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Build-up of Electrostatic Charge in Polymer Dispersion Reactors

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Highlights

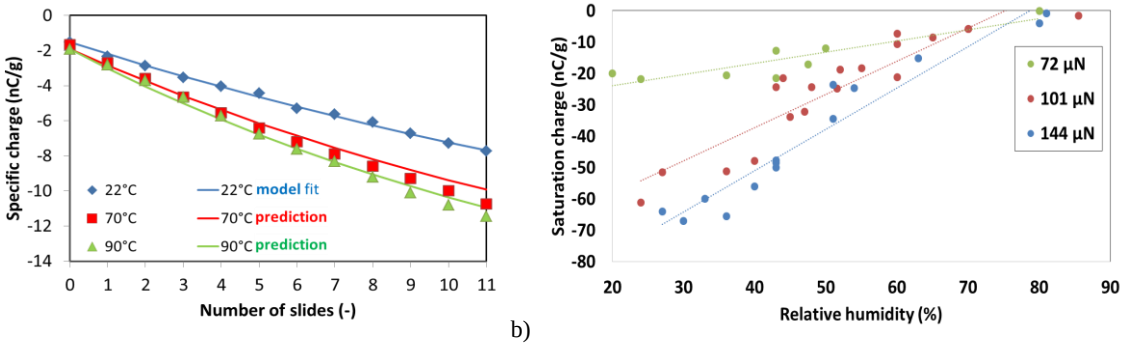
- PE particles charge faster at elevated temperatures due to particle softening.
- The bigger is the impact force, the higher is the attained saturation charge.
- These effects are most apparent in systems of low or no humidity (reactors).
- Reaching critical charge triggers rapid formation of aggregates and sheeting in reactor.

1. Introduction

In industry, significant build-up of electrostatic charge due to particle-particle and particle-wall collisions takes place typically in systems of dielectric powders like polymers, pigments, flour of medicaments. An example of industrial system where the build-up of electrostatic charge can lead to serious complications like fouling or aggregation is the production of polyethylene (PE) in fluidized-bed polymerization reactors [1] including also post-processing and transportation of the product. We performed a systematic series of experiments regarding electrostatic charging of PE and complemented them by particle dynamics simulations. This contribution is focused on charging caused by repeated collisions of PE particles with a metal wall as a function of temperature, impact force and humidity and predictions of charging caused by particle-particle collisions related to particle aggregation.

2. Methods

For experiments, we used nascent PE particles of 0.9 mm diameter and density 930 kg/m^3. The effect of temperature on charging was studied by the cascade method apparatus, i.e., metal chute with high-speed camera followed by Faraday's pale. Moreover, we developed the discrete element method (DEM) model including the capacitor model for particle-wall charging. Using this tool, we were able to study the build-up of charge caused by the collisions of PE particles with the chute up to the level of single collision of a single particle with the chute. We also developed a version of the model enabling prediction of charging dynamics for particle-particle collisions [2]. The effect of impact force of particles on charging during the collision with metal wall was measured in shaking apparatus. In this device, particles were enclosed in a metal box attached to the shaking apparatus and thereby the particles were charged.



a) b)

Figure 1. a) The effect of temperature on charging measured on cascade method apparatus and compared to the model predictions. Particle softening explains sufficiently faster charging at elevated temperatures. **b)** The saturation charge is affected by impact force of particle-wall collisions. The effect is most significant for systems with low humidities.

3. Results and discussion

Charging dynamics of PE particles measured using our cascade method apparatus at three different particle temperatures shows faster charging at elevated temperatures (Figure 1a). Experimental data are accompanied by our DEM model predictions (lines). The model assumes that the charging process itself is temperature independent, i.e., no charging parameters are altered by the change of temperature. The only model parameter that is temperature-dependent is Young's modulus of PE, thus particle softening is incorporated into the model. Figure 1a shows a good agreement with model predictions and thus we conclude that particle softening alone causing the increase of particle-wall contact area during collision is the explanation for the overall faster charging of PE particles at elevated temperatures. The saturation charge of PE particles, i.e., maximum charge at given conditions, was measured to be increasing with impact force during particle-wall collisions (Figure 1b). Such behavior can be explained by the rough surface of PE particles with asperities. After loading force on such particles, the asperities bend inside and thereby increase the total surface area of PE particles accessible for charging. That, in turn, leads to the increase of saturation charge. This effect is more apparent at low humidities since the charging is more pronounced. Utilizing version of our DEM model adapted for the prediction of particle-particle charging [2], we investigated the effect of electrostatic forces on charging and observed that when the particulate system reaches a critical charge, electrostatic forces overtake the system dynamics and a rapid formation of aggregates takes place (Figure 2).

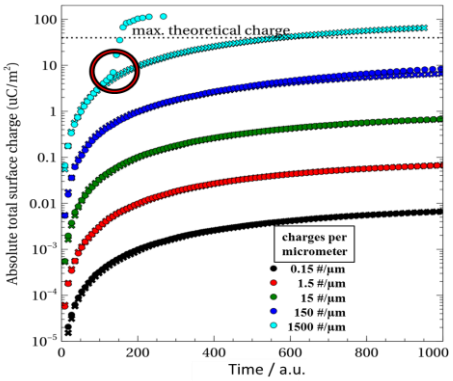


Figure 2. a) The charging of particulate system caused by particle-particle collisions with (circles) and without (crosses) the effect of electrostatic forces. Once the system reaches critical charge, rapid build-up of charge and the formation of aggregates take place.

4. Conclusions

Electrostatic charging is an important phenomenon for the safety of production and processing of polymer powders; however, even the fundamentals of charging are not fully understood yet. We attribute experimentally observed faster charging of PE particles at elevated temperature to the effect of particle softening and complement this finding by DEM simulation. The particles charge to a higher saturation charge with increasing impact force and this effect was again reproduced by DEM simulations with rough-surface particles (with fine discretization). We also identified conditions at which rapid aggregation takes place. Both temperature and the impact force of particles (affected, for example, by the fluidization regime in reactor) are parameters with high importance in regards to the production of PE. Although humidity is not directly relevant for fluidized-bed polymerization reactor, it can be present in downstream production or transportation steps.

References

[1] Hendrickson G., Electrostatics and gas phase fluidized bed polymerization reactor wall sheeting, Chem. Eng. Sci. 61 (2006) 1041-1064.
[2] Konopka L. and Kosek J., Discrete element modeling of electrostatic charging of polyethylene powder particles, J. Electrost. 87 (2017) 150-157.

Keywords
Electrostatic charging; Polyethylene; Discrete element method; Gas-dispersion polymerization reactors