

# Art turns to science

**W**hether in the lab, office or on the shop floor, whenever engineers turn the conversation to mixing, the three word prefix "the art of" magically appears. And not surprisingly, for while mixing is probably the most fundamental operation performed in the processing industry, it is also one of the most complex.

This combination of ubiquity and impenetrability has seen much lore grow up around the subject and, to all but the keenest aficionados of fluid dynamics, it is indeed a "black art".

One reason for its universality and complexity is that it embraces substances in all physical states and in all combinations of them. There are also a number of objectives.

For example, do you want to blend, disperse, emulsify, suspend solids or assist mass and heat transfer? Then there is the large number of variables, such as vessel size and shape and impeller type, size and speed, which can affect the results of the process.

Fortunately, the past decade has seen much development work on the computation of flow patterns in mixing vessels. As a corollary of this, mixer manufacturers have increasingly taken to computer aided design and manufacture (CAD/CAM) and introduced the principles of fluid dynamics into the design stage, so reducing substantially the risk associated with building working models.

## Computer modelling also used

This has taken much, if not all, of the "art" out of the process and replaced it with science, since computer modelling can also be used in matching the right mixer to a given process. Manufacturers can now be much more sure of their ground when discussing needs with the end user.

Another factor driving developments in mixing technology is the growth in demand for bespoke solutions from end-users. Increasingly sophisticated products often have unique requirements which mixer manufacturers are prepared to provide, albeit at a cost.

According to a survey *The Process Mixing Equipment Markets* published by Frost & Sullivan\*, these technology developments will help push the value of the European mixing

*The most common task in processing can also be the one in which it is most difficult to achieve the desired results. But help is at hand, writes Andrew Smith.*

equipment market up 17 per cent to £290 million by 2005 from its 1998 level of £241million.

The report says the market will be increasingly influenced by the growing expectation from end-users for sophisticated process mixing equipment, both portable and fixed, "as customers become aware of the possible benefits that can be gained from using advanced technology for their specific requirements."

## Consolidation in the industry

The report also warns, however, that while quality remains a critical element in customer choice, price competition and the need to maintain sizeable R&D departments is likely to hasten consolidation in the industry.

So, end users may ultimately be left with less choice on the market, but they should have the reassurance that suppliers exist, able to provide customised services, from unique lines to bespoke impellers, which may in the long-term improve productivity and product quality. Continuing research into mixing technology is also likely to promote product development by allowing the creation of new, previously unworkable, formulations.

Given the array of different mixing systems available – agitators, saw tooth blade, closed rotor, rotor-stator – and the number of variables that can affect the process, how does one ensure the best solution for the job in hand? Assuming there is no professor of fluid dynamics readily available, or that the job is merely a repeat of an already successful application, the first stop must be with the suppliers.

There are a number of established players which, as mentioned above, fund R&D departments and, given that an order could be in the

offing, will offer access to them for tricky applications. Loan machines may also be available to test applications before making a commitment.

The first consideration is configuration: do you need a batch or in-line mixer? Batch mixing is most common in the higher added value process industries where limited volumes are being produced, whereas in high volume chemical applications, for example, an in-line solution may be more appropriate. An in-line answer may also be recommended if improvements to an existing process are being sought.

