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CFD Stirs Up Mixing

Progress in simulation provides improved mixer performance

By Seán Ottewell, Editor at Large

The era of mixing simulations requiring experts in computational fluid dynamics (CFD) and sometimes taking weeks to run is long gone. Driven by huge leaps in computing and related technologies, companies such as Ansys, Comsol and Flow Science are bringing easy-to-use mixing simulation to the engineer's desktop.

"Advances in parallelization and high-performance computing, as well as templatization, have brought accurate CFD simulation into the reach of non-expert chemical engineers," says Bill Kulp, lead product marketing manager, fluids, Ansys Inc., Pittsburgh, Pa.

Exemplifying this, the company has just begun a project with Nalco Champion, Houston, that will give chemical engineers there — none of whom are experts in simulation — access to Ansys Fluent and a simulation app based on an analysis control technology (ACT) template to quickly and efficiently scale up processes for new chemicals.

"The company has been quite frustrated with failures, especially with new reaction designs that won't work with their library of tank models, and are looking to CFD simulation to reduce costs and increase the success rate of their scale-ups," explains Ansys senior account manager Erik Shank.

Up to now, Nalco Champion's workflow typically involved completing hundreds of new reactions, 10–15% of which wind up moving into production test phases. Of these, only a handful eventually go forward, based on reaction yield, availability/cost of feedstock chemicals and other relevant data.

With each scale-up costing around $250,000, Nalco intends to use simulation to improve process costs and efficiency by eliminating at a very early stage the ones that are less likely to succeed.

"Chemical engineers can now focus on reactions and not complex CFD. The overall goal is to automate the process with a user defined field (UDF)/ACT extension to allow them to submit reactions into the simulation for on the fly decision-making," adds Shank. Success In India

Kulp points to a 2016 project carried out with Aditya Birla Science & Technology, Navi Mumbai, India, which resulted in an improved impeller for the mixing tank used in viscose staple fiber (VSF) manufacturing. VSF is produced by dissolving a wood pulp slurry in caustic soda and then forcing the solution through tiny holes in a metal cap. Mixing the slurry and caustic soda solution is both time consuming and expensive in terms of electricity use.

The Ansys team started with a steady-state multiphase simulation of the existing mixer to better understand the turbulent nature of the VSF mixing process. They employed a number of models to do this, including the frozen rotor mixing model for impeller motion and the Euler-Euler inhomogenous multiphase model to simulate the liquid/solid mixing in the system.

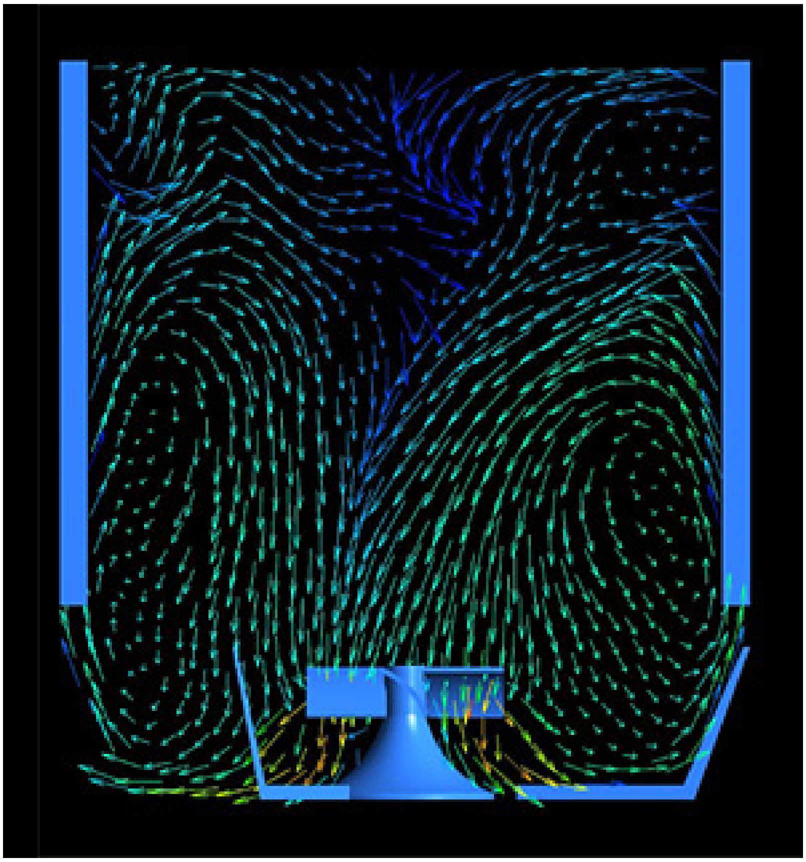
This led to an initial impeller design, which then went through six iterations to optimize the tradeoff between mixing performance and power consumption. The final design (Figure 1) uses a curved-blade impeller placed near the bottom of the tank and provides a five-fold improvement in mixing of the solid suspensions together with a 12% cut in electricity consumption.

FASTER DECISION-MAKING

CFD technology itself continues to advance, driven by improved computing resources and robust, accurate and scalable numerical methods. Important, too, is the ability to successfully perform multivariate analyses.

"These enable our customers to carry out hundreds of 'what if?' types of analyses early in the design phase and quickly assess product performance for strength, power, thermal, pressure, flow rate, electrical or a number of other performance requirements. Through this digital exploration, designers and product engineers can identify optimal combinations while eliminating outlying designs — saving time and money. This multivariate design-of-experiment approach helps them to identify the 'best' operating condition rather than one that is simply 'good enough,'" says Kulp.

This thinking is reflected in the launch of Ansys 18 at the end of January. The latest version of the company's simulation



IMPROVED IMPELLER

Figure 1. Velocity vectors for the final impeller design show improved mixing performance with a stronger downflow than achieved with the original. Mixer also uses 12% less electricity.

Source: Aditya Birla Science & Technology Co. Pvt. Ltd.

technology also integrates with Internet of things platforms to ease the use of “digital twins” of assets in operation.

