Introduction to Dispersion Technology with the Bead Mill DISPERMAT® SL

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.

Function and task of the bead mill

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

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

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

3. 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.

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).

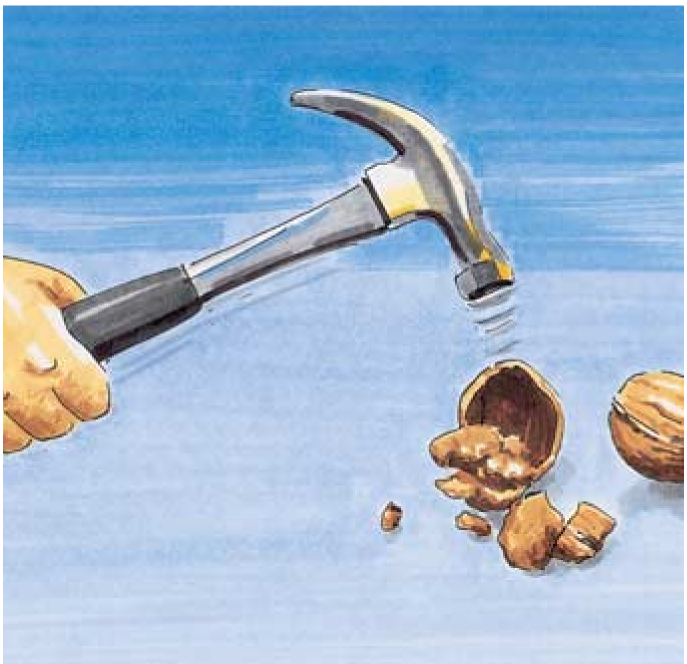
The mechanical division may be illustrated by comparing it with the attempt to crack a nut with a hammer.

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.



