Introduction to the milling technology with the bead mill DISPERMAT SL

Table of contents:

---

1. Function and task of the bead mill

In many technical processes it is necessary to divide solid material into fine particles and distribute them evenly within a liquid carrier. This process is generally known as ”dispersion”. During dispersion, the adhesive forces that act between the extremely fine solid matter powder particles must be overcome. When the requirements on fineness are high or the solid matter is difficult to disperse, a dispersion with the dissolver is often insufficient.

Due to their ability to process a wide variety of solid matters that are difficult to disperse, high speed bead mills have gained particular acceptance.

In the dispersion process, three partial steps run in parallel:

The wetting of the surface of the solid matter to be processed, by liquid components of the millbase.

The mechanical division of agglomerates into smaller agglomerates and primary particles.

The stabilisation of primary particles, agglomerates and aggregates against renewed attraction (= flocculation).

While the stabilisation against flocculation is primarily a property of a colloid-chemical system, which depends on the interaction of the liquid components (in varnishes for instance: binders, solvents and additives) with the solid matter parts (e.g. pigments and fillers) or on that of the solid particles with each other, the dispersion machinery used plays a vital part in the mechanical division and more important aids the wetting process. The actual dispersion system in a bead mill consists of a milling chamber and an agitator; the milling chamber is filled with the grinding beads (material e.g. glass, zircon oxide, steel) and the product to be dispersed. In the milling vessel, the grinding medium is kept moving by the agitator, which itself is driven by a motor. The dispersion process takes place between the grinding beads sliding on each other and between the rotor and/or the vessel sides and the grinding beads.

↑table of contents

---

2. The Step of Mechanical Division in Dispersion

Just like the dispersion, the mechanical process can be divided into the three steps wetting

mechanical division

flocculation stabilisation

The step of mechanical division can itself also be separated. To enable the agglomerates to be dispersed, they must

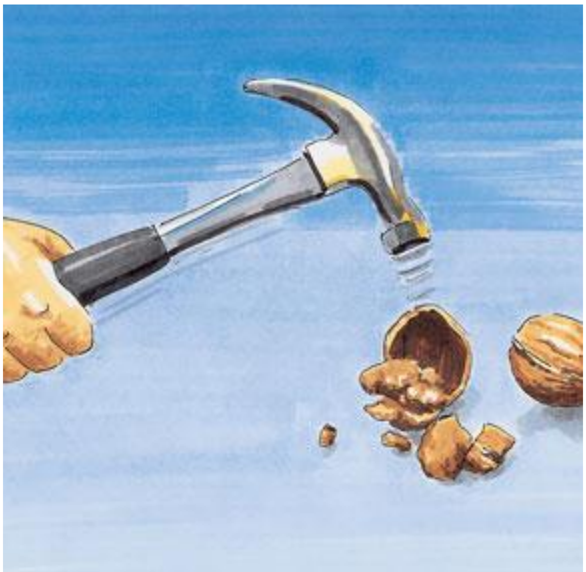
get into a dispersing situation, e.g. into the shearing zone between two grinding beads (spatial condition) and

be stressed enough so that they break (energetic condition).

The mechanical division may be illustrated by comparing it with the attempt to crack a nut with a hammer.

In order to break the shell, the nut must be hit in the first place (spatial condition), but it must also be hit hard enough (energetic condition). For a proper understanding it is important to realise that both conditions - spatial and energetic - must be fulfilled at the same time. Although this model may seem rather trivial, it clearly demonstrates the function of a dispersing machine.

In principle the validity of the model can be proved with any dispersing instrument.



For reasons of simplicity, one should imagine a batch bead mill, filled with a millbase which with progressing state of dispersion illustrates a measurable change of a technical property. In paints, this may for instance be the colour strength, the gloss, the viscosity or the fineness (to be measured with a Hegman Gauge according to DIN 53203). Our example uses colour strength. When all operating parameters, grinding bead filling quantity, bead type, speed, cooling etc. are kept constant, the measured colour strength reaches a finite value related to the time of dispersion. Longer dispersion will not improve the colour strength. Only by increasing the speed it is possible to further increase the colour strength.

