Gericke

When Liquids and Solids Meet in a Mixing Process

Introduction:

The mixing of bulk materials is one of the oldest and most important basic operations in process engineering. A distinction can be made between batch, continuous and semi-continuous processes. Even though this basic operation may seem simple, it is highly complex and has not yet been conclusively researched. The pure mixing of powders is already a demanding task. This makes it even more complex when liquids are added to the powders. The tasks are very diverse, from the dispersion of powders in liquids to the opposite case, where little liquid is mixed with powders and granulates. This article deals with processes where the product of mixing powders and liquids is still a powder.

Machines and processes for powders, bulk materials or granulates are demanding and cannot be designed with a pure theoretical approach. In contrast to gases and liquids, bulk solids change their characteristics due to mechanical stress, which influences the bulk density or other instantaneous properties. At the latest when these aspects are considered, the theoretical approach reaches its limits. Theoretical considerations on mixing processes can be found in the specialist books "Mixing of Solids" by Ralf Weinekötter and Hermann Gericke (both published by Springer Verlag).

In addition to theory, the Gericke company has been focusing on trials for over 125 years. The accumulated knowledge is documented and supported by modern simulation tools, which can discretise every particle and can be integrated into existing CFD programs. Although these simulation tools can represent everything in detail, they quickly reach their limits with a larger number of particles. State of the art software can manage 10 million particles. For comparison, a mixer with a filling volume of 2000 l contains over 23 trillion particles with an average particle size of 200 µm.

When liquids are added to the bulk solids, the situation becomes even more complex. Even if liquids can be better described by characteristic quantities, when particles or granulates are mixed with a liquid, we are still in the area of bulk solids, where models only have a limited effect. Only from the point where the particles are suspended in the liquid or the mixture has the properties of a paste we move into the area of liquids. For liquid, for example, the size of the pump can be calculated using data such as viscosity, density, pipe length and the nozzle. However, it is very difficult to predict how a mixture of powder and liquid will behave. In many cases agglomerates must not be formed; in other cases, the formation of the agglomeration is the aim of the mixing process. Undesirable agglomerates in connection with liquids are caused by a local overconcentration of the liquid, which then "sticks" the particles together by means of liquid bridges.

As mentioned above, there are countless characteristics that are important for a bulk material. It is therefore not surprising that the mixing of bulk solids and liquids can produce countless other combinations. Almost as many parameters as properties are available when mixing solids with liquids. So you are spoilt for choice as to which parameters to focus on.

The mixing of powders with liquids follows the same idea as pure solids mixing. Mixing is achieved when each solid particle is wetted with the same amount of liquid. This theoretical approach is never quite achieved, but it is already very helpful if the liquid, the so-called continuous phase, is atomized into small portions (drops) and these are then mixed with the particles.

Nozzle types

Single and two-phase nozzles are used for the so-called atomisation, the actual generation of drops. Which type of nozzle is used depends strongly on the liquid and the application. If fine atomisation is essential to avoid unwanted agglomerates, the following approach is important: Only use two-phase nozzles if the single-phase nozzle cannot produce sufficiently fine drops. Or if there is an increased risk that the nozzle will be clogged with ~~by~~ the bulk material thrown up. Single-phase nozzles have the following advantages over two-phase nozzles: Firstly, the operating costs are lower with a single-phase nozzle, as only the liquid has to be compressed (with two-phase nozzles, a gas compressor is required that is typically less efficient) and secondly, the product is less swirled in the mixer with a single-phase nozzle, as no additional air is introduced into the mixer. Thomas Isenschmid found during his doctoral thesis (1992) that with a two-phase nozzle the atomising air fraction after 0.3 m is less than one tenth of the local air mass flow. This means that after only 0.3 m the spray jet attracted nine times as much ambient air as is used for the atomising air. Two-phase nozzles thus generate enormous turbulence in the closed mixer, the fine droplets are deposited undesirably on metallic surfaces and lead there to product caking. Such caking is rarely desired and leads to product contamination. As soon as the liquid is broken down into fine droplets, it must be suitably brought together and mixed with the particles. This mixing can be done in a batch mixer or in a continuous mixer.

Mixing of bulk materials with liquids in a batch process

The Gericke Multiflux® mixer is a horizontal mixer with two mixer shafts whose paddles ensure optimum axial and radial transport. These paddles overlap in the central zone of the mixer housing, so the drive of the two shafts is synchronised. In this overlapping zone the particles are fluidised, this zone being the ideal place for continuous liquid addition. The liquid can be added to the solid without the droplets coming into contact with paddles or mixer walls, thus minimising the risk of lump formation.

