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Investigation of droplet deposition during tablet coating in pharmaceutical drum coaters

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Abstract

In pharmaceutical industry tablets are mostly coated in a rotating drum where the tablet bed continuously moves underneath several spray nozzles which atomise the normally very high viscous coating liquid. In order to be able to predict the coating result without running time-consuming lab-scale experiments, it is intended to be able to numerically simulate the entire tablet coating process. By combining CFD and DEM, the fluid, spray and tablet motion can be solved. Therefore, it is necessary to characterise in a first step the local droplet size and velocity distributions in different spray cross-section by means of PDA (Phase Doppler Anemometry) measurements [1]. This study focus on the development of a collision model to determine the collision outcome during the coating by the atomising nozzle. Therefore, the predefined, in pharmaceutical industry used, tablet shape, material properties of the tablet and coating material, needs to be taken into account.

Introduction

The spray coating is a common industrial process to produce granulates or tablets in pharmaceutical industry, where droplets collide with solid particles and the resulting coating or film thickness determines the product properties. For example, the film thickness remarkably influences the dissolving behaviour of tablets. In addition, the coating provides mechanical protection for the API (active pharmaceutical ingredients) and helps to neutralise the taste of the API and ensure colour identification. Therefore, models are required to describe all relevant droplet-scale processes, such as the collision outcome of the inter-droplet collisions inside the spray (see e.g. Sommerfeld and Kuschel [2] and Sommerfeld and Pasternak [3]) or the impact of droplets on solid walls (Pasternak et al. [4]).

Experimental setup

To develop a model for the tablet coating process, detailed experimental studies are required. Therefore, an experimental setup (see Fig. 1 left) was developed, which allows the microscopic analysis of the droplet properties inside the spray as well as the analysis of the spray droplet collisions on the surface of a moving tablet bed. The collision of the droplets with the tablet surface is performed in a test facility that allow the linear transport of tablets through a monosized droplet chain with velocities up to 1.35 m/s (see Fig. 1 right). To visualize the collision outcome, a Photron SA4 high-speed camera records the colliding droplets with an exposure time of 1 µs. To achieve this exposure time and compensate the larger f-number of the telecentric lens, a high power LED Luminus CBT-90 is used for backlighting. By using High-speed shadow imaging, the collision parameter, like: droplet/tablet vel., droplet dia., impact angle on the tablet surface and collision outcome are detected. By increasing the droplet velocity, the transition from fully deposition on the dry tablet surface to liquid breakup/splashing can be obtained.

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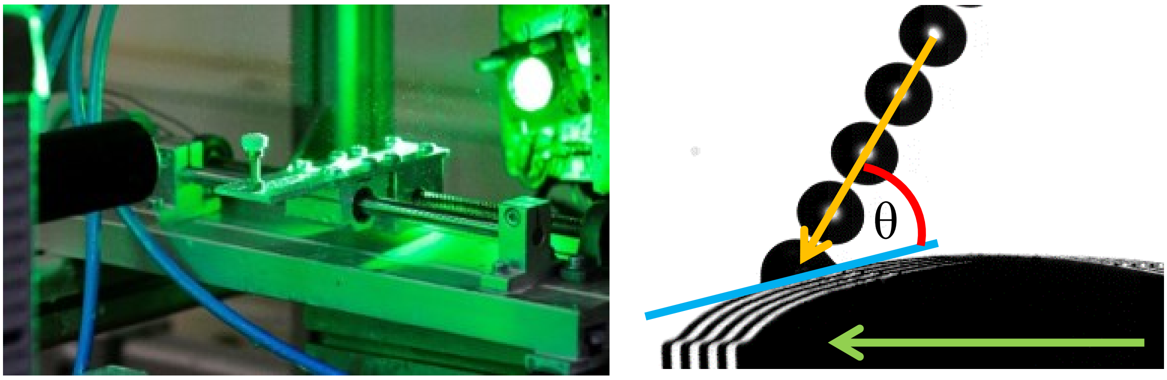

Fig. 1 left: Experimental imaging setup with linear tablet transport system, shadow imaging high-speed camera system with single high-power LED; **right:** Overlay of 9 instantaneous images to visualize the droplet/tablet motion and the analysis technique of the tangential impact angle and droplet/tablet vectors.

Results and Discussion

In order to understand the influence of the tablet surface, two different tablet formulations are used to identify wettability effects. In **Fig.2**, the outcome of Pharmacoat 606 (7%w/w, 83 mPas) colliding with round smotth/rough SRC 8 mm tablet is shown. Each point in the plots represent a single droplet, colliding with a dry tablet surface. As image processing outcome the droplet/tablet velocity, droplet diameter, the tangential impact angle and collision outcome are identified. Droplet breakup in the region <1.5 droplet diameter from the tablet edge are defined as edge breakup. The transition point between liquid deposition and breakup from the tablet surface for the rough surface can be identified at *We* ~ 1200 and *K* ~ 100. The other tablet type, with a smooth surfaces, indicate a shift of the transition point to *We* ~ 1600 and *K* ~ 130. At least for this combination of industrial used coating liquid and the tablet formulation, an influence of the surface roughness on the collision outcome is recognisable. Combining these transition point values with droplet parameter in a pharmaceutical industry used spray , the deposition efficiency can be estimated. Therefore, the PDA results of the spray characterization are used. The local mean droplet Weber and Ohnesorge numbers in the spray are shown for the 100 mm cross-section in **Fig. 3**. Related to the local velocity and droplet size distribution, the highest number based values are located in the spray center. Since the spray has a large droplet size and droplet velocity distribution, droplets with a We number up to 15400 are detected by using the PDA. Therefore, the beside the number based averaging the volume based averaging needs to be taken into account.

