Many roads lead to Rome for optimal mixing process

The objectives of industrial mixing processes are mostly the same. What is wanted is a homogeneous mixture in as short a time as possible, with as little product damage as possible and at minimal energy consumption. Depending on the process requirements and the components to be mixed, a well-considered choice is made from a range of mixing principles and mixer types.

MAP, the mixer division of the WAM GROUP, started manufacturing their own mixers in 1983. The machines were a success on the market and the numbers of mixers manufactured grew from a few dozen to several hundred a year today. They include plough share mixers, ribbon mixers and also paddle mixers. MAP has not only optimised and standardised these machines, but has also added specific mixers to their range, such as the DUSTFIX, WETMIX, WETDUST, MESC and the MLH laboratory mixer. In this way, MAP offers a complete range of solutions for the mixing, granulation and conditioning of powders, granules and slurries. The machines are used in practically all industrial sectors. It goes without saying that over the years MAP has gained much experience in mixing technology.

Fig. 1 A single-shaft plough share mixer

Definition

For proper insight into all aspects of mixing technology, it is necessary to define a number of concepts clearly. Mixing is the systematic combination and agitation of two or more components in order to create as homogeneous a mixture as possible. There may be great differences between the nature, amount and state of the various components to be mixed. There may be materials of different particle size, shape or specific weight, and it is also possible that liquids need to be distributed through the mixture. As well as 'mixing', there is a category of processes we call 'conditioning'. This means moistening a mixture, for example to make it dust-free, or to make a formulated product containing a certain amount of liquid. A third category related to mixing is 'granulation', in which the idea is to convert fine powders into more manageable and less dust shedding granules or into a more easily dispensed product with the help of a liquid.

Objectives

In general, the objectives in mixing materials are the same in each industrial sector, whether it is a batch or a continuous process. What is wanted always is to realise a homogeneous mixture in as short a time as possible, with as little product damage as possible and at minimal energy consumption. Depending on the process requirements and the nature of the components to be mixed, to produce an optimal mixture, a choice needs to be made from a range of mixing principles and mixer types. To start with, a distinction may be made between static and dynamic mixers.

Static or dynamic

A static mixer is a stationary mixing machine without moving parts. There are fixed mixing elements inside the mixer. The materials to be mixed (often including liquids) flow through the mixer and are agitated by these elements. This causes a mixing action to arise, but the homogeneity of the mixtures realised is often not great. Dynamic mixers in contrast displace the separate particles in different, random directions, at different speeds and over varying distances by mechanical means. In this way intensive and thorough mixing is achieved. This mixing principle provides very homogeneous products.

Convection and diffusion

In the case where fine powders are mixed, two mixing mechanisms may be distinguished: convection and diffusion. In convection, larger clusters of particles are displaced quickly and coarse mixing takes place. In diffusion, the particles move individually, which takes more time and for which more energy is needed. Ideally, diffusion and convection happen simultaneously in a mixing process.

Neutral mixtures

Mixtures in the bulk processing industry are almost always of a 'neutral' nature.

MAP SINGLE-SHAFT PLOUGH SHARE MIXER

During the mixing process, the MAP single-shaft plough share mixer realises a fluidised bed in the product thanks to the special shape, position and rotation speed of the plough shares. In this fluidised condition, the products particles can move individually and freely, so that intensive mixing takes place. Particles of different sizes, bulk densities and shapes are also homogenised maximally in this way. This applies as well to micro-components that are present in extremely small amounts. The MAP mixer is capable of handling a mix ratio of 1:100,000, which means that 1 gram of a component can be homogenised into a batch of 100 kilograms.

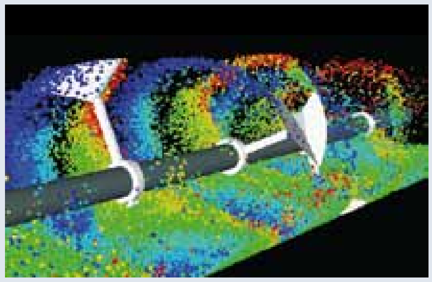

Fig. 2 A simulation of the mixing action in a plough share mixer

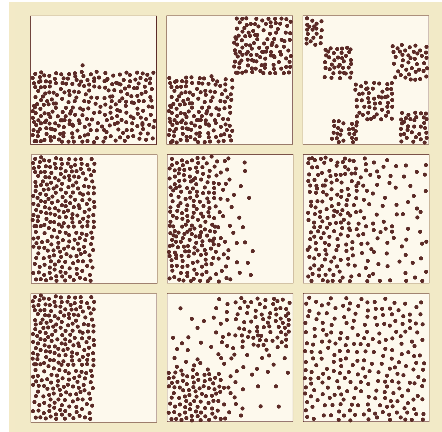

Fig. 3 Schematic representation of a convective (upper series) and a diffuse (middle series) mixing mechanism. Ideally, both mixing mechanisms happen (bottom series)

