By Quentin Hartley

The mixing process can be separated into two components, distribution and dispersion.

Distribution is the action of mixing fillers evenly throughout the rubber matrix so no area of the matrix is either rich or poor of filler. Essentially, this is achieved by moving materials around the mixing chamber.

Dispersion is the breaking down of the filler particles (often large agglomerations of particles stuck together by weak bonding) into their lowest possible particulate state—achieving a state of homogeneity throughout the rubber matrix. This is achieved by tearing, squeezing and rolling materials within the chamber, subjecting them to stress, strain and shear.

It is possible (and often the case) to have well distributed material with poor dispersion, or poorly distributed material with areas of high dispersion, and it is important to recognize the significance of achieving both for a good mix.

These two actions are performed in different ways with the different mixing technologies.

The tangential mixer achieves its dispersive function in much the same way as the rolling bank in a two-roll mill. The mixture is rolled in front of the rotor wing tip between the tip and the chamber wall, being squeezed and deformed, as it passes over the tip. Distribution is achieved again by the rotor wings (or “nogs”) pushing material down the length of the chamber, and by the physical pushing of materials from one rotor to the other.

Although the same functions are performed, the relative amounts of each are governed not only by the rotor-to-side wall interaction, but also by the rotor-to-rotor interaction. Because the method of execution is different, each type of mixer has comparative advantages over the other (depending on application).

In tangential mixers distribution occurs between the rotors and side wall, and dispersion is also between the rotors and between the rotors and side wall, and this gives improved dispersion because of the more intense dispersive action between the rotors.

There is a better temperature control on these mixers because of the higher surface area to volume ratio in the mixing chamber. More metal to compound contact offers a greater area through which to extract heat—assuming the metal surfaces can be adequately cooled. Because of these there is a greater energy input per unit weight of compound than in the tangential machine.

Because of these differences it has to be concluded that there is no such thing as the best mixer, but there is such a thing as the best mixer for a particular compound, or series of compounds. Each style of mixer has its own particular niche in the market place, and each mixer has been designed to fill that particular niche. It is important to recognize this fact, and to choose the type of mixer that fits the needs of your business.

HF Mixing Group offers the widest range of mixer types and rotor geometries of any mixer manufacturer: the N series tangential mixers, the E series intermeshing mixers, and also the vari-

Optimizing mix quality and productivity

In 1916 Fernley H. Banbury patented the first “Banbury” tangential mixer. Based on the principles of the two-roll rubber mill it was intended to remove the influence of the operator and significantly reduce the time taken to mix a batch of rubber. Some 16 years later the first intermix intermeshing mixer was patented, employing the same basic principles as the “Banbury.” So, what’s the difference?

● Both types of mixer perform the same fundamental task of mixing rubber compounds.

● Both employ the same basic principles to achieve this aim; and

● Both styles of mixer are market leaders in the increasingly complex business of mixing increasingly complex rubber formulations.

It is the differences between the mixer types that provide specific advantages to specific markets, and it is important to understand these differences to choose the right style of mixer for the right application, which is detailed in this paper.

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Many rubber, plastic and silicone based products can be dramatically improved with fibers. Adding treated or untreated cotton, polyester, pan carbon, aramids and/or nylon boosts performance in a multitude of ways. Characteristics such as coefficient of friction, vibration resistance, compression set, tensile modulus, temperature control, green strength, cut and tear resistance, noise reduction and many others can be positively altered.

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There is an obvious advantage here in terms of energy savings (the batch only needs to be heated up once), and also a vastly simplified process with reduced material handling and improved productivity.

Drive technology has advanced significantly over the past years (and continues to improve). The example given here shows how the use of an AC Variable Frequency Drive (1,400 kw) can offer an annual savings over a DC drive system of about $96,000 for a 270-liter mixer (Fig. 4). Added to these savings is the further advantage of an AC drive needing no maintenance.

Experience has shown us that moving from a fixed drive to a variable drive has realized a throughput increase of some 20 percent before energy savings through use of a modern system have been determined.

While we recognize that new drives systems are not always an option, a review of your current systems will always be worthwhile.

Ram pressure

Over the last 30 years there has been a move away from pneumatically operated ram assemblies to hydraulic systems. The economic argument for the move has been based around the efficiency of the hydraulic system over the pneumatic systems, where substantial savings can be realized. On a 270-liter mixer this can be as much as $256,000 (Fig. 5).

Added to these savings are additional processing improvements where ram movement can be adjusted to suit the particular part of the mixing cycle, with rapid ram movement when needed and a slower movement when bulk fillers are used.

Despite a slower movement, reduced cycle times can be realized by reducing cleaning times where fillers had previously been blown onto the ram top. IRAM (intelligent ram control) allows the speed and position of the ram to be controlled dependant on operator settings for individual recipes and steps within the recipe.

Temperature control units

It has long been considered that because the mixing action produces a temperature rise in the compound that full cooling is required to extract the maximum amount of this energy into the cooling water.

