Feedback Control of Dry Impact Milling Process

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Long Abstract

Introduction

Dry impact milling of particulate materials is widely used in various industries such as chemical, pharmaceutical, food, agriculture, etc. in order to reduce the particle size to a suitable size for the intended usage. Especially, in the pharmaceutical industry, the particle size of milled Active Pharmaceutical Ingredient (so called API)) should be kept at an appropriate size since it greatly affects its dissolution rate and solubility. However, it is very difficult to maintain the constant particle size in dry milling processes even if the API is milled under the same operating conditions because performance of the milling equipment vary depending on the physical properties of API such as moisture content, electrostatic charging, etc. So far, the problem has been avoided by the expert operators in many cases, relying on knowledge derived from their past experience. Therefore, it is necessary to develop a system that can automatically control the milling process. In this paper, a practical method for controlling the particle size in a dry milling process has been developed by using a novel fuzzy control system. The particle size of milled products is controlled by a fuzzy logic based on a linguistic algorithm employing IF-THEN rules. Performance and reliability of the system and accuracy of the control were investigated experimentally under various operating conditions...

1. Methods

Figure 1 shows a schematic diagram of the experimental apparatus. A hammer mill with a cantilever-supported rotor was used. This mill consists of a high-speed rotating disk having 8 hammers with dimensions of 15 mm in width × 8 mm in height × 8 mm in depth, a milling chamber with a diameter of 119 mm and a depth of 30 mm, a concavo-convex-shaped lining on the chamber wall, a classification screen with pores of opening size of 1 mm in diameter, and a collection pot of products. The maximum rotor speed is 267 rps and the hammer peripheral speed is 100 m/s. The perforated screen is installed between the grinding chamber and the collection pot. A raw material is continuously fed into the center of the chamber by a magnetic feeder, and milled between the high-speed rotating hammers and the static lining by collision, attrition and shearing actions.

A part of the milled particles is sampled out to measure the particle size distribution at on-line by an aspirator using a compressed air through a sampling tube connected between the screen and the collection pot. The particles are transported into a laser diffraction particle size analyzer by a pneumatic conveyor. The particle size distribution of products is continuously measured and sent to a fuzzy controller. The fuzzy controller determines the value of the manipulated variable (the rotational speed of the rotor, R) which is automatically adjusted to an appropriate value. In the experiments, a lactose powder (Pharmatose 80 M, DMV International, D_{50} = 254 μm) which is widely used as a pharmaceutical excipient was employed as a model sample to be milled.

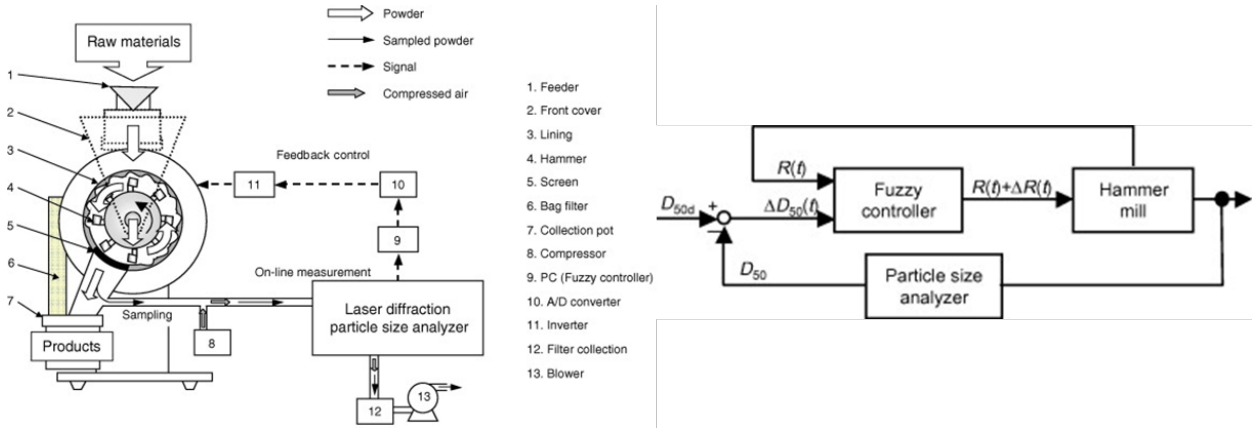

Figure 1. Schematic Diagram of Dry Impact Mill and Fuzzy Control System

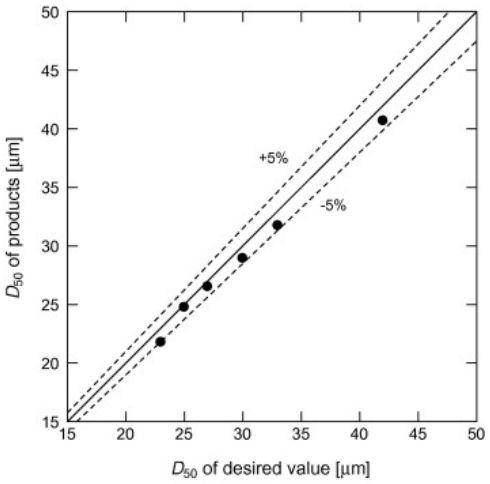

Figure 2. Accuracy of Fuzzy Control

2. Results and Discussions

Figure 2 illustrates accuracy of the control. The figure shows the average of median diameter by the on-line measurement. The results indicated that the average was regulated within ±5% of the desired set-point value. Therefore, it was found that this system and technique could control the median diameter accurately.

3. Conclusions

In this study, on-line measurement and control of particle size in hammer milling process has been developed. The fuzzy logic consisted of membership functions and control rules, in which complex dynamics and characteristics of a dry grinding process was taken into consideration, could accurately control the median diameter to various desired set-point values even if there were external disturbance, such as many kind of feed rate changes. Therefore, it was found experimentally that the developed feedback control system with fuzzy logic was a useful method for the control of particle size in dry grinding process. .