115g Size Distributions of Non-Spherical Particles from Chord Length Measurements: How to Account for Orientation Bias Due to Flow

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The measurement of chord lengths as an index of the particle size has become increasingly popular in recent times. Interpretation of such a chord length distribution (CLD) is of paramount importance in order to extract the actual particle size distribution (PSD), which can be significantly different from the measured CLD. Incorrect interpretation of the measured data adversely affects derived kinetic models and process monitoring leading to flawed process design and control.

The focused beam reflectance measurement (FBRM) technique has attracted considerable attention in the particulate process industry due to its simplicity and capability for online measurement. It consists of a rotating laser beam, which when passed through the suspension of particles receives backscatter for duration of obstruction by the particle. The time is then converted using the linear laser velocity to get the length, which essentially is detected as a chord of a particle. Obviously, the chord is not a direct measure of the actual particle size, and must be transformed appropriately to particle size.

The transformation of chord lengths to particle size has of course received considerable attention in the past. However, most of this effort has been directed towards either spherical particles or non-spherical particles of uniformly distributed orientations. In actual practice, the particle orientation must be biased by the flow of the fluid in which the particles are suspended. Such orientation bias becomes particularly serious for highly non-spherical particles such as those of needle shape that occur frequently in the pharmaceutical industry. This paper addresses the significant problem of transforming chord lengths of such particles with orientation bias to their sizes.

Our approach is predicated on the solution of an inverse problem for extracting the orientation bias by measuring the chord length distributions of particles whose sized distributions are known. As the flow in most process equipment will be a function of position, the orientation bias will depend on the site of measurement. Thus such a calibration approach will be specific to particle shape and measurement site as the flow conditions will vary with location.

In formulating the inverse problem, we resolve the dependence of particle size on chord length into two sets of variables; the first refers to particle orientation as described by Eulerian angles between a fixed Cartesian frame of reference relative to the measurement site and another Cartesian frame attached to the particle; the second refers to geometric variables necessary to uniquely identify the chord length from particle size for a given orientation. The orientation bias is described by a distribution function for the Eulerian angles which is to be determined by solving the inverse problem to be defined presently. The geometric coordinates are assumed to be uniformly distributed, an assumption consistent with the use of a device that essentially measures the size distribution averaged over the measurement volume without recognition of gradients within the volume. The orientation bias so extracted is a more reasonable input to predicting particle size from chord length measurements as long as the number densities are not so large as to affect the orientation bias by modifying the fluid flow.

The proposed methodology is the first of its kind, which we expect to be a promising approach to fully exploit the simplicity of the FBRM device.