However, there are combinations of powders and liquids, such as high viscosity liquids and very fine powders, where agglomerates are still formed. These solid-liquid combinations require additional high shear energy to achieve uniform distribution. Gericke uses high-speed cutter heads (Gericke Disperser) which are positioned in the front door for process and cleaning reasons (patented). In this way they unfold their full effect in the area where the maximum concentration of agglomerates can be expected. However, the Gericke disperser can only be used if the product allows a high energy input.

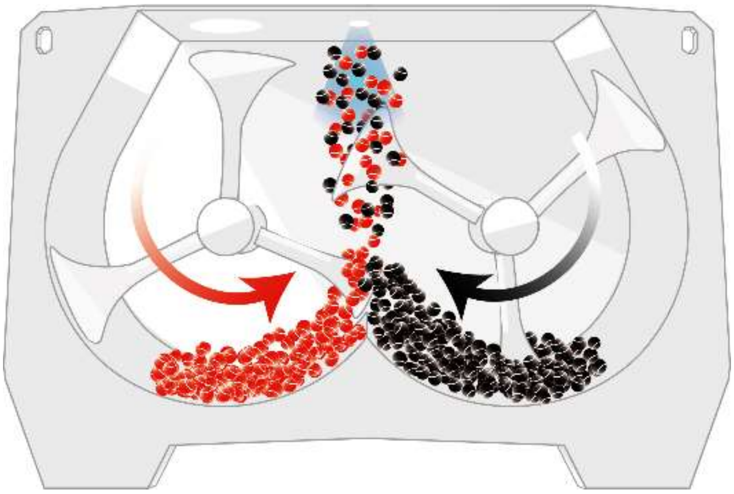

Figure 1 - Mixing principle of the GMS. The fluidised zone is created between the two overlapping mixing tools. In this area the liquid is sprayed directly onto the bulk material in a finely distributed manner

Figure 2 - A GMS 5000 ECD with 5000 l gross volume in cleaning position. Mixing tools and large front door are pulled away from the mixer housing. Access for cleaning is optimal. Fast running dispersers can be installed in the front door to distribute highly viscous liquids in powders.

Figure 3 - Interior view of a batch mixer type GMS. Two Gericke dispersers with a large effective diameter are integrated into the front door in an optimal position.

In a batch process, the total mixing time determines the capacity of a given mixer size. If the mixing process also includes liquids, the total mixing time can be divided into the following time intervals:

the **pre-mixing** time, the mixing time before the liquid is added to homogenise ~~homogenize~~ the solid;

the **spraying time**, the time required to add the liquid;

the **post-mixing time**, the time required to homogenise the bulk material even further and, if necessary, to dissolve (disperse) lumps.

Figure 4 shows as an example, using the GMS 140 C (100 l gross volume), the different mixing interval times as a function of the spray flow. The pre-mixing time is independent of the spray flow. The spraying time is inversely proportional to the spray flow. Of particular interest is the required post-mixing time; its absolute size is determined by the amount of unintentionally formed agglomerates. If the liquid is sprayed on very slowly, no agglomerates are formed, and the short post-mixing time serves only for homogenisation. A high liquid addition rate causes an increase in the formation of unwanted agglomerates, which then have to be dispersed with a longer post-mixing time. The size and number of agglomerates increases exponentially with increasing liquid flow rate. The total mixing time is then ultimately the sum of all mixing intervals and shows where the optimum lies between high liquid flow rate and post-mixing time.