Digital twins are virtual representations of individual operating assets that can be used to improve the performance and productivity of the actual equipment through simulation technology. Sensors on a mixer, for example, relay specific operating data such as temperature, vibration, impact and loading to the digital twin. This continuous feedback helps engineers optimize the operation of the mixer and can predict adverse conditions long before they happen — potentially unlocking massive production and maintenance savings for entire processes and plants.

“The use of digital twins is really exciting because it puts simulation at the heart of product and equipment development. You take simulations of individual components and processes and tie them together to form a complete digital prototype. This can be customized based on specific history of an individual device to predict performance over time — for example, reliability and likely failure modes,” he adds.

As simulation is adopted across the entire product lifecycle, engineers are becoming more empowered to imagine more options, a trend Ansys calls pervasive engineering simulation.

This, Kulp believes, is a glimpse of the future: “In 5–10 years Ansys simulation may be embedded with your PID/control software for pervasive predictive control of your mixing processes.”

SIMILAR STORY

Comsol, Stockholm, Sweden, is seeing the same thing. "Simulation is becoming much more widely used and understood by the chemical industry," notes chief technology officer Ed Fontes.

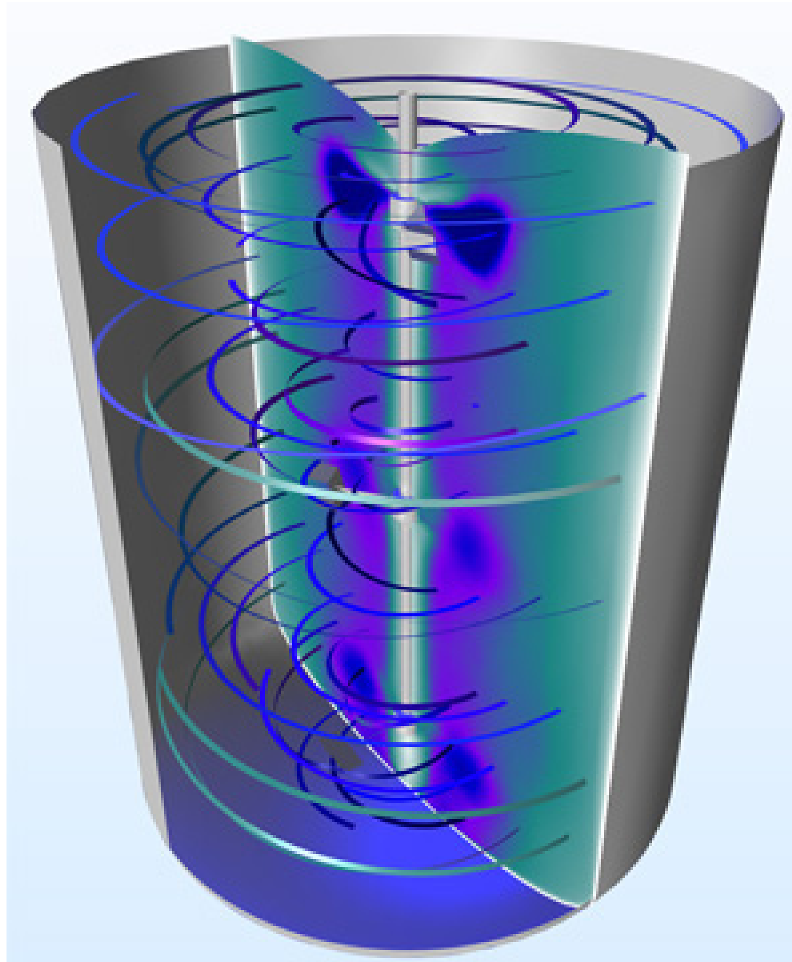
The company has developed a broad portfolio of software modules, including one for mixers that is particularly aimed at the batch, fine chemicals and pharmaceuticals end of the market, and the CFD and chemical reaction engineering modules that are targeted at bulk manufacturers.

As an example of the use of the mixer module, he cites an Argentinean laboratory that was working to take a fermentation process from pilot to commercial scale.

"It's quite easy to get a uniform mixture here, but if the shear rates are too high you will kill the yeast cells and you will not get any fermentation. So what we look for is an optimum of maximum mixing velocity with the minimum damage caused by shear rate — which is a kind of contradiction. So to achieve this we need to create eddies, a sort of chaotic flow, but with not too violent velocity gradients."

Once a pilot-scale process worked and a model had been validated for that scale, Comsol used the model to estimate the maximum shear rates; these data then served as the limit for the allowed shear rates in a model of a full-scale process (Figure 2).

"In other words, we can use the model to maximize the



VELOCITY FIELD
Figure 2. Simulation shows that mixing is not good but shear rates are moderate, which is crucial for fermentation application.

Source: Comsol.

mixing for the full-scale process under the condition that the shear rates are below the values that would kill the yeast cells. This type of scale-up problem is very common in the pharma industry, too. Processes that are sensitive to operating conditions can be dealt with in a similar way for scale-up and design," he adds.

The savings for users come from getting a much better product, plus only needing one pilot plant before going full-scale instead of the 20 or more that are used in some cases.

Comsol stresses that it takes a unique approach for generating the mathematical equations used in CFD and chemical reaction engineering modules. "Everyone in this field produces numerical models that make approximations of the continuous mathematical models by using different types of discretization such as finite difference, finite volume, finite element, etc. We are different in that we generate a full mathematical model with no approximations as a first step. Users can even apply their own mathematical equations via the graphical user interface (GUI) and these are incorporated just as any other 'native' equation into the problem. That's unique to us and it makes the simulation even more efficient for users. It's also patented," says Fontes.

Users don't need programming skills, just the math, he emphasizes, noting that chemical engineers typically already have — or can look up — the mathematical expressions they require. There's no need for a dedicated software operator to incorporate a company's own expressions for transport properties, material properties and reaction kinetics into a model.

CONTINUING CHALLENGES

Simulating multiphase flow still poses challenges. Comsol has adopted a twin approach with its interface tracking and dispersed multiphase flow models.

