369g Population Balance Modeling of Comminution Processes: Implications of a Nonlinear Theory for Practice

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Breakage of particles is a complex phenomenon that is intended in comminution processes to enhance specific surface area. As a unit operation, comminution is widely used in a variety of industries including ceramics, composites, foods, minerals, paints and inks, pharmaceuticals, etc. The operation can be carried out under wet or dry conditions in batch or continuous modes. Aggregation of fines, degradation of heat or shear-sensitive materials, media wear, and overgrinding can be minimized and controlled if a quantitative understanding of the process is developed. Among various approaches to the analysis of comminution processes, the use of population balance models (PBMs) provides such an understanding at the process length scale. Not only can PBMs be used as a tool for simulation, design, and optimization, but also they can elucidate the breakage mechanism(s) such as massive fracture, cleavage, and/or attrition.

Linear population balance theory has been applied to breakage phenomena with some success. On the other hand, researchers have observed some interesting and non-intuitive breakage phenomena that cannot be explained by the linear theory (refer to the review in [1]). Gradual accumulation of fines in a batch mill is known to alter the specific breakage rate of the relatively coarse particles. Purposeful addition of fines to a particle assembly has a significant impact on the breakage rates. Particle bed breakage tests in the literature also show that multi-particle interactions among particles of different sizes lead to a nonlinear breakage probability.

Bilgili and Scarlett [1,2] have recently proposed a nonlinear population balance theory, which decomposes the specific breakage rate into a size-dependent function and a population density functional. Using this theory, computer simulations of a batch milling process were performed. In this presentation, the capability of the theory in predicting the aforementioned complex breakage behavior will be demonstrated. We will also present some important implications of the simulation results. The use of mesh screens in batch milling equipment is common practice in the pharmaceutical industry. The slowing-down effect of the fines on the coarse will be minimized if the fines are removed from the mill through the screen as soon as they are produced. This investigation rationalizes such a practice on a theoretical basis. The application of the theory to continuous milling processes will also be discussed.

1. E. Bilgili, B. Scarlett, Population balance modeling of non-linear effects in milling processes, Powder Technology, 153 (2005) 59–71. 2. E. Bilgili, B. Scarlett, Formulation of a non-linear framework for population balance modeling of batch grinding: beyond first-order kinetics, Chemical Engineering Science, in press.