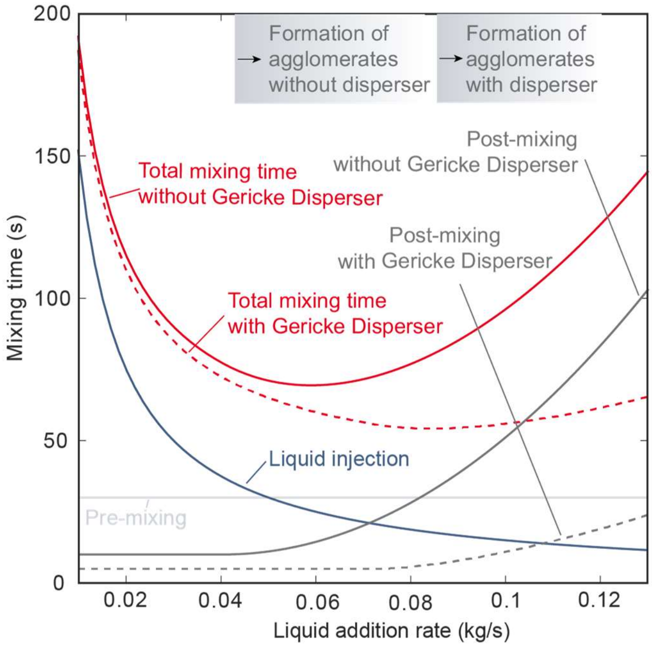

Figure 4 - Exemplary mixing time diagram of the GMS 140 C (100 l gross volume) with liquid addition. The diagram shows the individual mixing time intervals depending on the spray flow: pre-mixing time, spray time, post-mixing time without and with the Gericke disperser and the total mixing time without and with the Gericke disperser. The total mixing time is the sum of all mixing times. The diagram also shows from which liquid flow rate unwanted agglomerates can form. The absolute figures are for illustrative purposes only and can vary greatly depending on the product and recipe.

If the process allows, Gericke Dispersers are used. These highly toroidal rotating cutter heads are operated during the addition of liquid and break up or disperse the lumps immediately after they have formed. However, very high spray flow rates require a longer post-mixing time, even when dispersers are used. Overall, the total mixing time is shortened by the use of dispersers.

Mixing bulk materials with liquids in a continuous process

In the continuous process, the product streams are closely merged and homogenised in a constant and controlled manner. The mixing transport distances are very short, resulting in significantly shorter mixing times. This results in a much more compact design of the continuous mixer. In comparison, a continuous mixer contains about one tenth of the volume of a batch mixer with the same throughput. This not only makes the entire system more compact, but also reduces the energy requirement. In contrast to the batch process, the spray flow rate is not available as a parameter in continuous mixing. This is because it is predetermined by the recipe and the throughput capacity. On the one hand it is certainly easier to have one parameter less, but on the other hand the challenges are greater. In the continuous case, the mixing time is the average residence time of the products in the mixer. The axial position of the nozzle determines the ratio between pre- and post-mixing time (see figure 5). A special place for the addition of the liquid is provided by the continuous mixer type, GCM in the inlet nozzle through which the bulk material falls into the mixer. This place allows a very early addition of the liquid and thus maximises the post-mixing time. The spray pattern and the number of nozzles determine the spraying time. The GCM is designed in such a way that a highly homogeneous mixture can be achieved with average residence times of 5 - 40 s. These residence times are very short compared to many other continuous mixers, which has the advantage that start-up losses are significantly lower. If the resulting agglomerates are not dissolved in this time, a longer residence time must be considered.