The challenge with the first is to get an accurate description of the flow, droplet breakup and droplet coalescence (or bubble break up and coalescence) at a decent performance rate. Better performance allows for simulation of more droplets (or more bubbles), which also increases the fidelity of the description of the flow of the whole multiphase mixture.

The findings about interaction between droplets from detailed interface tracking models can be used in dispersed multiphase flow models, where the two phases are modeled as volume fractions rather than as individual droplets or bubbles. The dispersed models thus are approximations of the more-detailed interface tracking models.

"The challenge here is to accurately describe interactions between droplets, droplet break-up and droplet coalescence without having the detailed description of the interface. Dispersed flow models have to be adapted to the nature of the fluids and the conditions of the flow to a higher degree than do interface tracking models; these can be done ab initio, i.e., with a minimum of assumptions and approximations," notes Fontes.

Another initiative is Application Builder. This allows an R&D department to build an app specifically for use in its own processes or plants. It boasts an intuitive and user-specific interface, and allows process engineers access to a ready-to-use simulation app that is tailored for their needs.

"Some of our customers are using the Application Builder already and finding it a very efficient way of benefiting from simulation," he adds.

The company also hopes eventually to offer access to large eddy simulation (LES) technology which givesextremely detailed descriptionsof turbulence.

GIVING MIXING ITS DUE

"The chemical industry stands to gain a lot from using computational tools such as CFD, but mixing processes are sometimes overlooked because of their assumed simplicity. However, there are many interesting ways to achieve excellent performance using modern numerical techniques," notes Ioannis Karampelas, CFD engineer with Flow Science Inc., Santa Fe, N.M.

Many such techniques are included in the company's Flow-3D Multiphysics modeling software package and its dedicated post-processor visualization tool FlowSight.

"All commercial CFD packages come bundled with some form of visualization tool but FlowSight is designed to be very powerful, simple to use, and easy to understand. For example, an engineer trying to redesign a process needs a very intuitive visualization tool to evaluate the effectiveness of various design changes," he explains.

This approach works particularly well to better understand and optimize processes where experimental measurements are hard to obtain, i.e., for parameters that are not easily measured and for processes that are inherently dangerous because of the presence of toxic substances, for example.

The same approach also has helped suppliers of mixer-related equipment to more accurately develop and tailor their products to customer demands. "This avoids unnecessary prototyping costs or potential over-engineering. Both have been a problem for some suppliers," says Karampelas.

The CFD technology itself continues to evolve. In terms of numerical algorithms, for example, discrete element modeling now can be readily applied for a variety of problems where interactions of spherical particles are important for properly modeling heat transfer, while an LES turbulence model is ideal for accurately simulating turbulent flow patterns.

Despite its cost and demand on computational resources, Karampelas believes that it is important to be able to offer a full suite of turbulence models, not least as LES already is the method of choice for the majority of academics and some industries, for example power engineering.

“Nevertheless, there are certainly cases where the use of CFD may be limited or impractical. This includes problems where the scale of interest may vary by different orders of magnitude, for example, modeling bulk fluid evaporation from nanoparticles, and problems where important physical phenomena are still unknown, poorly understood or, perhaps, extremely complex, for example, modeling the Mpemba effect,” cautions Karampelas.

On the other hand, the advent of even more powerful hardware and updated numerical algorithms will make using CFD software the optimum approach for solving a plethora of design and optimization problems, he believes.

“The ability to model more and more complex processes such as complicated heat exchange systems and novel mixing technologies represents only a glimpse of what may be possible in the near future. The main advantage of using numerical methods is that designers are now only limited by their imagination, opening avenues for optimizing a variety of chemical plant processes from small-scale mixers to large-scale reactors and distillation columns. Although the experimental or empirical approach will always remain relevant, I am confident that CFD will be the tool of choice for the engineers of the future,” he concludes. ■

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Carefully Evaluate Blending Requirements

When choosing a mixer, consider these four key components that can lead to improved mixing.

By Roy R. Scott, Arde Barinco

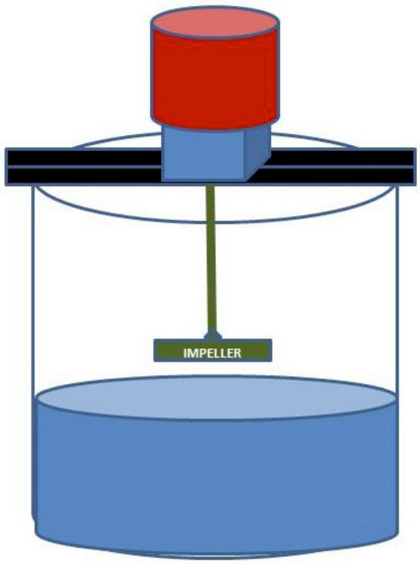
It is not unusual for mixing suppliers to receive the following request, or similar: "I need a mixer for a 500-gal. tank." The requestor then may expect a product suggestion to satisfy all requirements. The supplier's typical response is, "What is your mixture's viscosity?" Many times, this is the entire conversation, and a mixer's specification and pricing proceed from there. This often can lead to dissatisfying results. Here are four things to consider for successful mixing.

1. MAKE SURE IMPELLER IS IMMERSED

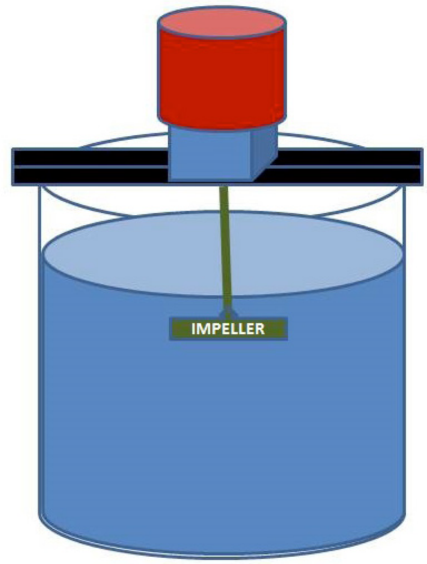
All batch mixers use some type of impelling device that typically is connected to a shaft driven by an electric motor. That impeller, sometimes known as a rotor or a propeller and other times as a turbine, must be in sufficient contact with the mixture if it is going to have any success impelling that mixture (Figure 1).