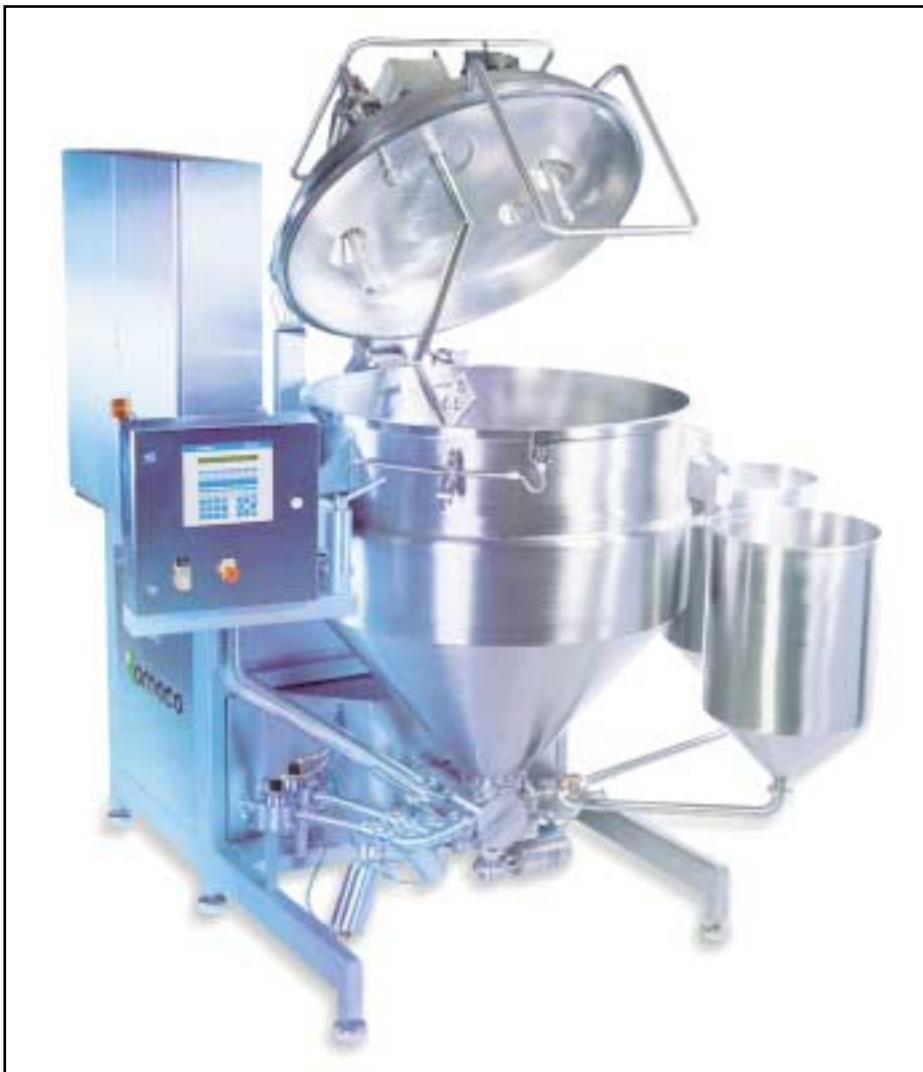
The next major question is what type of mixing action is required? In general, for liquids of similar viscosities, low shear operations are the most appropriate, while for liquids of differing viscosities, high shear mixing may be necessary. Similarly, when particles are in suspension, it is likely that shear will provide a more uniform, stable product.

In the food, pharmaceutical and cosmetics industries, a common task is the creation of emulsions and for these a degree of shear is desirable in order to promote stability. However, formulating a stable emulsion from a number of liquids which may well be immiscible and of different densities, while maintaining the required viscosity, is a daunting task. If solids are involved, will they dissolve fully and are any of the components heat sensitive? There is also a possibility that the shear force generated could damage the component parts or the resulting emulsion.

According to Silverson Machines, conventional agitators can give satisfactory results across a broad range of viscosities in many applications, but their effectiveness tends to be limited to simple duties such as blending liquids of similar viscosities, maintaining in-tank uniformity and promoting heat transfer.

## High shear rotor-stator

For more demanding duties, says Silverson, an agitator is, at best, only effective as a "process aid", supplementing the work of equipment with a more positive action. So for activities such as forming an emulsion or suspension, dispersion and hydration of powders – such as thickeners or stabilisers – and blending liquids with widely differing viscosities, another



**Single vessel:** FrymaKoruma DisHo can disperse and homogenise in one multi-chamber vessel



**High shear:** Silverson high shear batch mixer on mobile hydraulic floor stand

approach must be considered.

The company suggests that in the food, pharmaceutical and cosmetics industries, the chances are that a high shear rotor-stator mixer is the most efficient option for the more demanding applications. It argues that the advantages of the rotor-stator over conventional agitators stem from the multi-stage mixing/shearing action. As materials are drawn into the workhead by the high speed rotation of the rotor blades, they are subjected to intense hydraulic and mechanical shear, then forced out through the stator at high speed and projected radially back into the mix.

#### Shorter mixing times

"This positive mixing action results in dramatically shorter mixing times: in some applications a 90 per cent reduction is achievable," says the company. Other benefits include improved product quality and consistency and more easily reproducible results.

The rotor-stator principle is also very versatile. A single machine can mix, homogenise, "solubilise", suspend, deagglomerate, disperse and disintegrate solids. This is achieved by the

use of interchangeable workheads or stator screens which impart different flow patterns and shear rates.