This simplistic approach is, however, often detrimental to mix quality and adds greatly to the energy consumption in the process.

Returning to first principles, it is important to appreciate their relevance.

Friction ratio vs. synchronous technology

The intermeshing mixers obviously do not run at a friction ratio. Although they are in speed, a friction ratio does exist between the rotor surfaces by nature of the differing diameters at any point in the “juncture” between the rotors. Tangential mixers traditionally had a friction ratio across the rotors mimicking that of the two-roll mill they were designed to replace.

It was recognized, however, that this friction ratio did not always give the optimum results, and a mixer’s performance could be enhanced by keeping the rotors fixed at a certain orientation to each other.

With the NST rotor this orientation was found to be best at 0° to 90° orientation. At this orientation the area between the rotors remains consistent, resulting in good material intake and a good current stability. Compared to other orientations and to a friction ratio the effect of the mixer “gulping” periodically is greatly reduced. These results have been seen across the range of tangential rotors.

The use of synchronous technology has led to a series of developments within the mixer system to assist in the transfer of material from one rotor to the other—issues that were not apparent with friction ratios.

In intermeshing mixers, the contour of the drop gate follows the radius of the mixing chamber wall, but this has been altered in the tangential mixer to assist in material flow from one rotor to the other.

Similar modifications have been shown to be effective around the ram bottom profile, resulting in the “keel bottom” design.

Synchronous technology has provided savings of up to 5 percent in energy. These modifications have resulted not only in an increase in chamber volume—allowing for larger batch weights—but also in improved flow around the chamber with the associated reduction in cycle times – 5 percent (to be confirmed).

Throughout increases in the order of 5-13 percent have been reported using the new design of weight.

Variable speed mixing

Old technology typically offered two mixing speeds, high and low.

High speed gave the associated high shear rate and low speed the associated lower shear rate. The rest was determined by rotor geometry. Now that we understand the dynamics within the mixing chamber we can see why variable mixer speed offers such a considerable advantage over this two-speed model.

Variable speed allows for the required amount of mixing to be done while controlling the temperature rise within the compound, and this has resulted in a wide range of compounds now being mixed in a single stage where once a two-stage process was required.
Mixed components are parametrical in energy-efficient mixing. To this end, use of temperature control units, or TCUs, is important for maintaining the required temperature setting. In practical tests, this has been shown to reduce the energy consumption of the TCU by up to 50 percent.

Looking at the energy balance within a rubber mixing cycle when thermal equilibrium has been achieved, we can see some impressively large figures—up to 38 percent of the energy input into a batch is removed in the cooling water, up to 51 percent of the energy input before a batch goes into increasing the compound temperature.

The mixing cycle is triggered on temperature, and so the times are “averages” rather than precise. It would, of course, be naive to think that this cycle could be reduced to the 80 seconds that the mixer is actually pulling power. It doesn’t have to run at 100 percent capacity, but it should be implemented.

With the use of modern mixer control methodology it should be possible to reduce sections of the cycle, or at worst highlight those aspects outside the mixer control that need attention. The “mixing” part of the cycle isn’t attributable to “mixing.” More than one third of the cycle is attributable to feeding materials, and the variations in cycle times make up ≤10 percent of the cycle time.

HF Mixing Group recognizes the importance of this type of control and monitoring system throughout the mill room, and our Advise system is able to offer all aspects of this control methodology. Coupled with our upstream and downstream equipment knowledge (from rubber bale cutters, strip-feeders, oil injection systems etc. to convex twin-screw extruders, mills and batch-off systems) we are capable of creating a “unified” mill room, utilizing the “best” aspect across all aspects of mixing.

The mixer is the single most important part of the mill room because the mixer is the piece of equipment that produces the quality materials that your production relies on. Without it you have no product.

But what does this really mean? All the material handling equipment upstream should be designed around supplying the mixer in a timely fashion such that the mixer is not “waiting” for raw materials to be weighed or prepared. If it is, then it isn’t running to its full capacity.

All the materials need to get into the mixer as quickly as possible, or the mixer isn’t running at its full capacity. Looking at power traces very quickly highlights where the mixer isn’t doing the job you bought it for.

All the materials need to be removed from the mixer as quickly as possible once they are mixed so that the next cycle can start. All the downstream equipment needs to be able to keep up with the mixing cycle so the mixer isn’t delayed.

Pretty simple really, but it needs to be looked at more closely (Fig. 6). In this example we have an “average” cycle time of 155 seconds. This is divided up into sections as follows: 80 seconds for initial feed, 30 seconds mixing, 30 seconds loading, 25 seconds mixing, a 10 second sweep, 25 seconds mixing and around 10 seconds to discharge.

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With the use of modern mixer control methodology it should be possible to reduce sections of the cycle, or at worst highlight those aspects outside the mixer control that need attention. The control systems within the mixing room need to be able to monitor the complete process from material supply to the end of the batch-off if comprehensive cycle time reductions are to successfully be implemented.