HOW TO SPECIFY MIXERS FOR SOLIDS SUSPENSION

For
Florida AIChe Symposium
Clearwater, Florida
June 2006

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About 50% of the mixing applications involve solids of one kind or another. Sometimes these solids are part of the process reaction and other times they may be a nuisance in the process must be handled satisfactorily.

Sometimes the urge is to specify the degree of mixing in terms of mild, medium and violent agitation. This has a history of many years of practice, but is a qualitative description, and is not normally good for a quantitative definition of the process.

In general, the particle size in the solid phase has to specified even if it is a estimate based on information prior to actually having the feed stream available. If the particle size has arisen from different kinds of chemical reactions in the process, or the particle size comes from a source other than the process at hand, there needs to be some description of the particle size distribution. Very seldom are very closely single particle size fractions part of the in the process. Usually there is a variety of particle sizes, and if there is to be a reasonably quantitative specification, some sort of screening must be done, probably on dry solids if possible, but if it has to be, wet screening is possible. If the solid particles come from a grinding operation from different kinds of ball or roller mills, then there is a characteristic distribution of particle sizes with percent weight fraction that can be used for estimating the largest particle to be handled.

No matter what the average particle size distribution may be, long term the largest particle must be estimated and its progress through the system specified. Often the particle size at the 95% weight fraction may be specified, but that alone, without considering what the largest particle may be, may give a serious error in the process. Sometimes a screen with a certain particle size will be placed on the discharge from the grinding circuit prior to entering the mixing tank. As long as that screening remains operable, and as long as the oversized particles are somehow flushed out, that may be a good way of specifying the maximum particle size. Using the 95% weight fraction particle size with an estimated typical curve of many kinds of grinding circuits can introduce a serious error if bigger particles are present and are not designed for. If the 80% weight fraction particle size is given without any other data the estimation of the maximum particle size is even more likely to be in error.

Depending upon the percent solids and the amount of fine solids, defined here as particles smaller than passing a 250 mesh screen, there should be a reasonable design factor placed on this maximum particle size, since the power required to suspend the larger particle often goes up with the square or cube of particle size ratio. A practical design factor should be discussed with possible vendors if an understanding of the potential risk of bigger particles than those designed for are present. If it is not possible to suspend the larger particles in the overflow system, which may be either at the top of the tank or may be up through to a riser operating beneath the liquid surface, possibly down as low as very close to the tank bottom, these particles, over time, will collect. There are many different ways to design the system so that these solids can be removed, either continuously, thus avoiding a shutdown for cleaning, or allowed to build up over a period of time to a normal shutdown period and be removed at that time. If there are larger particles present than can be systematically suspended, it is only a question of time before they will

accumulate and cause many different kinds of process and mechanical problems.

There are essentially no published data on mixtures of particle sizes coming from a typical grinding circuit. The only quantitative publication at the moment is the article by Oldshue, (1972). Most of the solid suspension studies have been made in transparent tanks, using a mono size particle. To get visual observations it must be done at relatively low concentrations, sometimes as low as one half of one percent. The N_{JS} often used is defined as any particle in the process not staying on the bottom more than one second before being re-suspended. This obviously has a qualitative observation spectrum as well as not being a very practical unit of suspension for most industrial processes, and particularly not representing what would happen in a mixture of particle sizes. In addition, the shape of the bottom at the corner where the vessel bottom surface meets the normally cylindrical straight sided tank, makes a big difference in the readings obtained for N_{JS}. For example a typical glass cylindrical vessel has a contoured shape where the cylindrical top meets the glass bottom. It has a big effect on the results obtained. In addition the N_{JS} for different kinds of impellers varies greatly. It is possible to reduce the variation, but not eliminate it, by using the power for the just suspended point P_{JS}. There is really no satisfactory way to measure N_{JS} or P_{JS} in full size tanks of several cubic meters of volume. The only practical way to examine a full scale tank is by means of a sampling technique. There is no doubt that a sampling technique is very specific to the method used. There is no way to sample a point in a mixing vessel and show that that is the absolute concentration at that point. The shape and method of introducing the sample into the sampling devise, plus random turbulence and velocity patterns at that point make the sampling data very specific to the method of sampling. It is not to easy in the field, for example, to measure and take samples in a tank with appreciable power levels so there random forces on the sampling devise can render the method very dubious in accuracy, as well as potential safety problems in suspending sampling devises at various points in a large tank.

The only literature data that I know of is the article by Oldshue mentioned above. That procedure involved taking samples at various places in the tank, in a tank approximately 100 centimeter in diameter and filtering, dry screening, and measures the various sizes of particles which is a very tedious and time consuming process. This fact probably accounts for much of the reluctance to use a sampling technique.

Published in a book by Oldshue (1983) is a typical procedure for estimating the power level in liquid solids systems. What seems to be the most practical relative description of the solids in a tank are found by, (1) on bottom motion, in which every particle including the largest is moving with a position velocity across the bottom of the tank, (2) off bottom suspension, in which every particle, even the largest, has a vertical velocity, and the ultimate, (3) complete uniformity, with a concentration variance throughout the entire volume is at a minimum. In addition to that description possibilities, there is also the condition where there may be settled a fillet at the outside corner of the tank bottom. For non-reactive solids, or relatively inexpensive solids, this is to be a very practical way of streamlining the tank bottom without very expensive tank shape construction.