This may seem obvious, but the details of the process vessel's shape determine the details of the mechanical design of the shaft connected to the mixing impeller. In short, the impeller's drive shaft has to be long enough to reach down into the liquid at all times if mixing is to proceed. If the mixing vessel usually is close to full, then the mixing impeller will make good contact with the mixture in almost any circumstance (Figure 2).

If the batch begins with the vessel half-filled and then the other half of the mixture must be added while mixing, then the mixing impeller must make good contact with the liquid even when the tank is half-full. This



IMPELLER LENGTH
Figure 1. Impeller shaft must be long enough to reach liquid mixture.



PROPER CONTACT
Figure 2. This impeller is well covered and in contact with mixture.

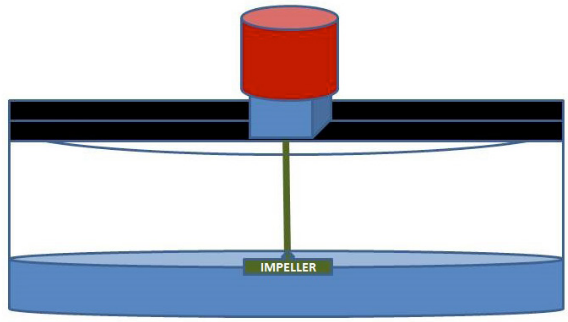
result is even more difficult to achieve if the vessel must be stirred at a less-than-half-filled level (Figure 3).

The mixing vessel's diameter and depth will determine how much volume exists at a given fill level. These dimensions are required to calculate the fill levels to make sure that the impeller can impel the mixture. Most impellers require some minimum immersion, such as 6 or 12 in. of mixture over top of the impeller, to do the job.

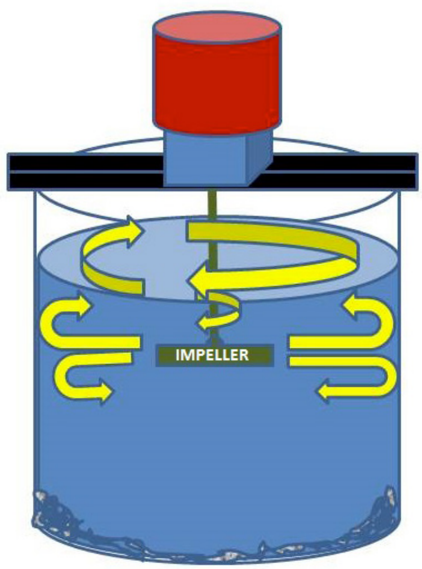
After the mixing impeller is configured and located so that it can start doing its job of pumping and moving the mixture throughout the mixing vessel, the pumping and circulation must be strong enough to mix all areas in the mixing vessel. No stagnant locations can exist because, if any of the mixture's components enter an area with no flow, they will, by definition, stay there and not get mixed with the other components (Figure 4).

2. MAKE SURE IMPELLER IMPARTS FLOW TO ALL AREAS OF MIX VESSEL

The mixer supplier must offer an impeller capable of moving the mixture throughout the vessel, and that impeller will require a certain amount of mechanical power. The mixer manufacturer must configure a power source (motor) along with its shaft and impeller that can pump the mixture's viscosity and density. However, just causing good flow from top to bottom and round and round may not produce any mixing at all. The impeller must produce a pattern of flow that causes swirls and eddies that can intermingle the various components.



FILL LEVEL
Figure 3. Here, the fill level is too low to cover the impeller and the mix vessel is too wide and shallow.



POOR FLOW
Figure 4. Impeller is well covered but good flow doesn't reach lower areas of vessel, allowing settling to occur.

Sometimes the impeller-produced flow needs to be baffled by installing stationary vertical obstacles in the mixing vessel. Other mixers operate at very high flow rates that cause natural flow patterns to produce good mixing without the installation of baffles (Figure 5). Once there is sufficient flow to produce different velocities within a mixing vessel, these shearing zones then can produce the desired result (Figure 6). That is, all of the various components must exist in the correct percentage for whatever sample size is taken from the mixing vessel. *This is the definition of successful mixing.*

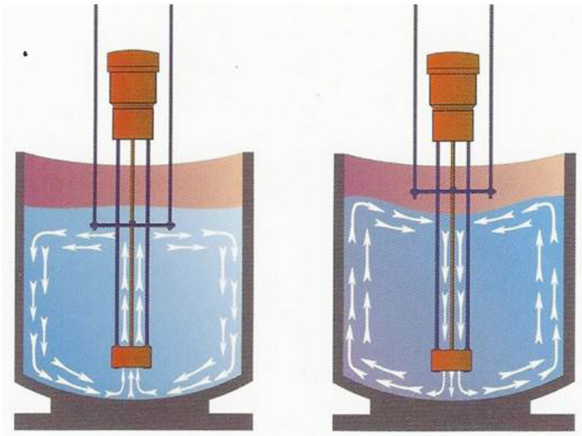
3. MAKE SURE MIXING QUALITY GOALS ARE MET

Even if the mixer has impelled all of the various components into the correct percentages, additional quality requirements may exist, such as a desired particle size distribution of a solid dispersed into a liquid or an emulsion droplet size distribution. Perhaps solids need be dissolved into the liquid at a given concentration.

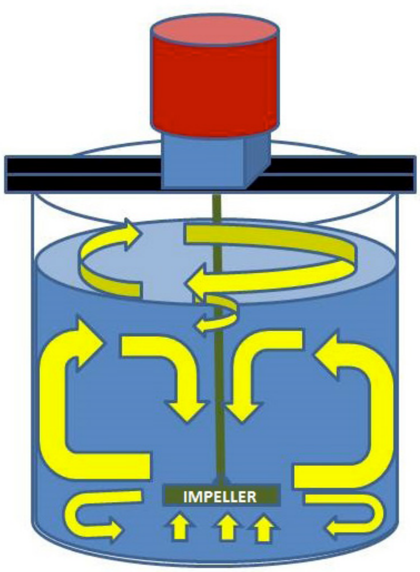
Mixing quality can be measured in different ways. Different desired process results often will require different types of mixing equipment. For fine-particle-size dispersion, mixing equipment generically described as "high shear" may be required. However, "high shear" can refer to thousands of mixer types. In short, the mixing impeller not only must mix the components to the right ratio but also may be required to achieve some other physical or chemical result.

