through insulators. Overall, if grounding the column wall would have helped in charge dissipation, it would have been expected that the net q/m of the particles to approach zero and the collected mass would decrease. However, such outcomes were not observed. Another study has shown that the charge transfer and conductivity of a fluidized bed composed of copper particles was independent of particle size and dependent on the void fraction of fluidized bed and the presence of chain-like particle in contact [12]. Therefore, with the factors mentioned above and the experimental results presented here, it is evident that grounding the column wall for systems containing non-conductive particles cannot provide an adequate method for electrostatic charge reduction through charge dissipation as previously expected.

![Graph showing m% and q/m of particles that adhered to the column wall at different size ranges.](image)

**Figure 1.** The m% and q/m of particles that adhered to the column wall at different size ranges.

![Typical imaged obtained from wall fouling taken from the bottom of the column with 300-425 μm and 600-710 μm particles with the column a) Isolated; b) Grounded.](image)

**Figure 2.** Typical imaged obtained from wall fouling taken from the bottom of the column with 300-425 μm and 600-710 μm particles with the column a) Isolated; b) Grounded.
4. Conclusions
It is often believed that grounding the fluidization column wall can help in reducing electrostatic charges and ultimately wall fouling in gas-solid fluidized beds. However, it was shown that grounding had no effect on the reduction of charging and wall fouling of non-conductive particles in a pilot-scale fluidized bed, and in one case even promoted more wall fouling. This also validates that in industrial size gas-solid fluidized beds grounding the fluidization column does not provide any means of electrostatic charge reduction.

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References
[1] Hagerty R O, Muhle M E, Agapiou A K, Kuo C-T, Goode MG, Hussein F D, Pannell R B and Szul J F 2005 Method for controlling sheeting in gas phase reactors. US Patent 2005/0148742 A1
[2] Ciborowski J and Wlodarski A 1961 On electrostatic fluidized beds Chem. Eng. Sci. 17 23–32
[3] Sowinski A, Miller L and Mehrani P 2010 Investigation of electrostatic charge distribution in gas-solid fluidized beds Chem. Eng. Sci. 65(9) 2771–81
[4] Sowinski A, Salama F and Mehrani P 2009 New technique for electrostatic charge measurement in gas-solid fluidized beds J. of Electrostatics 67(4) 568–73
[5] Giffin A and Mehrani P 2010 Comparison of influence of fluidization time on electrostatic charge build-up in the bubbling vs. slugging flow regimes in gas-solid fluidized beds J. Electrostatics 68(6) 492–502
[6] Ally M R and Klinzing G E 1985 Inter-relation of electrostatic charging and pressure drops in pneumatic transport Powder Tech. 44(1) 85–8
[7] Kisel'nikov V N, Vyalkov V V and Filatov, V M 1967 On the problem of electrostatic phenomena in a fluidized bed Int. Chem. Eng 7(3) 428–31
[8] Fujino M, Ogata S and Shinohara H 1985 The electric potential distribution profile in a naturally charged fluidized bed and its effects Int. Chem. Eng. 25(1) 149–59
[9] Ali F S, Inculet I I and Tedoldi A 1999 Charging of polymer powder inside a metallic fluidized bed. J. of Electrostatics 45(3) 199–211
[10] Moughrabiah W O, Grace J R and Bi X T 2009 Effects of pressure, temperature, and gas velocity on electrostatics in gas-solid fluidized beds Ind. Eng. Chem. Res. 48(1) 320–5
[11] Boland D and Geldart D 1971/72 Electrostatic Charing in Gas Fluidised Beds Powder Tech 5 289-94
[12] Sabacky B J and Evans J W 1977 The electrical conductivity of fluidized bed electrodes – its significance and some experimental measurements Metal. Trans. B 8 5–13