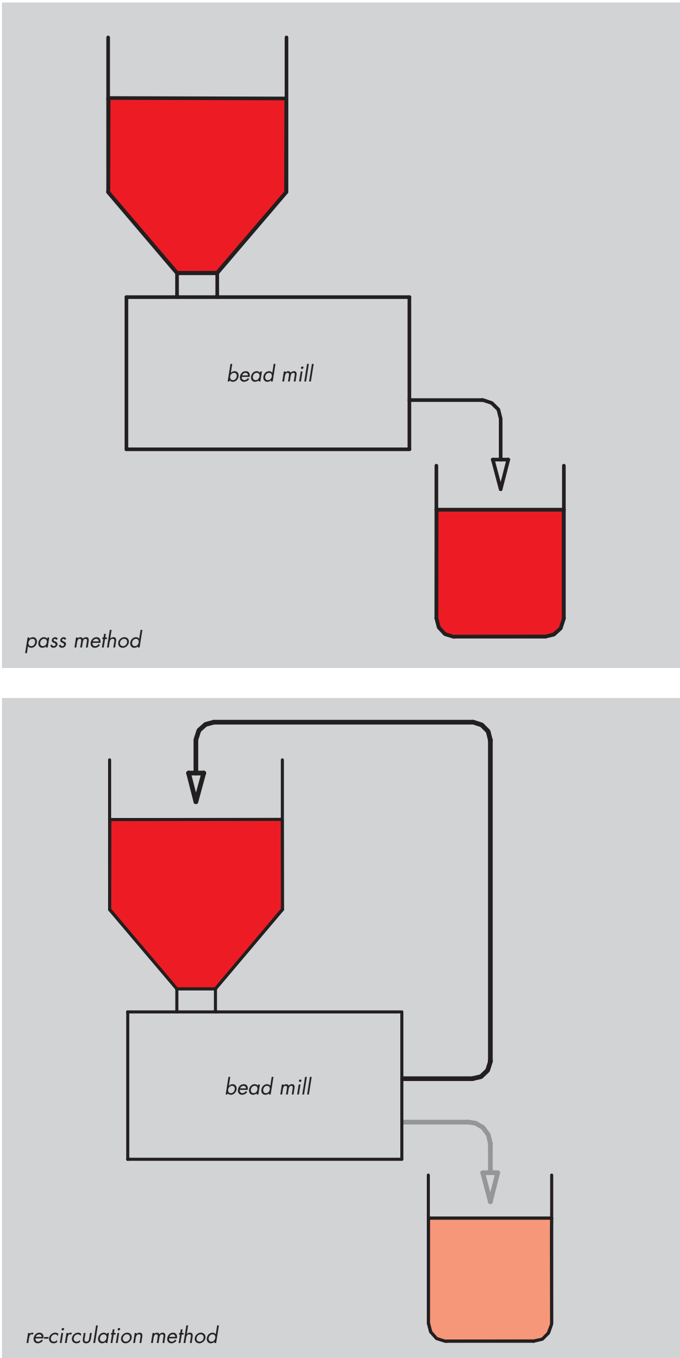
Pass and re-circulation method

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).

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.

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.



schematic view of pass and re-circulation method

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.

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:

$$P = 2 \pi n M$$

Where:
P power [Nm/s = J/s = W]
π = 3,141…
n speed [1/s]
M torque [Nm]

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 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-C 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.

Introduction to the dispersion technology with the world wide patent bead mill DISPERMAT® SL

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
- increased mechanical power input
- improved cooling
- smaller or harder beads
- increased bead charge
- modification of the millbase (e.g. by using additives)

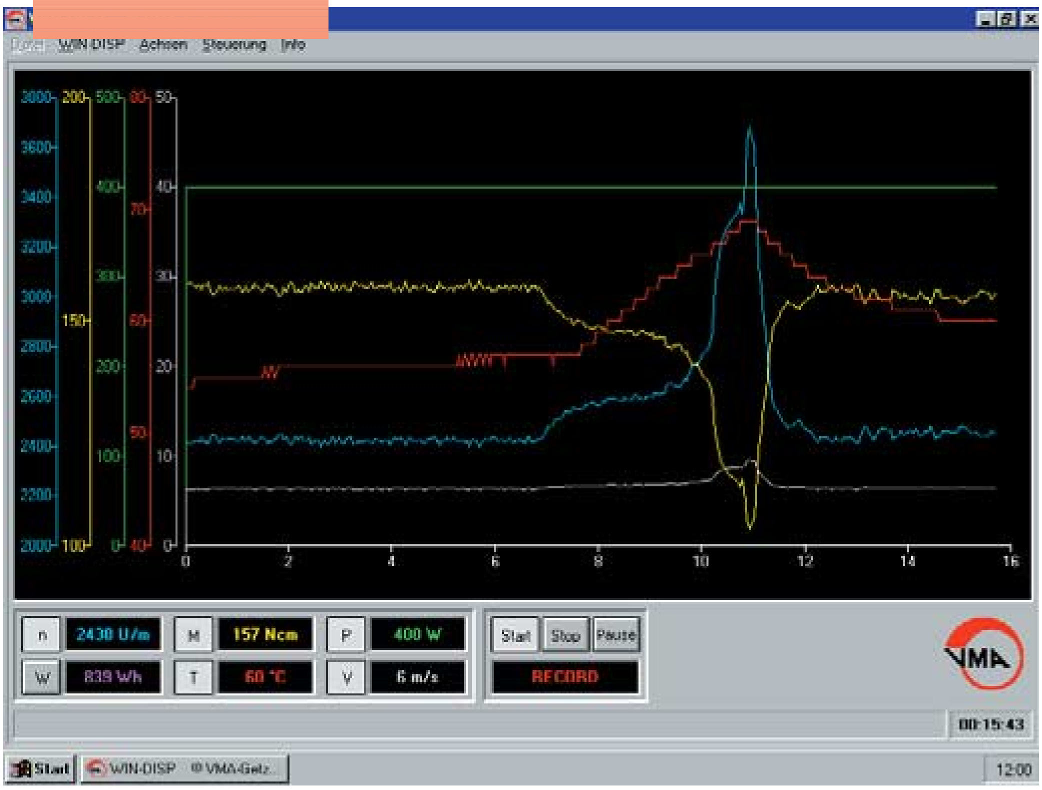
DISPERMAT® SL-C EX,
optional: double walled stainless steel supply vesselhl

Hint
Here is WIN-DISP an excellent tool for the recording and documentation of dispersion results.

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.