A workhead with round holes gives an exceptionally vigorous mixing action, ideal for general purpose use and particularly suitable for disintegration of solids and the preparation of gels, suspensions and solutions. Slotted holes produce a more scissor-like shearing action, suitable for disintegration of fibrous or elastic materials. Square hole screens are used in applications where particle size reduction is required and for preparation of emulsions and fine colloidal suspensions.

#### Volumes up to 2000 litres

As for the batch versus in-line, Silverson says batch mixers are generally suited to volumes up to 2000 litres, depending on viscosity. Mounting them either on top of a vessel or on a mobile floor stand allows the mixer to be repositioned during operation to give the optimum mixing pattern.

For example, it can be positioned so as to create a vortex for rapid incorporation of powder into a liquid. Once this is achieved, the unit can be lowered to decrease surface movement, reducing aeration to a minimum.

Where improvements to an existing process are sought, the company says an in-line high shear mixer "can be added with a minimum of disruption and expense."

Based on the same principle as the rotor-stator immersion mixer, the workhead is mounted inside a chamber in a pipeline. This can be configured for re-circulation around the vessel if working on a single-pass basis, or for flowing the product backwards and forwards between two vessels. As the vessels, pipework and mixer form a closed system, aeration is eliminated and bypassing is impossible: the entire contents of the vessel must pass through the mixer.

The company says there are also several other advantages. As the machine's effort is concentrated on the small volume of material inside the workhead at any given moment, power is not wasted moving large volumes of liquid. Consequently, a relatively small unit can process volumes which would require a much larger immersion mixer.

A further advantage claimed is that in-line mixing can offer greater process hygiene by eliminating the problems associated with an immersed shaft and potentially difficult-to-clean paddles and scrapers.

Turning to specific problems, the company

has addressed its attention to one of the most difficult mixing applications: incorporating powders into liquids. Additives such as gums and thickeners are by nature liable to form agglomerates which must be broken down to achieve a smooth end product and maximise yield and the thickening or stabilising effect. Light powders can float or "raft" and may form a "scum line" around the top of the vessel, while partially hydrated materials could stick to the agitator and vessel walls.

### Adding powder to liquid

One means of overcoming these problems is to add the powder to a stream of liquid, as with the venturi principle, which can reduce the formation of agglomerates, but this still does not produce a completely "lump-free" dispersion. Following research, Silverson combined the venturi principle with high shear rotor-stator mixing technology to produce the Flashblend powder/liquid mixing system.

Powder is fed into a purpose-designed hopper which is separated from the venturi assembly by a valve. The base fluid is forced through the venturi at great velocity by a centrifugal pump. Once the valve is opened, the powder is drawn by vacuum into the high speed fluid stream and both liquid and powder pass immediately into a modified high shear in-line mixer.

Silverson says this results in the powder being completely wetted before agglomeration can occur and low density powders are easily incorporated, while "powder handling is reduced to a minimum and operator error is virtually eliminated."

To complement production units which can incorporate powders at a rate of up to 15,000kg an hour, Silverson has recently introduced the FLB20 which enables users to reproduce the results of production scale units in the laboratory or pilot plant.

Another major player which utilises the rotor-stator principle in its line-up is Romaco's FrymaKoruma, formed earlier this year by the merger of Switzerland's Fryma with German manufacturer Koruma. The two product ranges have now been consolidated into a single line-up which, claims Romaco, "addresses every mixing requirement in the food, healthcare and chemicals sectors."

The new FrymaKoruma is already benefiting from investment in ProTec, its process technology centre in Neuenburg, Germany, which is equipped with the complete range of equipment and will shortly boast an explosion-proof



**Faster processing:** A toothed colloid mill and a guide cone are combined in FrymaKoruma's Frymix

laboratory for research and trials into solvent-based formulations.

The most recent addition to the division's portfolio is a laboratory version of the DisHo range of mixers, the DisHoLab. Based, like the production versions, on the rotor-stator principle, it allows feeding, dispersing, homogenising, de-aerating, heating and cooling of trial batch sizes from three to 12 litres. The unit features identical geometry to its larger counterparts, for simplified scale-up, and is said to be easy to clean with no blind spots.

### Single multi-chamber vessel

The DisHo name derives from the unit's capability to disperse and homogenise in one multi-chamber vessel. Romaco says this system allows the production of homogenous, highly stable product in short batch times, "increasing output by as much as 70 per cent over traditional methods." The company also claims improved product consistency and more easily reproducible results. Most significantly, it says, the feed principle reduces or, depending on the formulation, eliminates the premixing of dry ingredients.