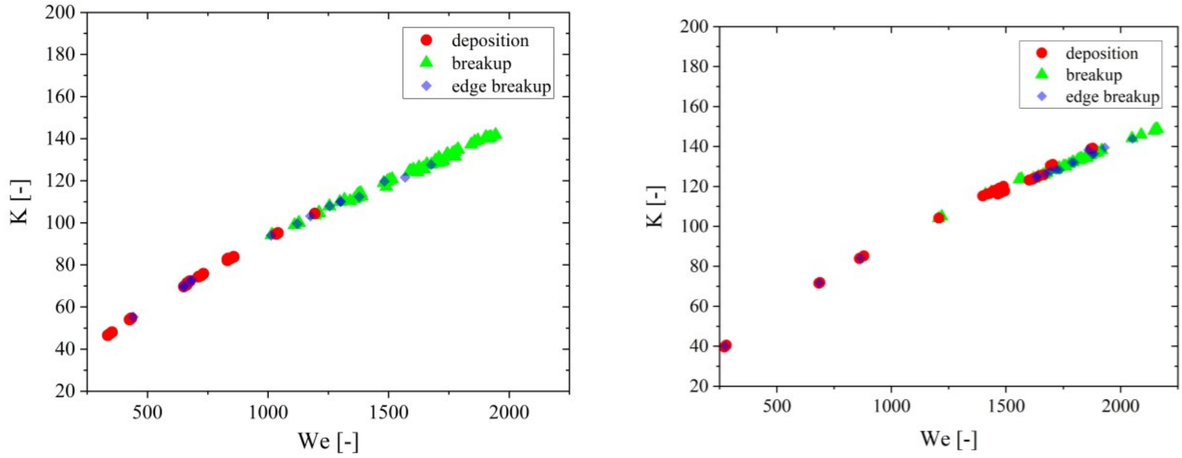

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Fig 2. left: Transition of deposition to breakup of single droplets colliding with a moving, dry tablet surface (rough surfaces), based on the K number (e.g. Mundo et al. [5]) ; **right:** Transition of deposition to breakup of single droplets colliding with a moving, dry tablet surface (smooth surfaces).

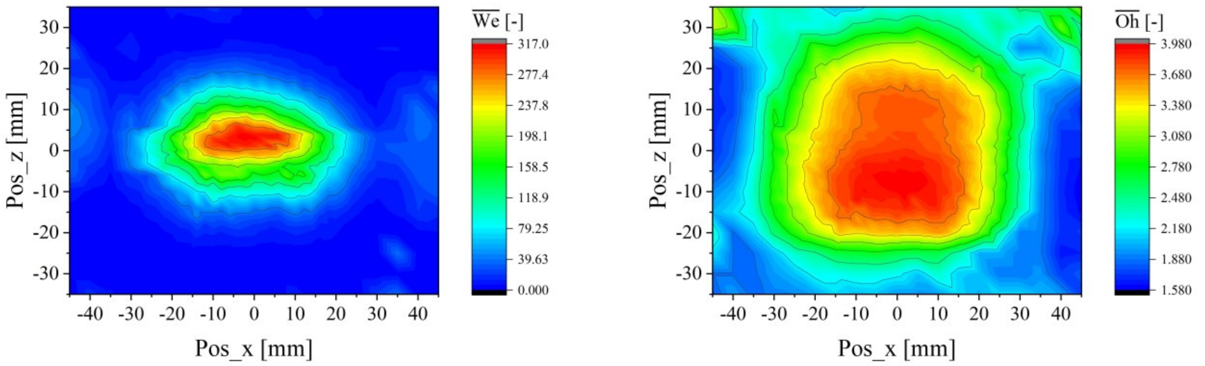

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Fig. 3 left: Local mean Weber number of the droplets in the tablet bed region at 100 mm in the real coating spray, based on mean droplet diameter and velocity of the spray PDA results [1]; **right:** Local mean Ohnesorge number of the droplets at 100 mm in the real coating spray

In **Table 1.** the number fraction and total volume fraction of droplets for *We* > 1200 and 1600 in the centre of the spray is shown. Without taking the collision geometry and thermal conditions in the rotating drum into account, mapping the single droplet collision results (see **Fig. 3**) to the instantaneous PDA spray results point to a high liquid volume which is not directly depositing on the tablet surface for the industrial coating process.

Table 1: Fraction (number, volume) of the droplets inside the spray (Fig. 3 left) with We > 1200 and 1600.

	0;100;0 (center)
We > 1200	Counts: 2.7 % Volume: 49.9 %
We > 1600	Counts: 1.7 % Volume: 42.9 %

Nevertheless, it has to be taken into account for this approach to predicting the collision outcome that comparable Ohnseorge numbers, shown in **Fig.3 right ,** could not be achieved in the single droplet experiments. Since the actual facility design allow single droplets experiments with Ohnesorge number up to 0.5.

Keywords
Spray coating, droplet-particle collision, liquid deposition, droplet deposition modelling

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