4. MATCH BATCH COMPLETION TIME TO REQUIRED OUTPUT

One more requirement for a mixer to be successful is that it must do everything



FLOW PATTERNS
Figure 5. These mixers operate at very high flow rates that cause natural high shear flow patterns to produce good mixing.



SUFFICIENT FLOW
Figure 6. Impeller is well covered and close enough to the vessel bottom to reach lower areas of vessel to prevent settling.

described above and also do it in the right amount of time. For a 500-gal. batch, it has been assumed the mixer will produce the volumes required for the mixer's owner. How much of the mixture needs to be made, and how much per day and how much per year?

Suppose the annual requirements are 100,000 gal. Mixing time for a 500-gal. mixer includes filling the vessel, adding the other required components, mixing, dispensing and cleaning the vessel to make it ready for the next batch. If these steps take an 8-hr. shift, then it would take 200 days on a one-shift basis to make the required 100,000 gal. Because a typical work year is 200 days, the mixer is successful. However, if 200,000 gal. are required annually, the facility would have to go on a two-shift basis or install two 500-gal. tanks.

Another alternative would be to specify a faster mixer that might complete the mixing process twice in one shift. The decision to use the 500-gal. mixing vessel size might be reconsidered. Perhaps a larger batch with a larger, faster mixer would cost less than starting a second shift.

Extensive research for blending applications is available in a number of textbooks. However, for many processes, no substitute exists for doing experimental trials on a small scale and then scaling up. ■

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Industrial Mixing Technology Challenges Require New Approach

Individually adapted mixing systems improve productivity and reduce costs

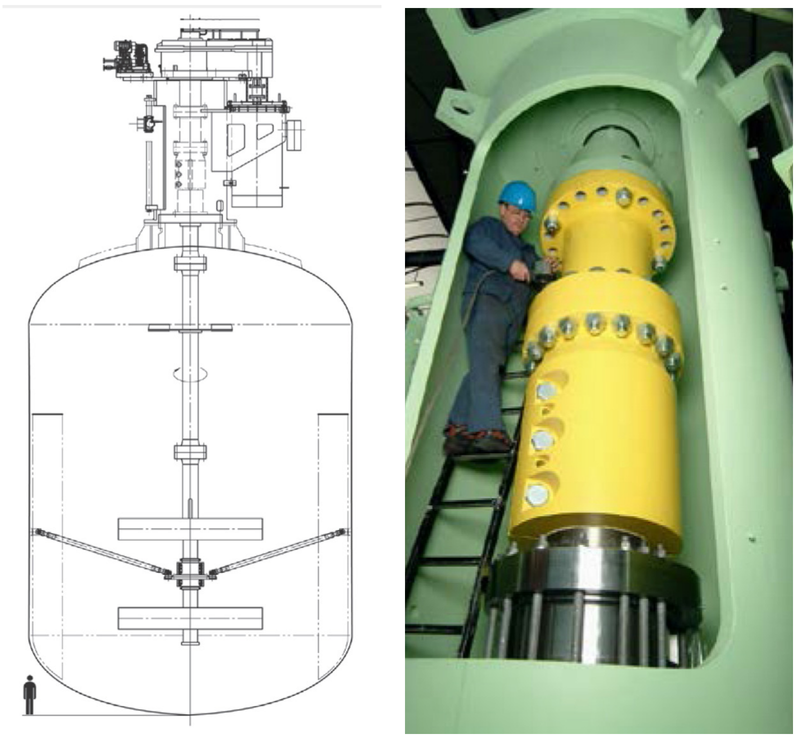
By Ekato

Mixing technology historically has meant simple, universally standard impellers operating in standard vessels with standardized vessel internals. Blade impellers, pitched-blade turbines, flat-blade disk turbines and anchor impellers for viscous applications all belonged in this category. They were popular partially because characteristic flow values were well-studied and written about. Also contributing to their popularity were the simple geometries beneficial to grid generation for flow simulations, which explains their attractiveness to users of numerical simulations.

The prevailing opinion was that such mixers were reasonably priced. However, when considering the specific hydraulic values of the blade impellers and flat-blade disk turbines — particularly the power number and radial force coefficients — then it becomes obvious that the high forces and torques will lead to a more expensive mixing solution.

In current industrial practice, a reverse trend from standardized to more individualized solutions is beginning to take hold. This can influence impellers developed for specific mixing tasks such as suspension or gas dispersion. In addition, adapting a mixer to an individual process or process step no longer is unusual. All functional components such as the vessel itself, baffles, feed points and heat exchangers are taken into account with respect to their interaction with the impellers.

We no longer talk about an agitator alone but about a mixing system. The aim is to



IN OPERATION
Output up to 1 million tpy per reactor
V_N = 500 – 700 m^3, P = 1,500 – 1,900 kW
P = 20 bar(g), t = 200 °C

PROJECTED
Output up to 1.5 million tpy per reactor
$V_N \leq$ 1,000 m^3, P $\leq$ 3,000 kW
Material titanium

ECONOMY OF SCALE
Figure 1. Economy of scale is demonstrated with this oxidation reactor for chemicals.

increase profits and integrate factors that influence production process effectiveness by reducing production and investment expenditures.

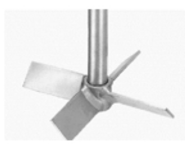
Factors that influence production process effectiveness and profitability include:

- productivity (throughput per vessel volume);
- production process stability (reproducible quality);
- energy consumption (higher efficiency);
- precise reaction control (less raw material consumption and waste), and;
- low wear (less maintenance and reduced cleaning efforts).

