To the Editor:

A recent contribution by Serra and Casamitjana, "Effect of Shear and Volume Fraction on the Aggregation and Breakup of Particles" (August, 1998) has a number of features that those interested in aggregation processes should take into account. First, the use of a Couette-type flocculator with inner cylinder rotation: Serra and Casamitjana have used a device in which the ratio of length to annular gap is about 24. This is relatively small and may lead to propagation of disturbances from the ends. Flow in a concentric cylinder device in which motion is dominated by the rotation of the inner cylinder undergoes an evolutionary transition process in which a succession of stable secondary states is possible (see Coles, 1965). Fluid motion driven by rotation of the outer cylinder is centrifugally stratified, and, thus, theoretically stable (although not practically so). As noted by van Duuren (1968), rotation of the outer cylinder is clearly the preferred choice for flocculator operation. As a practical matter, no concentric cylinder device should be used as a defined velocity gradient ("G") flocculator without thorough hydrodynamic evaluation. Without such testing, it is impossible to state categorically that transition in the device occurs at 58 s^{-1}, or any other strain rate for that matter. It is also unclear when the authors speak of transition, whether they are referring to Taylor vortices, wavy vortex flow, or actual turbulence. Based upon my calculations, the condition for globally stability (small gap) would limit the rotational speed of the inner cylinder in the Serra-Casamitjana device to about 0.7 rpm (for the appearance of Taylor vortices). Turbulent flow would be expected at about 8 to 10 rpm, rather than 98 rpm as stated in their article. The origin of the error is apparent in the cited, earlier contribution: Serra et al. (1997), p. 466.

Additionally, the authors have resorted to an unusual step in their modeling of the disintegration process; they have assumed a "well-shaped distribution" of fragment sizes ranging upwards from the primary particle diameter. In no way can this be taken to represent what is occurring in the flocculator. In our experience, no suspension of flocs can be pumped without causing extensive disintegration. Furthermore, the fragment sizes produced by this process will not match those produced by breakage events actually occurring within the confines of the flocculator; the hydrodynamic environments are totally different. This underscores a difficulty inherent in population balance modeling in systems with both aggregation and breakage occurring simultaneously. When the breakage kernel has not been identified, parametric choices can produce virtually any result desired.

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Reply:

We thank Prof. Glasgow for his comments. A Couette flow device was used in the work done by Serra et al. (1997). We recognize that a Couette flow leads to a variety of flow states—Taylor vortices, wavy vortices, modulated wavy vortices, turbulent Taylor vortices, and so on—and that the transition between different flow regimes depends not only on the Reynolds number, but also on the radius ratio, and the aspect ratio of the cylinders (Di Prima and Swinney, 1981). The purpose of the work done by Serra et al. (1997) did not pretend to be a full description of these states; rather, the focus was to explore the change in the mean size of the particles as the shear evolves from laminar to turbulent conditions.

Although our estimation of the angular velocity at which the transition to turbulence occurs, based on Van Duuren's equation (1968), was used in previous works with a similar experimental setup (Oles, 1992), we agree with Prof. Glasgow that this is not the best estimation that could be given. Taylor instabilities and the transition to turbulence occur sooner in a Couette flow system when the inner cylinder is rotating, and the outer is at rest than vice versa. A better estimation can be obtained from Koschmieder (1979), Andereck (1986), and Boubnov (1995), which follow the pioneering work done by Coles (1965). These authors show that the turbulent Taylor vortices occur at $Re = 3{,}000$, Re being $Re = (R_2 - R_1)R_1\omega/\nu$, where ω is the angular velocity of the inner cylinder, R_1 and R_2 are the inner and the outer radius of the cylinders, respectively, and ν is the fluid viscosity. By applying these results to our case, we obtain $\omega = 20$ rpm, approximately; although, as pointed out by Coles (1965) and Andereck et al. (1986), there could be patches of turbulent flow together with patches of laminar flow at lower Re values. Recent works have studied the behavior of the turbulent regime in the Couette flow device. Smith and Townsend (1982) and Barcilon et al. (1979) found a transition from the turbulent Taylor vortices to fully turbulent flow at a value of $Re = 30{,}000$ ($\omega \sim 200$ rpm, approximately).

Addressing now the issue of end effects and the effects of the pump: ideally, the cylinders should have infinite length; in practice, the ratio is limited. In this work we settled on an aspect ratio of 24 and the end effects were minimized by using a Couette flow device mounted vertically with one end open (Van Duuren, 1968). Oles (1992) used the same value of the aspect ratio to study the flocculation of latex particles due to the shear rate in a Couette device. In order to avoid the effects of the pump on the aggregates of particles, it was placed after the analysis system (see Figure 1 in Serra et al., 1997) and the flow was kept at a low pump velocity. Different flow velocities in the tubes were used in order to determine if the pump produced any measurable effect in the aggregates. No difference was observed at different low values of the pump level.

The third issue concerns the nature of modeling. Although the process of disaggregation of particles has been studied for a long time by several authors (Argaman and Kaufman, 1970; Boadway, 1978), any breakage kernel has not been proposed to exactly describe the breakup process. Several mechanisms can induce breakup of particles (erosion, splitting, and so on) (Shamlou, 1993), giving a broad distribution of fragments. One way to take into account all of these fragments with several sizes is assuming a well-shaped distribution of particles (Spicer and Pratsinis, 1996).

Similar models have been used for a long time to explain various types of phenomena. Examples range from biological phenomena, Kirboe et al. (1990) (coagulation efficiency and aggregate formation in marine phytoplankton), Jackson (1990) (formation of marine algae flocs), Burban et al. (1989) (aggregation and disaggregation of sediment particles), to the work of Spicer and Pratsinis (1996) who proposed a balance model in order to study the aggregation and disaggregation of latex particles caused by the action of the shear rate. Population balances are not without drawbacks; we know however, of no other modeling alternatives to interpret these results.

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To the Editor:

I read with interest the article by Proctor et al., (April 1998) describing the influence of Marangoni forces on the efficiencies of packed columns.

We observed droplet formation during the distillation of surface tension negative systems, indeed photographing them (Boyes and Ponter, 1970) and later calculating the surface tension driving forces responsible for the ejection of drops (Boyes and Ponter, 1971a). We also reported enhanced efficiencies for a number of negative systems caused by the spray formation (Boyes and Ponter, 1971b). It should be expected that this phenomenon is more influential for larger packings since the surface to interstitial liquid flows will be greater. Finally, the use of surface tension at the boiling point measured under equilibrium conditions is inappropriate when mass transfer takes place. We proposed a method to determine surface tension during distillation (Ponter et al., 1978) which, while unrefined, gives a more accurate evaluation.

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