With this typical result (e.g. fineness), a test series should be made with the DISPERMAT® SL-M laboratory bead mill.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-C 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-C and formulations worked out in the laboratory can be transferred into production.
With the DISPERMAT® SL-C, 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.

Bead Mills

Laboratory and Pilot Plant Bead Mills

DISPERMAT® SL-C

DISPERMAT® SL-C EX

DISPERMAT® SL-M

DISPERMAT® SL-M EX

Feeding Presses and Accessories

Feeding Presses

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Accessories

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DISPERMAT® RS 5
RS 5 EX

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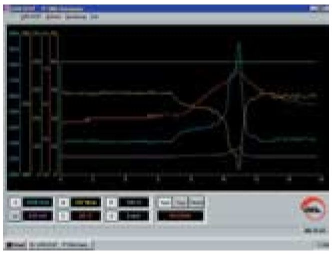


Software WIN-DISP

page 22

Bead Mills

DISPERMAT® SL-C EX,
with double walled supply vessel

DISPERMAT® SL

DISPERMAT® SL EX

DISPERMAT® RS 5

Software WIN-DISP

The DISPERMAT® range of horizontal bead mills includes instruments for applications, including research and development, quality assurance and production of larger quantities.

Dispersion with Bead Mills

DISPERMAT® SL

DISPERMAT® SL laboratory and pilot plant bead mills are closed, horizontal bead mills with high output and extremely low dead volumes in the millbase inlet and outlet pipes. During the dispersion process, the product to be dispersed is fed through the horizontal milling chamber and continuously dispersed.
The DISPERMAT® SL bead mills can be used for the pass as well as for the re-circulation process. After the dispersion, the integrated air pressure system presses the remaining millbase out of the milling chamber which allows an almost complete recovery of the dispersed material.
Due to minimised dead volumes, even the smallest quantities can be dispersed with a high yield.

Therefore the DISPERMAT® SL is an ideal tool for Research, Development and Quality Control.
Also, larger quantities can be processed within a very short period of time. In order to minimise the product loss, the mill base is transported directly from the supply vessel into the milling chamber. The dispersed product passes through the millbase separation (dynamic gap) and is recovered either in a vessel (pass method) or flows back into the supply vessel (re-circulation method).

DISPERMAT® SL-C,
optional: Stainless steel supply vessel

- Quick and cost-effective development of new formulations through exact reproducibility of dispersions.
- Quick and reliable transfer of laboratory development into production because of quantitative knowledge of the required mechanical power input.
- Quality control and assurance of production.
- Efficient control of incoming raw materials by measuring product properties relevant for the application.

DISPERMAT® SL-M,
optional: stainless steel double walled supply vessel and integrated pumping and stirring system

DISPERMAT® SL-C EX,
optional: stainless steel double walled supply vessel

DISPERMAT® SL-M EX,
optional: stainless steel double walled supply vessel and integrated pumping and stirring system

Milling System

- Milling system (stainless steel milling chamber, nitride steel milling rotor)

Option:

- hard metal
- ceramic (ZrO_2)

- Millbase separation by dynamic gap
- Volume of milling chamber: 50, 125, 250, 500, 1000 and 2000 ml
- Master-batch from 50 ml to 50 l
- Shaft seal by means of mechanical seal, built into easy to install cartridge system integrated, pressurised and cooled lubrication liquid
- Minimised dead volume
- Dispersion of small quantities of millbase is possible due to almost complete product recovery
- Very high millbase yield
- Excellent temperature transfer due to veined cooling water system with extremely large surface area
- Cooling water connections: two self-sealing fittings and two quick couplers
- Milling beads of glass, zirconia etc.

Operation

- Easy to use and secure to handle
- Easy cleaning, allowing rapid change of material

Procedure

- One-pass-procedure and continuous pass procedure
- Circulation procedure with integrated pumping- and stirring system
- Dispersion of flowing and non-flowing products
- High mechanical power input permits processing of difficult to disperse systems

Patented World Wide DISPERMAT® SL-C Process Control

- Excellent process control through measurement and recording of speed, power input, torque, work, product temperature and peripheral speed of the milling rotor.
- Operation with either: constant speed or constant power.