The reason for this behaviour is that in a very long dispersion all agglomerates have the opportunity to get into the zones of the maximum shearing effect. Those that are dispersed under these conditions cause a visible increase in the colour strength. Those that have such a high stability that they are not divided under the conditions of the maximum available shearing effect, are still undispersed. By increasing the speed, zones with stronger shearing effect develop where more stable agglomerates can also be dispersed.Therfore, the colour strength may continue to rise with increased speed.

Only after a sufficiently long dispersion time combined with sufficiently high speeds, can it be expected that all agglomerates are dispersed. Only then the spatial as well as the energetic conditions required for a full dispersion are met. Too low a speed can generally not be compensated by longer dispersion and vice versa.

↑table of contents

3. Pass and re-circulation method

In principle, two methods can be distinguished in the operation of the DISPERMAT® SL bead mills. Either, the complete millbase is collected after each pass through the bead mill (single or multiple pass), or else the millbase is fed directly back into the supply vessel from the outlet of the milling chamber (re-circulation method).

schematic view of the single pass method

In the single pass method, the product is filled into a feed vessel and pressed through the milling chamber via continuously adjustable pneumatic transport system or with the feed press.

schematic view of the re-circulation method

In the re-circulation method, the product is filled into the feed vessel and repeatedly pumped through the milling chamber with an integrated, continuously adjustable pumping and stirring system.

The method of operation to be chosen depends on the type of task. Easily dispersible pigments can often be processed with the single pass method, whereas with pigments that are more or difficult to disperse the re-circulation method is more efficient.

Over a period of time the re-circulation method ensures , that every agglomerate will get into a dispersion situation. Here, it has spatial and energetic condition and is dispersed. This means that the re-circulation system is more efficient and economic.

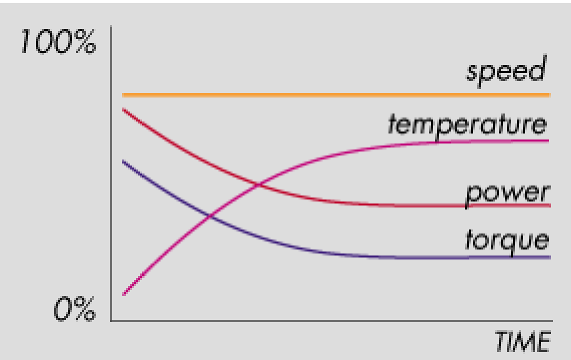
↑table of contents

4. Relationship between Power Input and Dispersion Result

Basic scientific research has shown that the mechanical power that is transferred into the millbase is closely related to the dispersion result. The mechanical power determines the energy that is transmitted by the agitator via the grinding beads to the product. The power P is calculated from the speed n of the agitator and the torque M generated on the agitator according to the following equation:

$$P = 2\,\pi\,n\,M$$

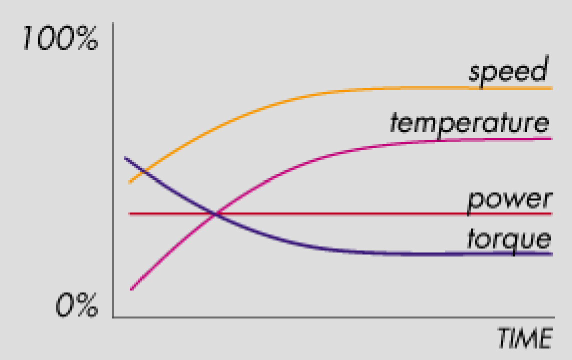
P	=	power [Nm/s = J/s = W]
π	=	3.141...
n	=	speed [1/s]
M	=	torque [Nm]