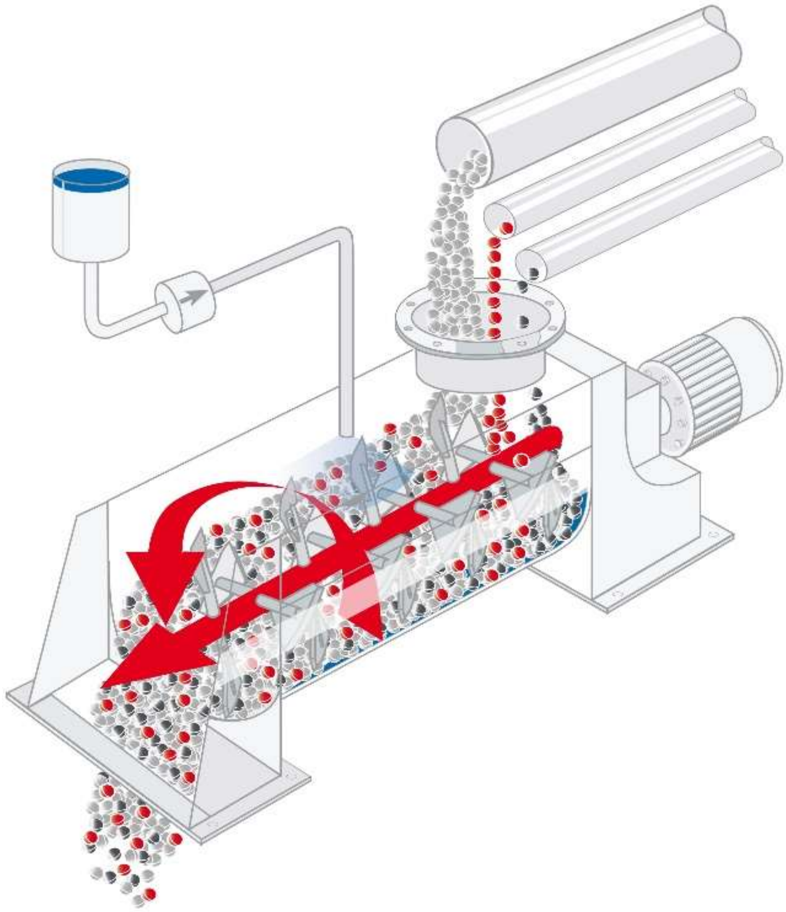

Figure 5 - Mixing principle of the GCM. The axial addition point of the liquid divides the mean residence time into the mixing time intervals such as pre-mixing and post-mixing time.

Due to the compact design of the continuous mixers, they can also be operated at very high speeds. Thus, the mixing tool is also used as a disperser.

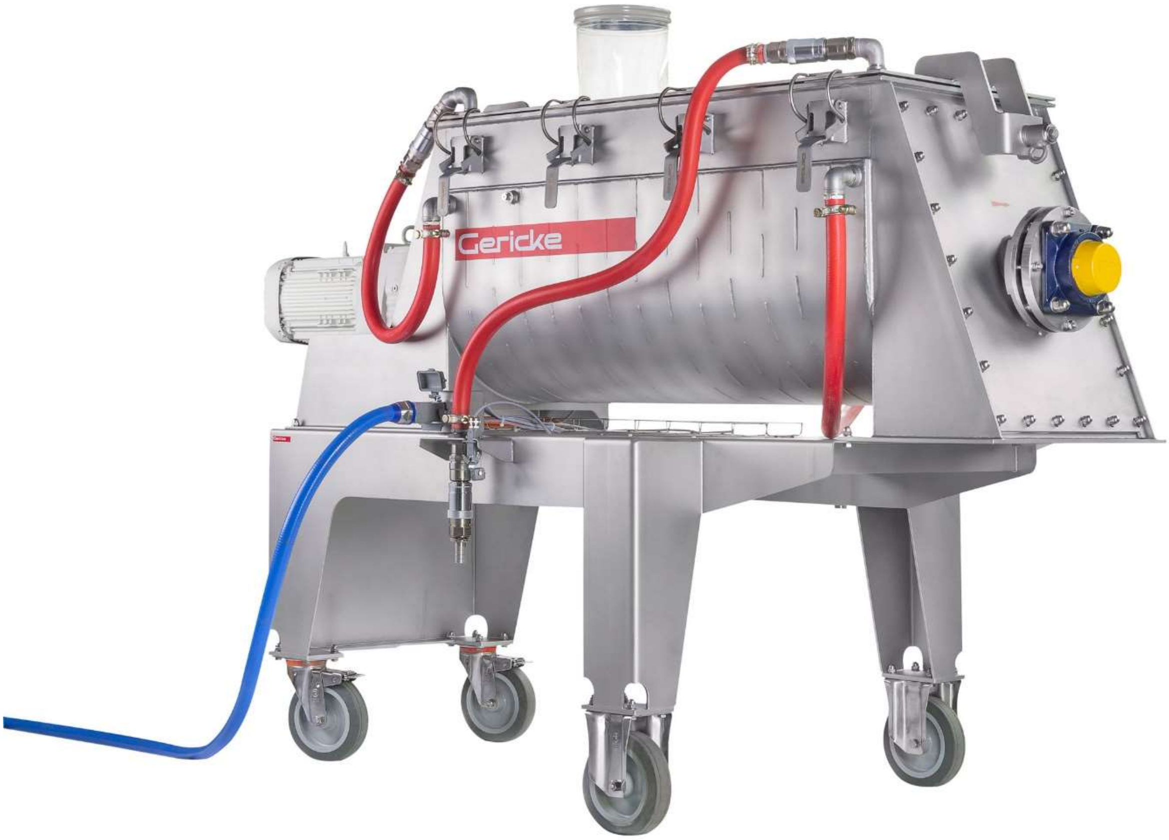

Figure 6 - A GCM 1200 with a heating or cooling jacket. Heated mixer walls are often used for highly viscous liquids.

