Characterization of Tribocharging Behaviour of Pharmaceutical Granules in a Turbulent Flow Tribocharger

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INTRODUCTION

As pharmaceutical granules are typically organic materials, they can easily be charged due to repeated collision and separation of particles along with particle-wall friction during various powder handling processes in pharmaceutical industry [1-3]. Previous works have been mainly focused on tribocharging behaviour of individual excipients or mixtures of them. However, limited research efforts have been placed on tribocarhging behaviour of pharmaceutical granules [4-6]. In this work, tribocharging behaviour of pharmaceutical granules was investigated in a newly developed turbulent flow tribocharger.

EXPERIMENTAL APPARATUS AND MATERIALS

In the experiments, a newly developed turbulent flow tribocharger was used to charge granules. The tribocharger consists of a cylindrical vessel connected to a cyclone as shown in Fig.1.

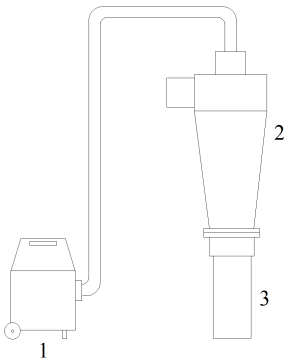


Fig. 1. Components of the turbulent tribocharger. (1) Air vacuum pump, (2) cyclone, (3) cylindrical container.

An air vacuum pump was supplied to the cyclone to provide a vortex of air flow in the cylindrical containers made of different materials (copper, PTFE (polytetrafluoroethylene), and PMMA (polymethylmethacrylate). The inner diameters and inner height of copper, PMMA, and PTFE containers are 6.3, 6.3, 5.7 cm and 21.6, 21.6, 20.4 cm, respectively. The air velocity at the inlet of the cyclone was measured by an anemometer (HHF81, OMEGA, US) and the velocity was maintained at 10.2 m/s.

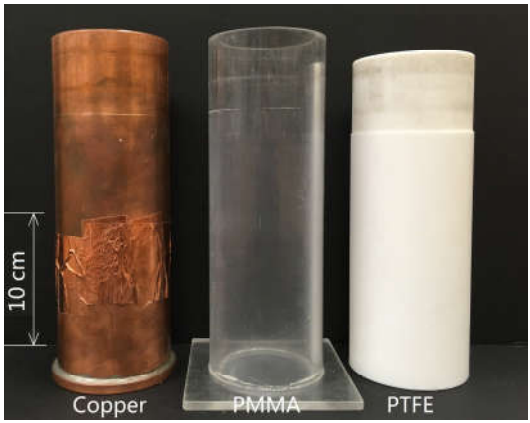


Fig. 2. Cylindrical containers made of copper, PMMA, and PTFE.

Tribocharging behaviour was investigated under different operating parameters including granules-wall contact time, granule loading mass, and different contact surfaces. The pharmaceutical granules used in the study were made based on a typical pharmaceutical formulation containing α-Lactose Monohydrate (α-LMH), Microcrystalline Cellulose (MCC), Hydroxypropyl Methylcellulose (HPMC), and Croscarmellose Sodium (CCS). The compositions and particle sizes are detailed in Table 1. The particle size was measured by particle size analyzer (Malvern Mastersizer 2000 S Long Bench 2000, Malvern Instruments Ltd., UK). Particle morphology was investigated through SEM imaging (JSM 6010, JEOL Ltd., Japan) and is shown in Fig. 3.

TABLE 1: GRANULE FORMULATION ALONG WITH PARTICLE PROPERTIES

Component	Percentage by mass (dry basis)	Supplier	Size (D_{50}) μm
Lactose Monohydrate (LMH) (filler)	50%	Foremost Farms	55
Microcrystalline Cellulose (MCC) (filler)	44%	FMC BioPolymers	106
Hydroxypropyl Methylcellulose (HPMC) (binder)	4%	DOW Chemical	72
Croscarmellose Sodium (CCS) (disintegrant)	2%	FMC BioPolymers	41

The total charge of granules was measured by a Faraday cup connected to an electrometer (6514, Keithley, USA). The diameter of the internal cup of the Faraday cup is 100 mm and a height of 100 mm, as well as an outer cup with a diameter of 150 mm and a height of 140 mm. The weight of samples was confirmed using a balance (ME4002TE, Mettler-Toledo, USA). The specific charge, q (nC/g), of the granule samples was obtained by dividing the total charge measured, Q (nC), by mass, m (g), of the granule samples loaded into the Faraday cup:

$$q = \frac{Q}{m} \tag{1}$$

All experiments were conducted at ambient conditions (Air temperature: 23.6-24.0℃; and relative humidity: 10.6-41.0%). Each experiment was repeated five times and the average values were reported.