TESTING ECONOMIES OF SCALE

Also occurring is the move toward larger plant facilities to benefit from the so-called economy of scale. With respect to investment and fixed operating costs, one large unit typically is less expensive than several smaller units that provide the same total output. This trend places new challenges on design engineers; traditional scale-up rules haven't yet been proven with these sizes. Economy of scale is being applied to all branches in the process industry; especially impressive are examples in the production of bulk chemicals.

Figure 1 shows an oxidation reactor in which paraxylene in a continuous reaction with at-

	- Stable performance (Ne/Ne_0), improvements with respect to… • smoother, quieter operation • higher pumping capacity and flow velocities
	Short blending times under gassing, higher homogeneity (concentrations, temperature)
	- Extended flooding limits, potential for increased mass transfer
	- Lower radial forces, lower torque • expenditures for agitator and vessel

CONCAVE IMPELLERS
Figure 2. This table compares conventional impellers for gas dispersion with concave impellers.

mospheric oxygen is transformed to terephthalic acid as a precursor to polyester. It now is possible to produce up to one million tons of terephthalic acid per year in a single vessel; the agitator power approaches 2 MW.

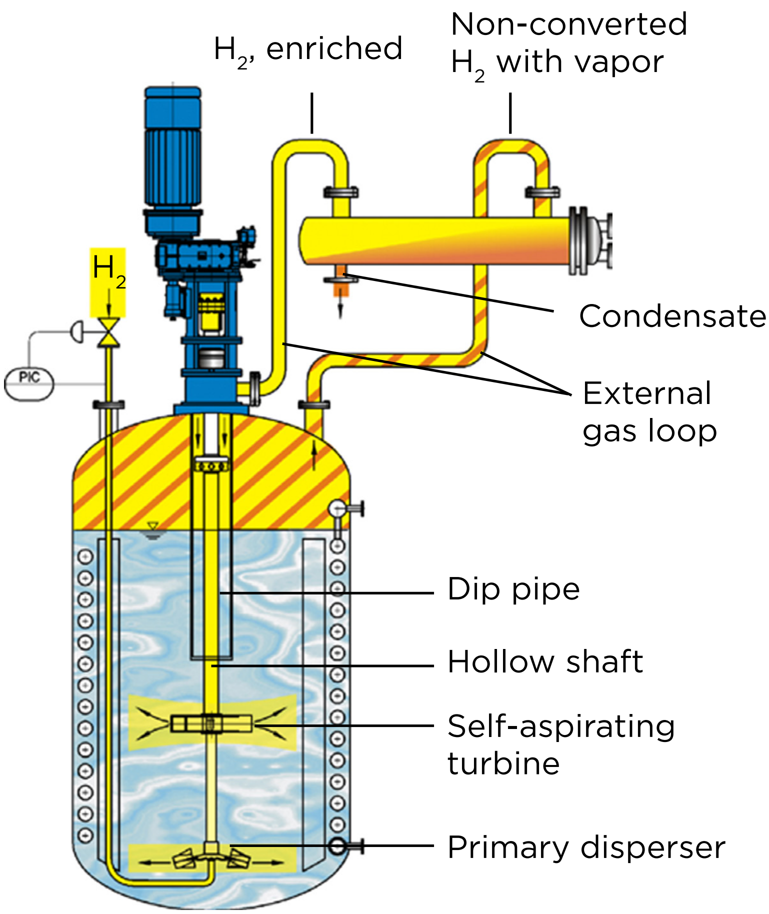
The impellers in this case no longer are the pitched- and flat-blade disk impellers that were used for decades. They were replaced by concave impellers that demonstrate a number of advantages as shown in Figure 2. The systems approach led to a complete reworking of the reactor concept by taking into account reactant feed points and product discharge as related to the kinetic and thermodynamic reaction parameters.

This fulfills the requirement for further performance consolidation and larger reactors. In addition, revamps of reactors in older units amortized themselves within less than half a year. Factors leading to profitability include higher productivity and lower raw material consumption resulting from fewer byproducts.

NEW CONCEPTS FOR SPECIALTY CHEMICALS

Investment and production costs also can be lowered for specialty chemicals with smaller production amounts using the system approach. One example is a reactor concept based on combined gassing (Figure 3). This system has gained a firm position when it comes to reactions using purified gases such as H_2, CO and EO.

With the standard design, the fresh gas is finely dispersed using a primary disperser but is only partially dissolved. The nonreacted gas enters the headspace and permanently is recirculated into the fluid by a self-aspirating impeller. This leads to high mass transfer rates and a fast and complete conversion of the gaseous reactant. This concept can be extended to include an



COMBINED GASSING WITH EXTERNAL GAS LOOP
Figure 3. This shows an example of hydrogenation with water (vaporous) as a byproduct.

agitator-driven external gas loop.

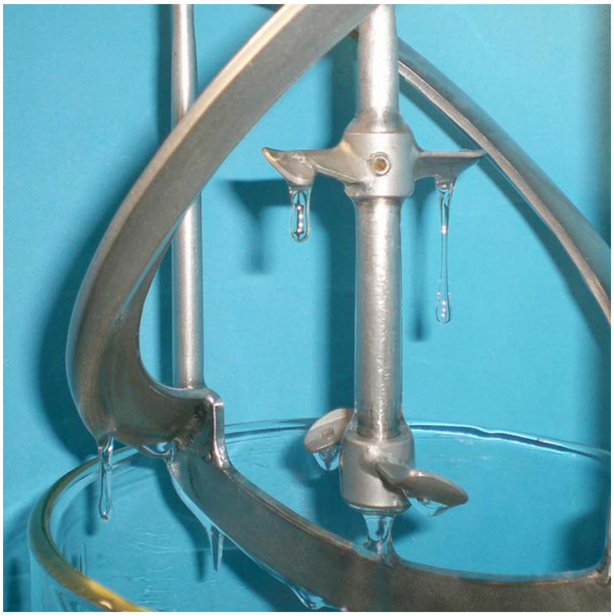
Reactions occur where gas or vaporous byproducts are created, e.g. when producing tertiary fatty amines — first water (vapor) and then ammonia in a later process step. These gases can accumulate in the headspace and bring the reaction to a standstill because of pressure buildup and in case of an equilibrium reaction lead to an incomplete conversion. In such cases, you must apply the traditional technology of external separation and gas recirculation with an additional blower or dispose of the discharged gas.