Addition of highly viscous oils to fine-grained powders

A fine organic powder should be sprayed with a highly viscous liquid. Due to the small throughput quantities, this was implemented with a batch process. Figure 7 shows the highly viscous oils sprayed onto the organic powder. The suitable nozzle was determined at the Gericke Test Center. An internal mixing two-phase nozzle with high air and oil pressure is used to produce this special mixture. The high energy input enabled this highly viscous liquid to be atomized into fine droplets. The high viscosity of the liquid and the fine-grained powder favour the formation of agglomerates. Thanks to the Gericke disperser, agglomerates were never found in the whole batch at any time and the total mixing time remained below one minute. Figure 8 shows the mixed product, a mixture of a white organic powder with a reddish high viscosity oil. The product shows no colour irregularities or lumps.

Figure 7 - High viscosity oils sprayed as fine droplets into the fluid zone of the GMS by an internal mixing two-phase nozzle with high air and liquid pressure.

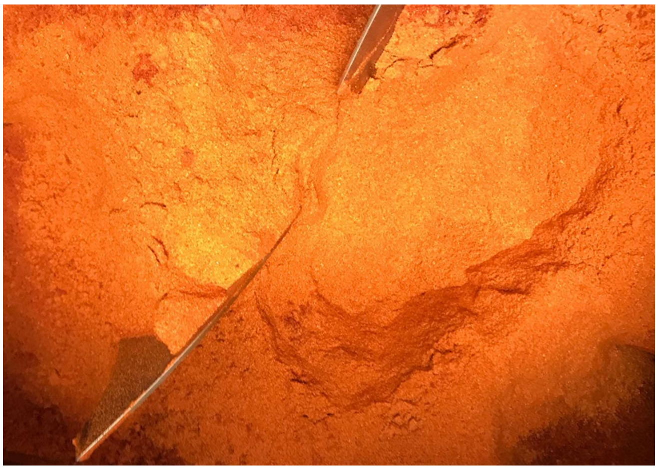

Figure 8 - Mixture of the original fine-grained white powder with highly viscous oil. With the Gericke disperser the formation of agglomerates could be prevented, despite challenging properties of the ingredients, such as the fine grained powder and the high viscosity of the oil.

Continuous mixing of solids with a liquid polymer

An existing batch mixing process, whose capacity is insufficient, is to be replaced by a continuous mixing process. It was important that the products are fed in the same order as in the existing batch process. This is the only way to ensure that the end product has the desired properties. In concrete terms, the sequence in the batch process was as follows: First the main component in powder form was fed in, then a liquid polymer was sprayed onto that powder in a second step. After a defined mixing time, the second solid component was added and further mixed. In the continuous process, the time intervals between the addition of the individual ingredients are much shorter. One advantage was that the liquid polymer could be added right at the inlet of the first solids ingredient. This arrangement ensured that the residence time between the addition of the liquid polymer and the second solid component was sufficient. Figure 9 shows the test mixer in operation. The fluidised zone is clearly visible (the lid was removed for demonstration purposes).

The nozzle is hidden by the inlet spout of the first solid component. Due to the high viscosity of the polymer, a two-phase nozzle was used from the beginning. It turned out that an internal mixing two-phase nozzle is superior to the external mixing one, as the latter does not get blocked by the polymer. Figure 10 shows the spraying of the liquid into the fluidised zone with the internal mixing two-phase nozzle. The high air flow causes the particles to be strongly swirled.

Figure 9 - Continuous mixing of solids and liquids at the Gericke Test Center in Zurich. The cover was removed for demonstration purposes. The typical GCM throwing mechanism is clearly visible. The addition of the liquid polymer is hidden by the inlet spout of the main component.

Figure 10 - Spraying of solids with an internal mixing two-phase nozzle. As can be seen in the picture, the atomising air interferes with the particle cloud.

In this case, despite the challenging conditions, it paid off for the customer to switch the process from batch to continuous. Due to the lower overall height, the packaging plant could be placed directly under the mixer and thus a further conveying step was not necessary. The throughput capacity was significantly increased. In addition, the current plant consumes only about 15 % of the energy of the batch process.

Summary

The homogeneous mixing of bulk materials and liquids is a great challenge for batch and continuous processes. The formation of agglomerates is promoted by fine powders and high quantities of liquid, but is usually not desired. A successful technical implementation is based on two principles: The division of the continuous liquid phase into small droplets by means of different nozzle types and the use of efficient dispersers which finely distributes the liquid and undesired agglomerates by means of very high shear forces. This complex field of tasks is close to a theoretical approach. Detailed designs, such as type, number and position of the nozzle(s), can only be mastered with the help of empirical experience. Empirical experiments in the test centre are necessary. Two completely different mixers were successfully used for this application.

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