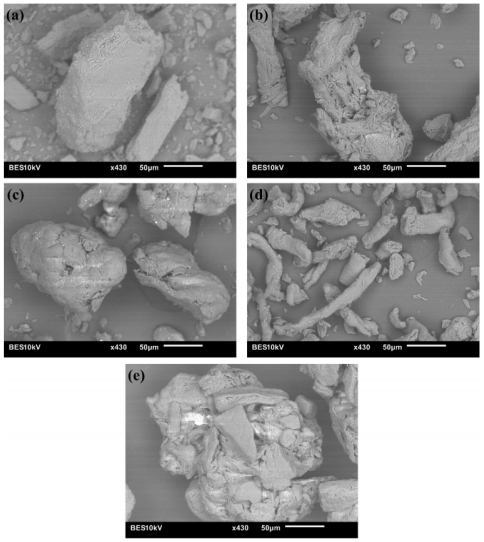


Fig. 3. Scanning electron micrographs of the pharmaceutical powders. (a) Lactose monohydrate (LMH), (b) Microcrystalline Cellulose (MCC), (c) Hydroxypropyl Methylcellulose (HPMC), (d) Croscarmellose Sodium (CCS), (e) dry granule sample

RESULTS AND DISCUSSION

The influence of operating time on tribocharging behaviour in the copper container is shown in Fig. 4. The copper container was electrically grounded during the test. In general, the negative charge was observed when the granules were contacted with the copper container. The results show that pharmaceutical granules tend to accumulate charge gradually at the initial contacting period with the wall. Then, the charge accumulation rate of particles decreased after 120 s. The net charge on particles continued to increase after 120 s.

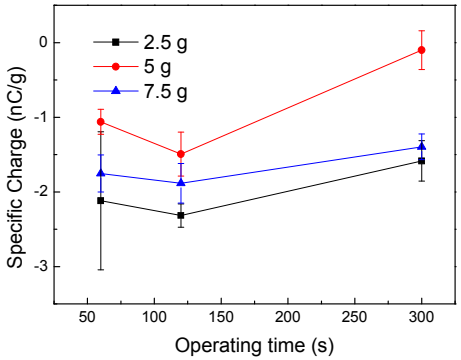
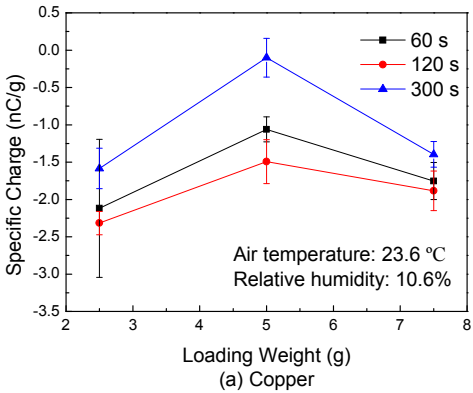


Fig. 4. Effect of operating time on specific charge in copper container (Air temperature: 23.6℃, relative humidity: 10.6%).

The influence of the granule loading weight is shown in Fig. 5. In general, the specific charge decreases with increasing the particle loading weight, as particle-wall contacts frequency per unit mass decreases with increasing the particle loading mass. The specific charge resulted from contacts between pharmaceutical granules and the copper wall is lower than that measured with the PTFE and PMMA walls. Charges generated from contacts with PTFE and PMMA walls show a similar trend. In general, the granules were negatively charged when copper was used as the contact surface while granules were positively charged with the contact surfaces of PTFE and PMMA. This result relates to the work functions (or ionization potential) on each material and can be used in creating an assumption such as the triboelectric series. The work functions of PTFE, PMMA, and copper are 5.75 eV, 4.68 eV and 4.53-5.10 eV, respectively [7].



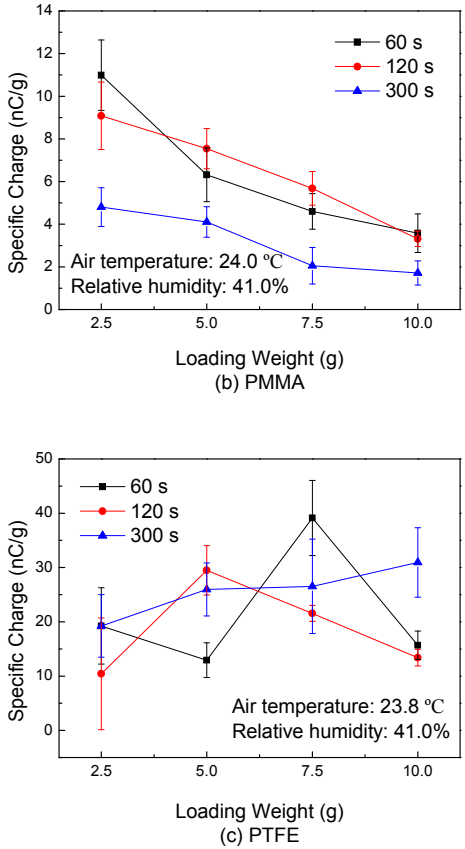


Fig. 5. Influence of granule loading weight on specific charge in different containers.

CONCLUSIONS

A newly developed turbulent flow tribocharger was used to investigate tribocharging behaviour of pharmaceutical granules. The present work has revealed that when contacting with the copper container, pharmaceutical granules tended to be negatively charged while pharmaceutical granules were positively charged when contacted with PMMA and PTFE containers. This implied that the work function of pharmaceutical granules should be within 4.53-4.68 eV.

ACKNOWLEDGMENTS

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