The technique involves placing the vessel under vacuum and drawing powder in through the homogeniser, thus avoiding the entrainment of air bubbles and ensuring complete homogenisation of agglomerates. The solution is then pumped into the upper part of the ves-

sel through a re-circulation line where an agitator mixes it horizontally and vertically.

In many applications, pre-milling of ingredients can also be eliminated due to the high shear rate of the rotor-stator which is said to be able to process even the toughest formulation into particles of 1 micron. Problems of contamination may also be avoided as the vessel can be loaded under vacuum and discharged via the homogeniser direct to storage containers or filling lines. The "one-pot" approach also minimises space utilisation.

The DisHo is said to be particularly suited to applications where high sterility needs to be maintained, thanks to a range of CIP/SIP options. In its standard executions, the DisHo is available for batch sizes in the range of 20 to 1000 litres: bespoke units are also available, with the largest supplied to date having a vessel size of 5500 litres.

### Toothed colloid mill

Also available from FrymaKoruma is the Frymix, another one-bowl system, suited for many of the same applications but based on an entirely different processing technique. This is a patented combination of a toothed colloid mill with stepless speed adjustment and a guide cone: the so-called Master Module.

Key aspects of the process are said to be the forcing of all product through the colloid mill and the formation of a thin film of product on

the inside walls of the guide cone, which can be de-aerated very quickly. Romaco claims that the positioning of the guide cone at the centre of the vessel eliminates a zone where product would normally move relatively slowly, with a resulting negative impact on batch times. By utilising this space for the guide cone, batch times are shortened and the energy efficiency of the process maximised.

A range of mobile, variable speed mixers that can be inclined at each mix to provide the optimum angle for blending a variety of powders is built by Swiss manufacturer Prodim, represented in the UK by Sussex & Berkshire Machinery.

Equipped with a central screw within a vessel mounted on pivots for inclined operation, the Prodim batch mixers are available in capacities of 20 to 2500 litres. Within this there is also broad batch size flexibility as they are said to operate with equal efficiency on fills between 10 and 90 per cent of vessel capacity.

"The screw carries product to the top of the mixer where it accumulates against the upper wall and returns under gravity, giving a gentle counter-flow for blending even delicate materials without risk of attrition", says Sussex & Berkshire.

### Eliminate dead zones

An inspection window allows the process to be monitored and the angle of operation adjusted via the computer-based controls to eliminate dead zones for homogenous mixing within 3-5 minutes, depending on the product. For particularly lumpy materials, the machine can be set to provide a rocking motion and cutting blades can be added if required.

To cater for applications in which liquid, typically heated to 70-75deg C, is added to the dry mix, Prodim has developed a system of injection through the axis of the cutter assembly which eliminates crystallisation. Other optional equipment includes a system for adjusting the height of the mixer, lowering it for drum loading within a limited headroom and raising it for discharge at a higher level.

Strip down and cleaning of the entire machine is said to be possible in less than 20 minutes, with the mixing screw removed from its mountings simply by the removal of two bolts and an air bearing. Alternatively, a CIP system is available.

Customised solutions are available from manufacturer of CIP systems and hygiene process equipment, Suncombe. The company offers a

range of vessels for the food, pharmaceutical and healthcare industries, from 200 to 2000 litres and above, each manufactured to customers' individual requirements. A choice of agitators and contra-rotating mixing systems and bottom-mounted or recirculating homogenisers are available.

Other options include spray devices for internal cleaning, vacuum transfer of materials, heating and cooling jackets – with or without temperature control capability – and computer-controlled recipe management packages.

Ready integration with Suncombe's CIP equipment is also claimed and all equipment is manufactured in accordance with cGMP, whatever the particular application.

Full validation packages are available for pharmaceutical applications if desired.

After the chemicals sector, the food and beverage industry is the next largest "consumer" of mixing technology. A specialist supplier in this field is Record Pelman which now offers a continuous mixer system manufactured by the French company, Simon. The Contimix system is based on a contra-rotating double screw principle and is designed primarily for use with pasty products, although Pelman says it is equally effective with a variety of other mixes. The range offers production rates extending from 200kg to 3000kg an hour.

### Modular design for flexibility

The Contimix is said to be exceptionally flexible because it is manufactured around a modular design "that can be adapted to suit any food manufacturer's requirements." For example, the length of the system can be altered and Simon offers a choice of mixing screw diameters from 63 to 340mm.