This means that if the mixture is at rest, it remains intact and no spontaneous segregation will occur. However, 'negative' and 'positive' mixtures also exist. In a negative mixture, even when it is at rest, spontaneous demixing occurs as a result of gravity or Brownian motion. A positive mixture in contrast homogenises inherently to a certain extent, so that the risk of segregation is absent.

Rotating shaft or drum

Dynamic mixers may be subdivided into mixers with either a rotating drum or a rotating shaft. The first group comprises mixers the drum of which features scoops or blades. When the drum turns, the material to be mixed is scooped up by the blades and gradually dropped down again under the influence of gravity. In mixers with a stationary drum, a rotating shaft with mixer elements causes the mixing action. This type of mixer is widely applicable. It is used for mixing powders and granulates with sometimes very diverse characteristics, and also for distributing liquids (such as water, oils, and fats) through mixtures. The quality of the mixtures may be established by analysing representative product samples.

Homogeneity

An important characteristic of a mixture is its homogeneity. In a mixture of two equal quantities of components, ideal homogeneity means that every particle of one component is surrounded by the other component, and vice versa. Ideal homogeneity can never be achieved in practice however. It is possible though to realise what is called 'stochastic' homogeneity. This is the case when, in a defined product sample, both components are represented to an equal extent.

Froude number $F_r = v^2 / r \cdot g$

Where:
v = peripheral speed [m/s]
r = radius of mixing drum [m]
g = acceleration of gravity [m/s^2]

$v = \pi \cdot D \cdot n / 60$

Where:
D = diameter of mixing drum [m]
n = rotation rate of shaft [rpm]

In the theoretical treatment of mixing processes, the Froude number, F_r, plays a major role. This dimensionless quantity says something about the relationship between the forces of inertia and gravity acting on a moving particle. Based on the Froude number, various design data for a mixer may be determined, such as the dimensions of the mixing drum and the peripheral speed related to the rotation rate.

In a mixer with a Froude number of less than 1, the product is only folded together. The particles move by rolling off the mixer elements. Such a mixer is suitable for mixing free-flowing components with comparable characteristics. In general, the mixing times are long, and the mix quality is only moderate. The mixers have

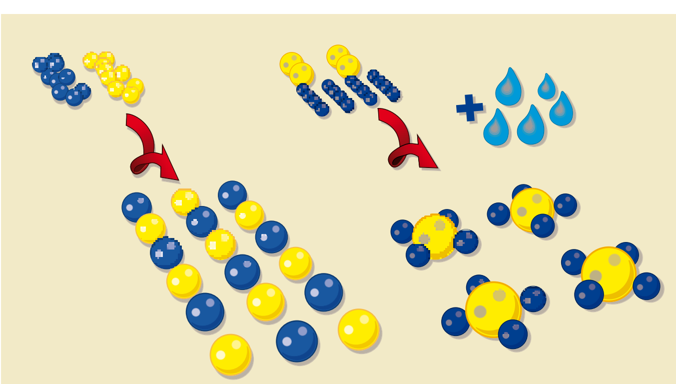

Fig. 4 Principles of mixing (l) and granulation (r)

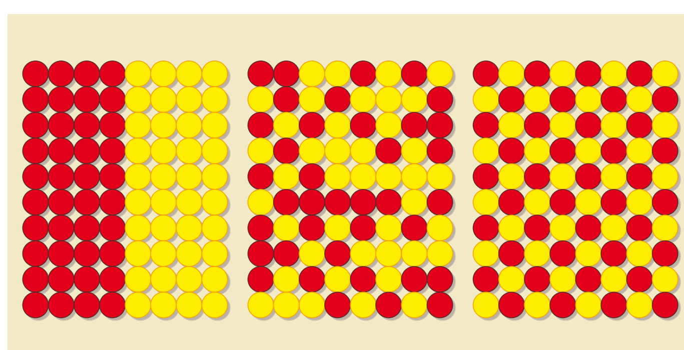

Fig. 5 Three situations: separated components, a stochastic mixture and an ideal mixture