DISPERMAT® SL-M

- infinitely variable speed
- speed and temperature indication

Dispersing with Constant Mechanical Power Input - DISPERMAT® SL-C - Patented World Wide

Bead mills are used to disperse (finely divide) solid material into liquid a phase. The actual dispersing system consists of a chamber and a rotor; the chamber is filled with grinding beads and the product to be dispersed.

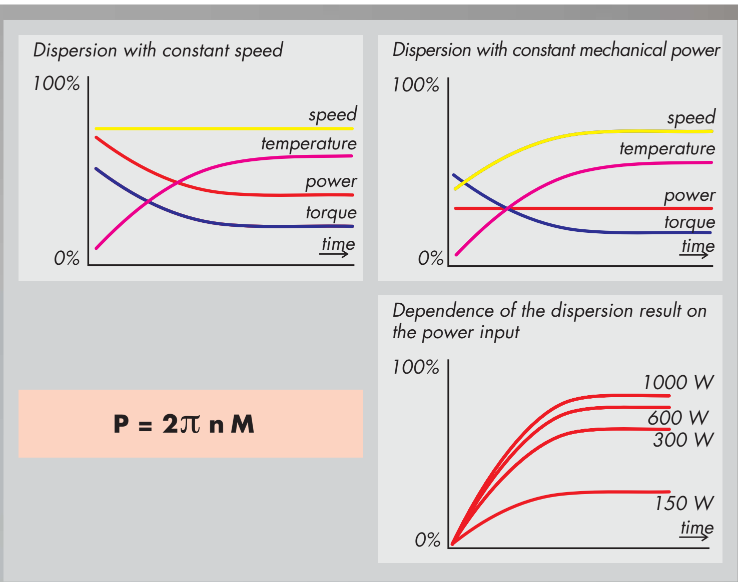
While in conventional bead mills, the rotational speed is an easily adjustable parameter, the torque strongly depends on the rheology of the mill base. These flow characteristics again strongly depend on the temperature of the mill base. Therefore, during the course of a dispersion at constant rotor speed, the torque and the power input into the product changes in an uncontrolled manner.

With the world wide patented DISPERMAT® SL-C the operating parameters of speed, torque, power input and product temperature are continuously measured and displayed. Operating at constant speed (conventional bead mills) provides information on the changes in the other parameters which affect the milling process.

However, the most valuable insight into the dispersion process is only provided by operation with "constant power input".

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.

DISPERMAT® SL-C
with stainless steel supply vessel



P = 2π n M

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:

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Where:
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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 behaviour of the millbase. If the viscosity changes in a 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 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-C solves this problem by permitting 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.

Compared with conventional bead mills, the DISPERMAT® SL-C has many advantages in applications where, exact reproducibility and process control are important, for instance in research and development, for checking incoming raw materials and in quality assurance.

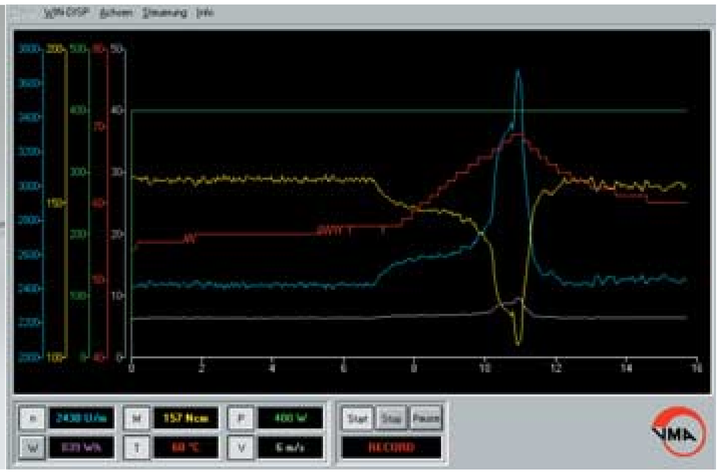
When milling with constant power input, not only can complicated dispersion processes be performed in a reproducible manner, but different dispersions can be compared exactly. The dispersion results from production machinery are easily repeated with the DISPERMAT® SL-C and formulations worked out in the laboratory can be transferred into production.
With the DISPERMAT® SL-C , 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.

