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An experimental study of die filling of pharmaceutical powders using a rotary die filling system

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ABSTRACT

Die filling is a critical process step in pharmaceutical tablet manufacturing. Mass and content uniformity of the tablets as well as production throughput depend upon the die filling performance of the formulations. The efficiency of the die filling process is influenced by powder properties, such as flowability, cohesion, particle size and morphology, as well as the process conditions. It is hence important to understand the influence of powder properties on the die filling performance. The purpose of the present study is to identify the critical material attributes that determine the efficiency of die filling. For this purpose, a model rotary die filling system was developed to mimic the die filling process in a typical rotary tablet press. The system consists of a round die table of 500 mm diameter, equipped with a rectangular die. The die table can rotate at an equivalent translational velocity of up to 1.5 m/s. The filling occurs when the die passes through a stationary shoe positioned above the die table. Using this system, die filling behaviours of 7 commonly used pharmaceutical excipients with various material characteristics (e.g. particle size distribution, sphericity and morphology) and flow properties were examined. The efficiency of die filling is evaluated using the concept of critical filling velocity. It was found that the critical filling velocity is strongly dependent on such properties as cohesion, flowability, average particle size and air sensitivity index. In particular, the critical filling velocity increases proportionally as the mean particle size, flow function, air permeability and air sensitivity index increase, while it decreases with the increase of specific energy and cohesion.

1. Introduction

Powder compaction is widely employed in manufacturing of tablets, which are the most common solid dosage forms in the pharmaceutical industry. The same manufacturing process is also widely used in such fields as powder metallurgy, ceramic and chemical industries. During powder compaction, a powder is first deposited into a die, which is the so-called die filling stage, and then compressed under high pressure to form a coherent powder compact.

The most important parameters in die filling are the weight consistency and uniformity, which are heavily influenced by the powder properties, particularly by its flowability. This explains why a significant amount of experimental work and computational studies have been devoted to the powder flow characterization and prediction, as described below. It has been shown that the flow behaviour is significantly influenced by powder characteristics as well as the filling system and the process conditions.

Powder flow from a moving shoe was investigated by Wu and Cocks (2004), who described two types of flow that contribute to the cavity filling: nose and bulk flow. Nose flow, which prevails at low velocities, is the most efficient in filling the die completely. As the shoe accelerates to reach the requested velocity, the powder contained in it moves towards the back of the shoe, forming a nose-shaped profile. The particles on the top of the powder can move more freely than the bottom layers as the shoe starts moving over the die. This kind of flow allows the air trapped in the die to escape more readily, thus improving the die filling efficiency. As the powder bed continues moving over the die, some particles start detaching from the bottom of the powder bed as well. This type of flow is known as bulk flow and it becomes predominant at high filling velocities, at which the shoe completely covers the die during powder discharge. Therefore, the filling velocity (i.e. the velocity of the shoe with respect to the stationary die) is an important factor. Generally, the slower the filling velocity the higher the fill density. However, it was also shown that the fill density can increase as

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