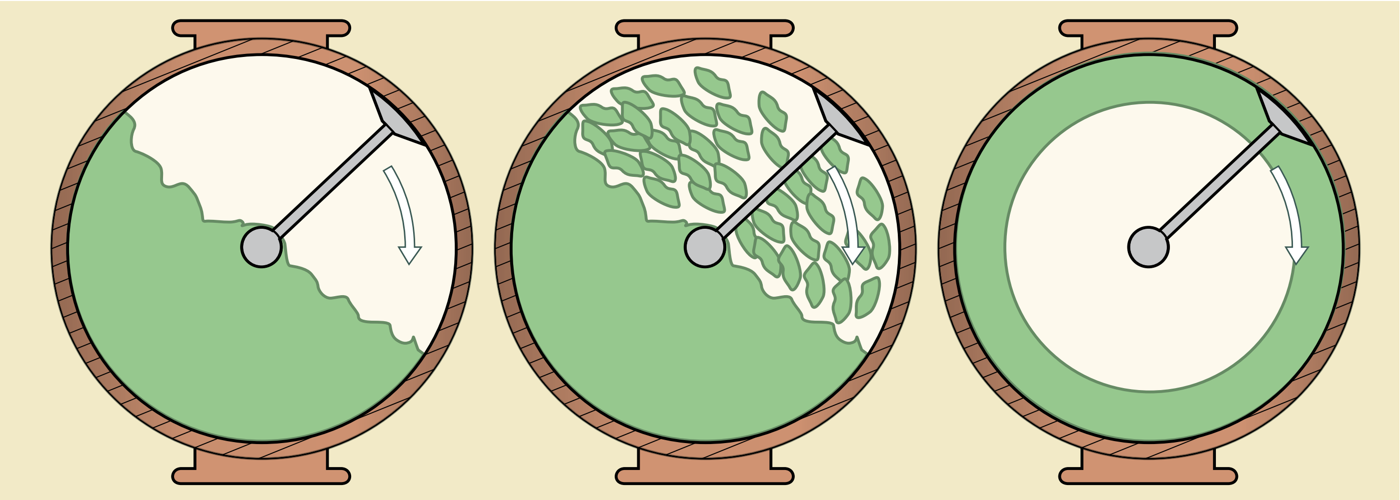

Fig. 6 Mixing processes at different Froude numbers: from left to right Fr<1, 1<Fr<6, Fr>6

a limited product capacity and are relatively large. Examples are ribbon mixers, conical screw mixers and mixers with a rotating drum. These mixers boast a long industrial history.

In mixers with a Froude number between 1 and 6, there is a mechanical fluidised bed, in which diffusion takes place as well as convection. The product is distributed throughout the volume of the drum. These mixers are suitable for components with very varied characteristics. Liquids and additives can be mixed in very well with these. The mixing time is short, yet a high, reproducible mix quality is realised. The production capacity is also high, while the machines are compact. Examples are plough share mixers and single and double-shafted paddle mixers. These mixers have been developed to the last detail during the past 30 years for modern day, exacting applications.

At a Froude number of greater than 7, a centrifuge effect arises. The product is then displaced towards the wall of the mixing drum. The product rotates rapidly as a result of the even greater peripheral speed of the mixer elements. This causes friction between the components and the mixer wall. Due to the high shear forces, such a mixer realises very good homogeneity, but for the same reason, damage to the product may arise. The energy consumption is also high.

Power

To determine the power consumed by a mixer, use could be made of the Reynolds number R_e. This number says something about the frictional forces that arise between the product and the wall of the mixer drum. These frictional forces affect the power needed for the mixing process. A more practical approach, however, is to conduct a mixing test with a mixer specially equipped for the purpose. WAM Holland possesses a WBH 150 litre plough share mixer for this. BULK

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WAM Holland Bulk Handling Equipment BV

WAM HOLLAND TEST MIXER

WAM Holland possesses a WBH 150 litre plough share mixer, featuring the necessary measurement equipment to record the parameters of the mixing process, such as rotation rate, power consumed, temperature changes and mixing time. The test mixer is also suitable for mixing in liquids. This means that investigation can be done into the granulation of particles with the aid of a binding agent. In a mixing text, the properties of the components to be mixed are determined, such as the bulk density, the granule sizes and particle shapes. Other aspects may be relevant here too, such as the brittleness or smoothness of the particles or the moisture and fat content of the components. After mixing, the product is analysed to allow the mixing process to be improved if necessary. Finally, the mixing process in the test mixer can be scaled up to an industrial mixing process by means of computer modelling.

Fig. 7 In tests with the WAM test mixer, the parameters of the mixing process are recorded meticulously