The agitator also can be used as a drive to circulate the gas externally through a gas-cleaning device. This cleaning device usually is a separator or condenser that removes the non-desirable components out of the gas. The purified gas then is returned to the reactor.

To avoid a remixing with the contaminated gas in the headroom, the purified gas is fed into a dip pipe that surrounds the agitator shaft located below the agitator lantern. This separates the purified gas from the contaminated headroom. The gas proceeds into the hollow shaft from the space inside the dip pipe and on to the self-aspirating impeller and back into the liquid. Instead of a condenser, another separating option can be used to clean noncondensable gases such as an acid or alkaline washer.

FLEXIBILITY FOR COMMERCIAL PRODUCTS

Another field for special impeller types or system so-



Separating the tasks blending dispersion

- coaxial/eccentric
- optional impeller combinations
- independent speeds/rotational directions, power inputs
- variable viscosities during batch (1 – 10^6 mPas, n-N, τ_0)
- Introduction of powder, disagglomeration, dissolving in the viscous media
- Degassing
- Heat transfer

⇢ Single-pot process

MULTI-SHAFT SYSTEM
Figure 4. This multi-shaft system with coaxial impeller is designed for a single-pot process.

lutions is formulated products. This includes ready-to-use commercial products, e.g., adhesives, sealing compounds, insulations, foods, food supplements and care products, and pharmaceuticals. All fields have in common the value (price per ton) as well as high requirements for a reproducible quality and therefore production process. They almost always pass through phases of high viscosity, most often with non-Newtonian flow behavior and yield stress.

The universal anchor impeller has been superseded by an axial forced flow impeller with markedly improved mixing behavior in the laminar flow area in this case, as well. This impeller is suited for viscous media and now is the starting point for a range of individual system solutions.

The functions of viscous mixing and dispersion have been separated using multi-shaft systems (Figure 4). Individually and adjusted to the mixing task, high-speed impellers can be combined with forced-flow impellers. The high-speed impellers also can fulfill an axial pumping function; often a dissolver disk or rotor-stator system is used. Independent of one another, the rotational direction can be adjusted and herewith the pumping direction or the power input depending on the speed. Cooling viscous media often are the rate-determining steps within a batch; fluids with a yield stress often create a layer on the vessel wall through which thermal conduction transfers heat.

The solution for slow-running impellers are scrapers that renew the wall layer continually

Economic production of chemicals and the resulting commercial goods no longer can be achieved with standard solutions.

and can increase the heat transfer coefficient by up to 10 times. It's possible to cover many process requirements using this system, including blending water-like to highly viscous media; processing in multiphase systems with surface entrainment; dispersing solids or liquids in the high-viscous phase; degassing steps and, parallel to this, achieving an efficient heating and cooling process.

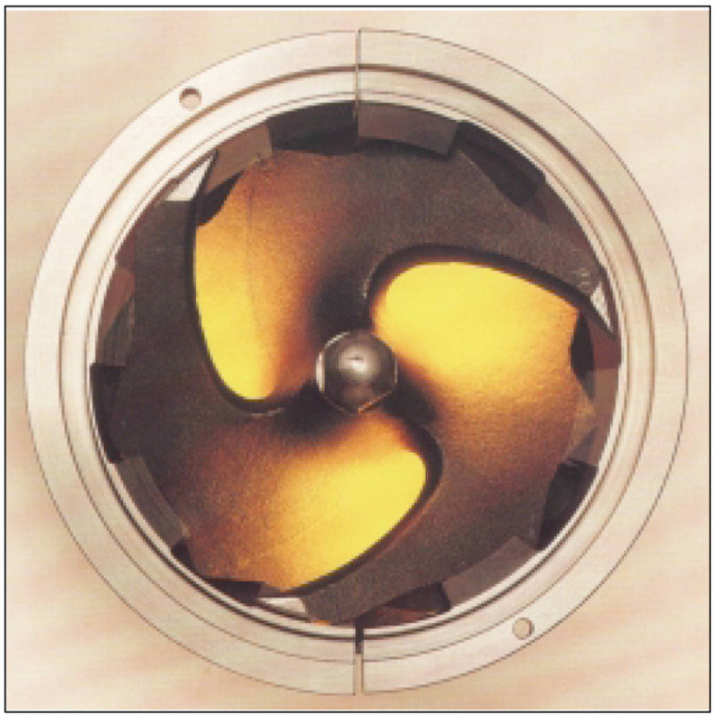
The combinatorial analysis of multi-shaft systems leads to the "single-pot process," which indicates that the manufacture of formulated products does not always have to be carried out in several different units connected serially. With modern mixing systems, they can be processed sequentially in a single vessel, which is a plus to those concerned with investment and operating costs.

OUTLOOK

Economic production of chemicals and the resulting commercial goods no longer can be achieved with standard solutions. Mixing technology addresses this challenge with individually adapted mixing systems. The impellers are planned according to the mixing task, and all functional components within the vessel are coordinated to fit respectively. The design of such complex systems still is impacted by the theoretical fundamentals of flow and process technology and by the equipment manufacturer's empirical knowledge as well as laboratory and pilot tests.

The latter continuously is being expanded by using modern tools such as flow simulation (CFD) and stress calculations (FEM). With increasing computational power that allows numerical full span models of reactors while including the hydrodynamic, kinetic and thermodynamic conditions, it will be possible to deliver valuable information and contribute to the operational efficiency in production processes. ■

EKATO develops, designs and manufactures industrial agitators, mixers, dryers, mechanical seals and turnkey mixing systems for chemical, cosmetic, pharmaceutical, and other industries. For more information, visit www.ekato.com.



Aim for Blend Uniformity

Ingredient characteristics, blend hold times and mixing equipment all affect final quality

By Matt Tousey, Techceuticals, LLC, and Matt Hicks, Federal Equipment Company

The "perfect blend" for mixed powders is best defined as a blend with 100% uniformity, but that is impossible. It can be relatively easy to achieve the close-to-perfect blend in a one-time mixing and blending process; however, ensuring as close to 100% uniformity as possible batch after batch is one of the most difficult issues those in bulk-solids processing operations face.