DISPERMAT® SL

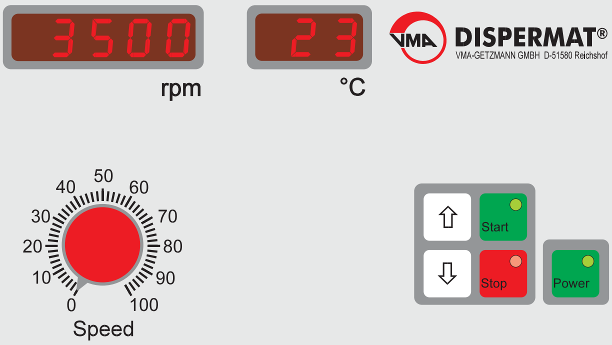
DISPERMAT® SL-M, optional: stainless steel supply vessel, with integrated pumping and stirring system

	Type	Milling chamber volume in ml	Power in kW	Volltage/ frequency in V/Hz	Speed in rpm	Recommended millbase volume
DISPERMAT®	SL-M5	50	1,1	230/50	0 - 6000	50 - 500 ml
DISPERMAT®	SL-M12	125	1,1	230/50	0 - 6000	100 - 750 ml
DISPERMAT®	SL-M25	250	2,2	400/50	0 - 6000	200 - 2500 ml
DISPERMAT®	SL-M50	500	3	400/50	0 - 6000	0,5 - 10 l
DISPERMAT®	SL-M100	1000	3	400/50	0 - 3000	1 - 20 l
DISPERMAT®	SL-M200	2000	4	400/50	0 - 3000	2 - 50 l
DISPERMAT®	SL-C5	50	1,1	230/50	0 - 6000	50 - 500 ml
DISPERMAT®	SL-C12	125	1,1	230/50	0 - 6000	100 - 750 ml
DISPERMAT®	SL-C25	250	2,2	400/50	0 - 6000	200 - 2500 ml
DISPERMAT®	SL-C50	500	3	400/50	0 - 6000	0,5 - 10 l
DISPERMAT®	SL-C100	1000	3	400/50	0 - 3000	1 - 20 l
DISPERMAT®	SL-C200	2000	4	400/50	0 - 3000	2 - 50 l

DISPERMAT® SL-C, optional: stainless steel supply vessel

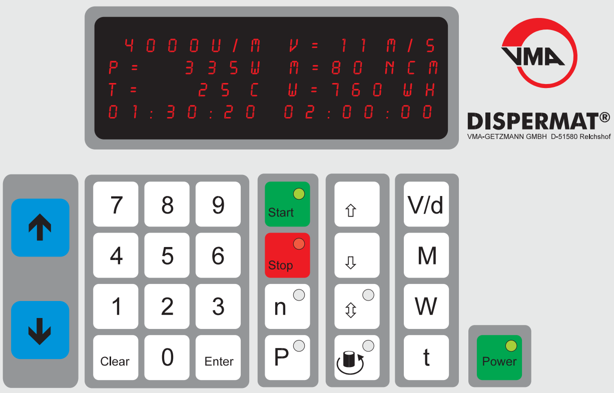


Software WIN-DISP



DISPERMAT® SL-M

The DISPERMAT® SL-M bead mills have an variable speed control. The compact instrument control panel is conveniently located in the stylish housing. Speed and product temperature are shown on a digital display.



DISPERMAT® SL-C

with process control measurement of:

- Speed (rpm)
- Power input (W)
- Torque (Ncm)
- Work (Wh)
- Product temperature (°C/°F)
- Peripheral speed of impeller (m/s, ft/min)

The DISPERMAT® SL-C enables a dispersion at either "constant speed" or "constant power". The measured values are shown on a digital display. A serial port enables the data to be transmitted to a PC for processing with WIN-DISP software (see page 22).

DISPERMAT® SL-EX

The DISPERMAT® SL-EX laboratory and pilot plant bead mills are designed for operation in areas where explosion proof equipment is required.

The main motor, as well as the control panel are explosion-proof.