Thus, a single two metre long module with a 170mm screw diameter would serve a line requiring 1.5 tonnes of biscuit dough an hour. Blender sets using winglets and bearing plates customise the mixer heads for specific recipes.

The Contimix design is also said to offer complete control of the mixing system. For example, the machine's stainless steel body is jacketed, allowing the mix to be heated or cooled, while optional extras include vacuum transfer and steam injection. All the mixers also have a CIP facility.



**Inclined for productivity:** Prodim mixer for powders

The Parma planetary mixer range from Food Processing Systems of Italy is also available through Pelman and the latest models are said to break with tradition by offering variable speed ratios between the mixing tools and the bowl scraper as an option.

The company points out that traditionally the mixing tool/scraper speed has been fixed. However, by offering a variable ratio, it says more control can be exercised over the mixing process so that, for example, a heavy mix can be set to have a slowly moving mixing tool, but a faster moving scraper to ensure a more homogenous end product.

Another food processing specialist, Weiler

Beehive Europe, claims it has cracked the problem of maintaining product integrity when mixing pre-ground meat products. The company says high paddle speeds can damage meat tissues causing meat smearing, whereas the low paddle speed of its mixers minimises product structure damage, ensuring a consistent, homogenous blend in the shortest blend time.

Conventional mixers run typically at 20-45rpm, while Weiler's run at 13rpm and are claimed "usually to require half the motor power of conventional mixers."

#### Aimed at dairy market

Dosys of France has developed a specialist dosing and mixing system aimed primarily at the dairy market for the manufacture of fruited yoghurts. The company explains that traditional processes use metering pumps for the base yoghurt and the fruit, feeding a balance tank on the packaging machine.

The disadvantage of this system, it says, is the losses which can be incurred during product changeovers, particularly on multi-flavoured applications.

The Dosys process, which is available in the UK through Jagenberg (London), uses the filling unit on the packaging machine as one of the metering functions. By injecting fruit and mixing in-line, the company says a "low inertia" system is achieved with no balance tanks and reduced product handling.

The Dosys pump is said to ensure high levels of accuracy and repeatability and the equipment can be cleaned without the need for dismantling. Static and dynamic mixers are available and options such as automatic recipe selection can be specified. ■

*\*European Process Mixing Equipment Markets. Report 3681-21. \$4150. Frost & Sullivan, (tel: 020 7730 3438).*

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**Liquid mixing:** *Welcome uses a range of vessels from 250 to 500 litres, with a variety of mixers for versatility*

## Custom service in food processing

Nottinghamshire-based Welcome Foods has established a successful business based on providing a highly customised service to the processed food and food services sector in the UK. Central to this success are two factories equipped with mixing and processing equipment supplied by Winkworth Machinery.

The directors of Welcome, Mel Hayes and Steven Nicholas, believing that many food ingredients companies had become large and inflexible, set out to establish a company geared solely to meeting customers' needs in terms of recipe development, pack sizes, order quantities development programmes and short lead times.

Mel Hayes says: "We offer customers the opportunity and flexibility to order in quantities that suit them rather than being faced with unrealistic minimum order levels and delivery times. To achieve this efficiently we need a highly versatile manufacturing facility which can handle dry and liquid products in small and large quantities."

One of the factories produces dry products and the other the liquid range. Winkworth recommended utilising a larger number of smaller machines rather than fewer large machines. This enables a wider number of different products to be manufactured at one time, while if large volumes of one product are required the

machines can be doubled-up to meet demand.

For dry products, Winkworth recommended its U-trough stainless steel mixers – two 1000 litre machines and a 240 litre machine – for mixing seasonings, bouillons and flavoured glazes. The U-trough range has capacities from 10 to 11,500 litres, can be supplied with a range of agitators and, depending on application, can be manufactured from mild steel through to hygienic stainless steel Cleanline units.

#### Variety of liquid mixers

For liquid production, a range of vessels with capacities from 250 to 500 litres was recommended. Capable of processing 250-500kg of product, they can be heated and are ideal for sauces, marinades and dips. The vessels have a variety of mixers, including low speed, scraped side anchor types with high-speed homogenisers which are said to provide great versatility in terms of the type of finished product that can be manufactured.

Using low or high speeds, or a combination of both, smooth homogenous products or liquid products with various particle sizes and textures can be produced. Manufactured from 316 stainless steel, the vessels are available in capacities from 65 to 3000 litres, although larger sizes can be custom-built.

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