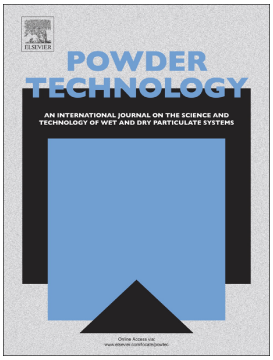

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Review of Noninvasive Methods to Characterize Granular Mixing

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Granular flow, Particle-particle mixing, Spectroscopy, Tomography, Velocimetry

Abstract

Granular mixing is a common process observed in a variety of industries such as construction, chemical processing, food handling, and cosmetics and pharmaceutical manufacturing. Over the years several methods have been devised to characterize granular mixing and to provide information on the quality of the mixture as well as mixing end points. In this work, three different noninvasive measurement categories are reviewed, namely: velocimetric, spectroscopic, and tomographic techniques. Velocimetric techniques such as Particle Image Velocimetry (PIV) and Radioactive Particles Tracking (RPT) are able to provide the trajectories and velocities of individual particles during the mixing process. Spectroscopic techniques focus on the chemical composition of the sample and are well suited for applications where there is little difference in the physical properties of the constituents such as particle size and density. Tomographic techniques such as X-ray Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) provide information such as the spatial distribution of the different constituents in the sample and are useful in determining dead zones and inhomogeneities. A few other techniques are also discussed, particularly passive acoustic methods which, though can neither provide spatial distribution nor individual particle trajectories, are still useful and can be employed to determine mixing end points. The objective of the work is to provide a comparative assessment of the various noninvasive techniques and discuss their ability to effectively characterize the mixing process. The reported techniques will be reviewed thoroughly based on their functionality, viability, and characterization capability. The advantages and disadvantages of the