If a tank is operating batchwise this may be a very practical way of defining the concentration gradient any given time and particle size description. However, the majority of solid suspension tanks are in a continuously flowing system, and a description of how the solids should be introduced and how the solids should be passed out in the slurry stream is a major factor in the overall process design. The tank can have a top overflow which the biggest particles must be suspended to the top of the tank for them to get out, or there may be a riser (sometimes a down comer or up comer) in which if possible the velocity in the “tube” puts it high enough to carry the biggest particles out of the tank to the next tank or the next process. If this is not possible due to the static or pressure heads available then there will be a build up of these large solids in the tank that need to be dealt with. Another concern is what should happen if there is a power failure and the solids settle around the impeller. In some typical processes, a draft tube may be involved in the design, and the introduction of slots in the draft tube and the impeller being up near the top surface means that there are practical ways of resuspending the solids in that kind of geometry. However, in a

completely open tank, which is by far the most common, the impeller is often down below the level of the settled solids. Various schemes have been tried with varying economic results including mechanical means of raising the impeller above the settled solids allowing the impeller to pump a low solids concentration stream down upon the settled solids. If the settled solids behave like "concrete" that may not be practical. Usually there must be a pumping system available that will start to circulate the slurry and then gradually introduce the settled solids into a fluid mixing zone. This can often be done by having a gas or liquid sparger available around the impeller to allow the slurry around the impeller to become fluidized to start pumping the slurry up into the major volume of the tank. However, unless there is a pump circulation available this may ultimately fail as well and shoveling out a "sanded-in" tank which is a major undertaking.

It is possible in the laboratory to study the suspension and restarting capabilities of geometry and using proper geometry scale-up techniques estimate what may or may not happen full scale. One problem that occurs is that if samples from process area are sent to a vendors testing laboratory, the shipping and storage may introduce resuspension and reconstitution problems that are very unique and potentially scalable. One of the problems is that any foaming chemicals that may be planned for the process if there is a gas introduced into the slurry system and concentration of this foaming agent and the reconstituted sample is not proper relative to the full scale unit. In general, the introduction of a gas stream into a slurry system is counter productive to the mixer rotator and higher particles need to be used than would be necessary without the gas introduction. Call me on the full scale installation is a much more serious concern than it may appear to be in a laboratory sample.

If mass transfer is involved in the process between the solids and the fluids then another type of analysis needs to be added to the solid suspension characteristics. It is very helpful to have a study made of the resulting product concentration vs. power for the minimum, the average and maximum particle sizes, Figures 3.

From this information, analysis is made of the total process result at various levels of suspension and may include the effect of different heights of the outflow riser in the tank. Figures 2 and 3 show then typical power plant results involved in the process reaction, coupled with two different heights of the outflow in the resultant particle size distribution for a multi particle size installation. The power level for various process results may supersede the power required for an appropriate level of suspension but that will result in different levels of process performance.

In addition, the D/T ratio has a large effect on solid suspension, but may have a very minimal effect on the process result at the power level. So in addition to a single D/T, it may be necessary to look at other D/T's, which may change the economics of the mixer selection dramatically in the terms of the torque required from the drive, and the critical speed shaft, diameter requirements of the mixer shaft. It may be that the ultimate impeller type which would be the most effective for solid suspension may not be the most effective for mass transfer and it may be necessary to look at different impeller designs in order to optimize the process.

In addition, take the case of a particular process in which there are five tanks in series each tank being about 9 meters diameter with a volume of 20 cubic meters. Estimates were made of the degree of solid suspension of three different particle size fractions, and a relative mass transfer effect of power on the mass transfer coefficient from liquid to solids. As shown in Table 1, the extraction performance based on the degree of suspension of the various particle size fractions and the effect of power on the mass transfer coefficient was estimated for four different mixers. The mixer cost depends upon the power, the operating speed and the design of the shaft and impeller. As a general rule, the lower speed for a given power level the larger must be the gear reduction unit and therefore the higher the relative cost. Based on Table 1, mixer No. B was chosen as well as a 10% fillet in the bottom of the tank. Another generality is that if the power supplied by the mixer is less than one-third of the power required for off-balance suspension, the tank is probably going to sand in with a complete blockage in the tank in anywhere from two to thirty days.

The results from the installation of mixer No. B the process performance predicted and the five tanks in series

operated as predicted. The volumetric efficiency, due to the blending of the tank compared to the residence time showed that about 85% of the tank volume was in an active mode to predict the process performance as a function of a number of stages.

In solid suspension, abrasion and corrosion is a constant maintenance expense that must be factored in to the design of the unit. Another factor is that if the impeller blades are covered with a plastic or rubber material, they have to be carefully controlled so that the pumping profile of the blade is not compromised by an inappropriate thickness and shape of the covering.