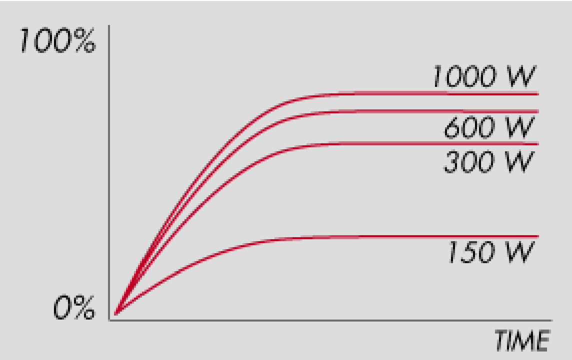
Dispersion with constant speed

The higher the energy density, the greater the probability that more stable agglomerates are also dispersed. It does not matter whether the power input which leads to the existing energy density, is applied with a high speed and low torque or vice versa. With a given bead charge and dispersion time, the dispersion result depends only on the amount of the mechanical power.

The torque therefore depends directly on the flow characteristics of the millbase. If the viscosity changes during dispersion at constant speed, the power input changes automatically. If the viscosity decreases during dispersion, the mechanical power drops, and if it increases, the mechanical power



Dispersion with constant mechanical



Dependence of the dispersion result
on the power input

rises. If the formulation is processed with more cooling, the power input is higher, and with less cooling it is lower.

This for example, is the reason why dispersion results may literally depend on the season, because in winter, the cooling water may be much colder than in summer!
The DISPERMAT® SL solves this problem by enabling the mechanical power input for dispersion to be pre-set. During dispersion the torque of the rotor is continuously measured and the speed controlled, so that the product of n and M leads to precisely the pre-set mechanical power.

Apart from the agitator geometry and the viscosity of the millbase, the torque transmitted by the shaft onto the millbase also depends on the type, quantity and size of the grinding beads. High bead filling volumes increase the torque on the agitator shaft and also increase the probability that agglomerates come into a spatial dispersion situation.

↑table of contents

5. Steps to Improve Dispersion Results

The relationship between the effects of energy and time enables the dispersion process to be optimised. If the required dispersion result is not achieved, it must first be determined whether this can be changed by increasing the dispersion time. The power input can be increased with higher speeds. This will normally improve the dispersion. Smaller and/or harder beads (e.g. zircon oxide or steel) can also improve the dispersion result. Further, the bead charge can be increased to about 80%. In order to operate the bead mill economically, dispersion should be made with as much solid matter as possible. If after the dispersion there is some flocculation, a suitable dispersing aid may help. A partial modification of the millbase formulation by using more suitable raw materials can also be made.

How can the dispersion result be improved ?

increased dispersion time

increased speed

improved cooling

smaller or harder beads

increased bead charge

modification of the millbase (e.g. by using additives)

↑table of contents

6. Transfer of Laboratory Tests to Industrial Production

Considering the many influences on the spatial and energetic conditions of dispersion and their difference in various bead mills, it is not surprising to learn that the transfer of the results from one machine to another is not automatically possible. Even if the same bead mill is used, but with different disks, the dwell time distribution of the millbase will be changed and, despite the same number of passes (single pass) or same dispersion time (re-circulation mode) the dispersion result will also change.

Nevertheless, if different bead mills are to be compared with each other, it is generally the case that production machines have less adjustment possibilities. First, the typical result has to be determined on a known millbase.

Bead mill DISPERMAT® SL | **Bead mill DISPERMAT® RS 5** | **Basket mill TORUSMILL® SK**

With this typical result (e.g. fineness), a test series should be made with the DISPERMAT® SL laboratory bead mill with M-control. The impeller speed should be adjusted and the dispersion continued until the result matches that which can be achieved in production. If a DISPERMAT® SL with C-control is available, the tests should be made using mechanical power input.
When comparable results have been achieved, the settings on the DISPERMAT® SL can be used to determine results that are possible in production.

When milling with constant power input, not only can complicated dispersion processes be performed in a reproducible manner, but different dispersions can be compared exactly. The dispersion results from production machinery are easily repeated with the DISPERMAT® SL and formulations worked out in the laboratory can be transferred into production. With the DISPERMAT® SL, problematic parameters like product temperature, cooling water temperature or rheological behaviour of the mill base, may be ignored as long as they do not reach limits critical for the product.