The Application of a Drag Force Flow Sensor and Positron Emission Particle Tracking (PEPT) to Evaluate Flow Patterns within a Mixer and the Relationship between Impeller Speed and Force

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Abstract

In-line Process Analytical Technology (PAT) tools can produce data for real-time monitoring and control without the need to disrupt manufacturing processes. In-line measurements have several advantages compared to off-line techniques: the data can represent both a greater proportion of the processed material and the process conditions that the particles are being subjected to. The combined application of an in-line Drag Force Flow (DFF) sensor (Lenterra Inc, USA) and Positron Emission Particle Tracking (PEPT) (University of Birmingham, UK) was used to monitor the flow of a dry mixing process in a mixer fitted with a bevelled, two-blade impeller.
A DFF sensor is a thin, hollow, cylindrical pin containing two optical strain gauges which detect deflections caused by the force of particulate flow. These sensors can provide highly sensitive in-line measurements of flow forces in a wide variety of applications in real-time.

To evaluate the impact of impeller speed on the forces experienced within a mixing process, the DFF sensor was used to monitor the forces exerted by a bed of glass particles agitated by the rotating impeller at a range of 13 different blade rotation rates between 25-350 RPM. A clear, positive, non-linear relationship was observed between the rotation rate of the bevelled impeller and sensor output as a Force Pulse Magnitude (FPM). The FPM quantified the magnitude of the particle impact on the sensor over a selected period of time, enabling the operator to average out characteristic frequencies of the mixing process corresponding to each passage of the impeller. The relationship observed between impeller rotation speed and FPM supports the commonly-held expectation that a compromise is required when processing more friable materials. A higher impeller speed may reduce the overall blending time but due to the increased forces and stresses generated, it can also increase the likelihood of particle attrition and permanent changes in the physical properties of the powder bulk.

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This investigation was supported by the application of PEPT, a technique capable of tracking a radioactively labelled particle in 3D, even within the interior of dense, opaque systems. PEPT was used to evaluate particle flow patterns within the mixer, both with and without the installation of the DFF sensor. The non-intrusive nature of the DFF sensor was demonstrated using depth-averaged images of PEPT, which showed that only marginal differences were observed between the flow patterns of the labelled particles with and without the presence of the sensor.
The DFF sensor was demonstrated to be a highly sensitive instrument for the routine monitoring and control of in-process forces during mixing. The thin, cylindrical shape of a DFF sensor means that it provides minimal intrusion to flow and is therefore appropriate for use across a diverse range of applications, including mixing and blending.

Keywords: Powder Flow, Powder Flowability, Drag Force Flow, PAT, Process Analytical Technology, Powder Behaviour