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Exercises 10

1. **What are the different types of rheological behavior possible for ceramic suspensions?**

Solution

Ceramic suspensions can be either Newtonian (the viscosity is constant, the shear rate varies linearly with the shear stress), or shear thinning (the viscosity decreases with shear rate) or finally shear thickening (the viscosity increases with shear rate). Most suspensions have complex behaviors, but we can say that agglomerated suspensions are in general shear-thinning and have a yield point (below which they do not flow), i.e. we have an overall attractive interparticle force which forms an attractive particle network. Well dispersed suspensions normally do not have a yield point and have a Newtonian behavior.

2. **How does the rheology of a ceramic suspension vary as a function of the pH and the volume fraction of the solids? Why ?**

Solution

See slides week 10 – 20-24,

Depending on the **volume fraction of solid**, the rheology of a suspension varies so that the relative viscosity increases as the volume fraction increases. For $\Phi < 2\%$, the relation is linear (Einstein's law), then the effects of the double layer increase and many body interactions have to be taken into account (Taylor series, power law dependence). The relative viscosity has two shear limits : low shear and high shear. At a certain fraction (0.64 for low shear rates) there is a divergence: we have a compact random packing of particles (64% solids packing) which does not allow the particle flow one past another (dilatant) but at high shear we can have a certain degree of order within layers of particles and the viscosity is lower than at the low shear limit. This is a consequence of an increase in the maximum packing fraction at high shear (towards 74%, hexagonal close packed)

See slides week 10 – 25-28

As a function of **pH**: around the isoelectric point, the intensity of the attractive interparticular forces increases, which requires higher shear rates and more and more energy to pull particles out of the attractive potential well, so the relative viscosity diverges. Far from the isoelectric point, the electrostatic repulsion is sufficient to give a strong repulsive barrier and the suspension has low relative viscosities i.e. no attractive forces between the particles. At extreme pHs, compression of the double layer due to the high concentration of electrolytes and the formation of attractive secondary minima, further increases viscosity (attention to reactivity, dissolution of powders...which will also increase the ionic concentration and compress the double layer and thus allow attractive van der Waals forces to be felt).

3. **What is the effect of agglomeration on the rheology of a suspension?**

Solution

Agglomeration effect on the rheology of a suspension. The viscosity increases compared to a well

dispersed suspension- due to increase in effective volume. i.e. a certain amount of liquid is lost in the pores of the agglomerate and is no longer available for particle to move through, decreasing the particle-particle distance and hence the number of particle particles interactions per unit volume. Its like increasing the volume of particle compared to the real solids volume. The suspension behaves in a shear-thinning manner if the agglomerates can be broken under a certain shear stress. This will release the liquid trapped in the agglomerate and reduce the effective fraction volume of solids.

4. What are the different possible mixing mechanisms?

Solution

There are three main basic mechanisms for mixing:

- diffusion
- convection
- shear

In reality, it is a mixture of all three but often one dominates the other mechanisms for one type of mixer.

5. What type of mixer is well suited for i) dry powders ii) suspensions iii) thick pastes?

Solution

i) Diffusion predominant or shear mixers (drum, double cone, random motion) are used for dry powders.

ii) For suspensions, all convection mixers: blade, mortar, propeller and screw mixers are recommended and even simple agitated ball mills

iii) For thick pastes, the best mixer is the screw extruder (shear dominant).

6. What are the different types of defects that can be found in granules produced by spraying?

Solution

Different types of defects in granules produced by atomization:

- Granules not dense enough
- Formation of a rigid crust on the surface (when suspension has a low volume fraction of solid and a high content of organic additives).
- Swelling of the drop due to an increase in the internal pressure of the drop when an excess of an amount of organic additives block the surface pores. This can lead to
- Hollow granules: when the internal pressure is greater than a critical stress, the crust breaks and the amount of solids cannot fill the centre of the “swollen sphere”
- Formation of a hollow sphere with a depression: surface does not dry evenly, the hot side with a thick crust and the cold side with a thin crust. The liquid will migrate towards the hot side and the cold side will be carried along by this diffusion front, creating a pressure gradient and depressed surface on one side.

Droplet explosion: air too hot, expansion of the liquid becoming gas and cannot diffuse quickly enough through the drying surface.