Although demonstrating a near-perfect blend across batches is a huge undertaking, it is key to showing an effective, repeatable bulk-solids manufacturing process. Many factors influence how powders mix. Ingredient characteristics, blend hold times and the equipment used for mixing and blending all affect blend uniformity.[1]

INGREDIENT CHARACTERISTICS

One of the reasons it can be so difficult to achieve blend uniformity has to do with the variations in raw ingredients. No two powders ever are alike, even when made by the same manufacturer using the same processing equipment. Factoring in these slight differences, the ingredients' general characteristics can help determine the best processes and equipment for the product's flow capabilities, as well as the batch hold times for any given powder blend. A common characteristic to factor in is a product's density — specifically, the bulk density and tapped density.

A product's bulk density is determined by powder density and the space between particles (i.e., air) in the powder bed. How a product is prepared, handled and stored influences its bulk density or bulking properties.

Tapped density is the increased bulk density noticed after mechanically tapping a container holding the powder sample. The difference between the bulk and tapped densities reveals clues as to how the powder will flow. This is beneficial because the better a product flows, the easier it is to achieve uniformity and compressibility later in the manufacturing operations. The closer the two measurements are, the more free-flowing the product will be.

On the other hand, the further apart the measurements, the more likely the product will have poor flow characteristics.[2] In addition to these factors, tapped density can be used to predict how long a mix will stay uniform.

BLEND HOLD TIMES

The blend hold time is how long a mix of powder will stay together after being blended. Almost all bulk-solid powders have a window of time before they start to "unblend" by segregating and compacting inside the bulk container. Powders with high tapped density, or fluffy products, will have shorter blend hold times. As the powder mass sits, it begins to deaerate.

During deaeration, air escapes upward, taking small, lighter particles along the way, while the dense particles compact and move down. This results in the product becoming segregated. Lower tapped density products tend to settle less in this manner and have longer blend hold times. Establishing blend hold times for each product will help identify peak performance for compression operations.[1]

EQUIPMENT USED FOR MIXING AND BLENDING

To obtain a uniform blend, the mixing and blending equipment must match the ingredients: A blender used in one process many not provide the results needed for a different process. In each case, the product's characteristics drive the selection of blender, as well as the proper sizing for the equipment to make the desired batch.

For instance, low-shear mixers randomly mix powders that are free-flowing. Common low-shear mixers that are used to mix powders include the twin-shell blender or v-blender (based upon the "v" shape), the double-cone blender and bin blenders or "tumblers" that actually mix the product inside the bulk container. Twin-shell blenders can be used for products that are not free-flowing if they have an intensifier bar that forces the products to move. However, be mindful that overusing an intensifier bar can cause dry and friable particles to break down. Additionally, a liquids bar can be used to introduce a liquid ingredient to the mix.

Ribbon and paddle blenders are low- to medium-shear mixing equipment often used to mix powders slowly and gently. These types of blenders are not always effective equipment for mixing small quantities into large quantities or for mixing lubricants into the blend needed for later compression activities. Random-flow blenders also tend to mix faster than the gentle and slow action of ribbon and paddle blenders. This equipment is best-suited for powder ingredients with close density and morphology.

For ingredients with unequal density and morphology that are hard to mix and not brittle or fragile, a high-shear mixer is recommended. High-shear mixing, as the name suggests, is an intense process used to treat ingredients in different forms that would not ordinarily mix, including solids, liquids and even gases. The high-shear mechanical force often is used to increase a blend's bulk density, which increases flow, blend hold time and compressibility.

After selecting the type of mixing equipment (again, based on ingredients), you have to size properly for your process. To fit the blender, determine a product's weight and density. Most people usually know the product's weight, but not the density. A simple way to calculate product density is to get the weight of a quart or liter of product. For example, 16 quarts or 15 liters is equal to one cubic foot (cf) at a density of 35 pounds per cubic foot (lb/cf).

CONCLUSION

Obtaining the perfect blend for your powder formulation is a combination of many factors, including ingredient characteristics, equipment used in the process, handling and time (among other factors). Most blended powders compact and deaerate over time, leading to segregation and unblending. Understanding the product's hold time before it begins to unblend will help consistently achieve the peak performance in your process. Additionally, the equipment used for mixing and blending should be sized for volume and appropriate for your product's characteristics to reliably produce powders with enough density for good flow and compressibility. ■

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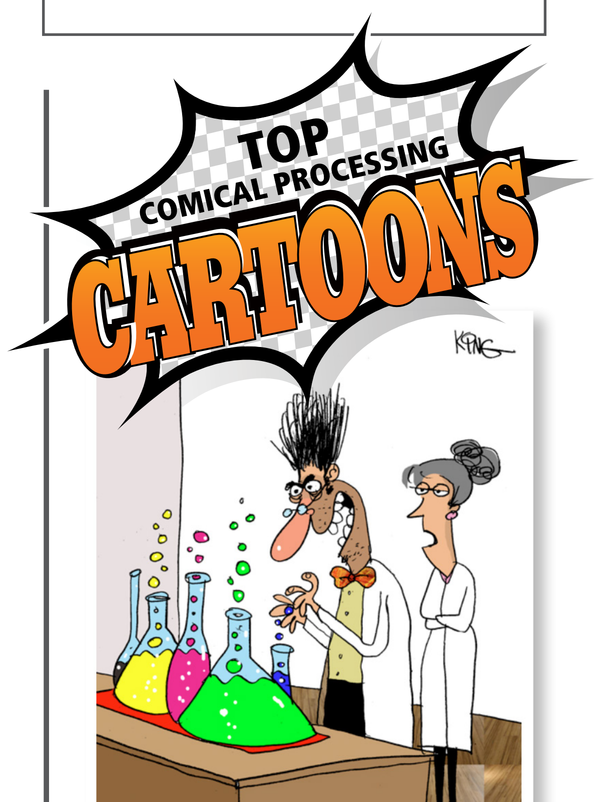

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