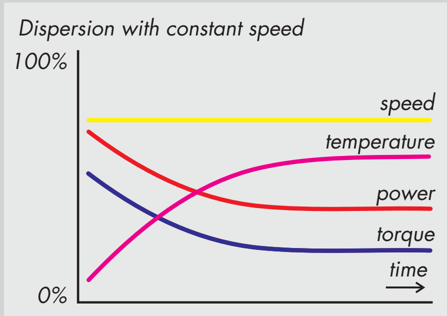
Only the enclosure with the built-in power electronics is not explosion-proof and has to be located outside the hazardous area.

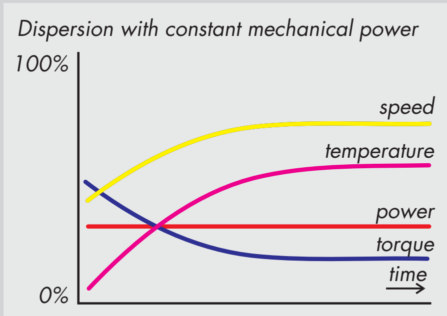
Process technology of the DISPERMAT® SL-EX is the same as the DISPERMAT® SL.
(see page 90-91)

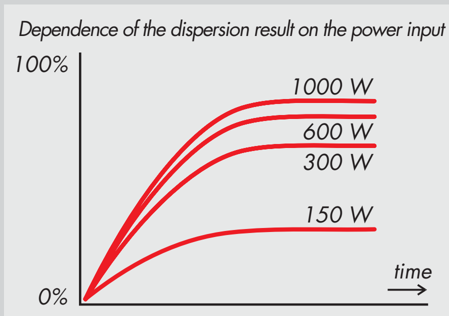
DISPERMAT® SL-C EX,
optional: double walled stainless steel supply vessel

The designation
of explosion-proof areas and correct choice of equipment should be carried out by suitably qualified personnel or by the appropriate authorities.

$P = 2\pi n M$





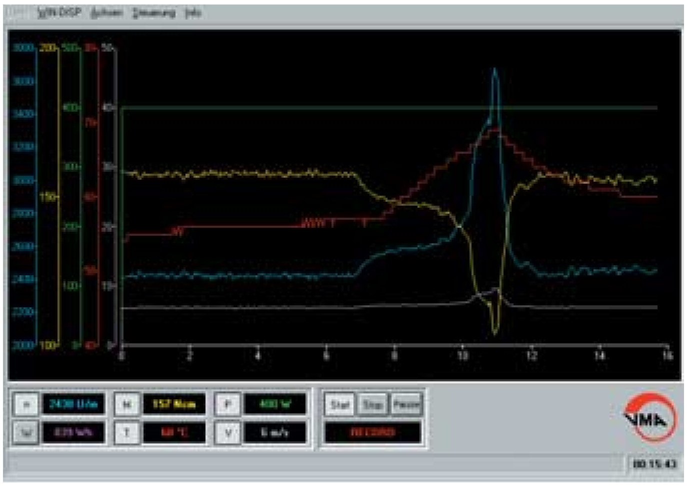


DISPERMAT® SL-EX

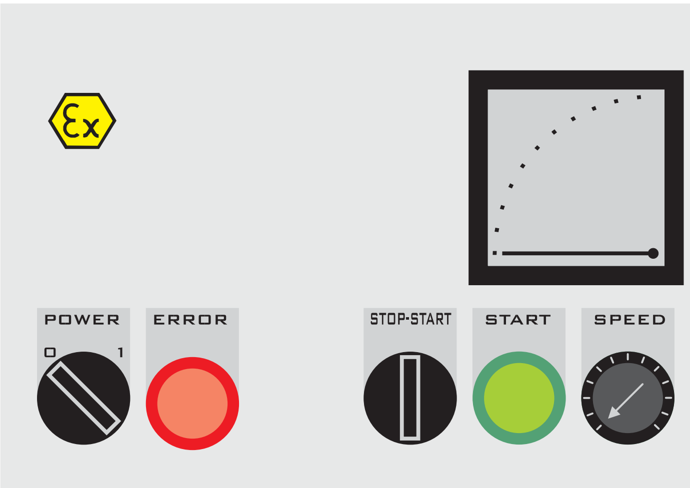
DISPERMAT® SL-M EX, optional: stainless steel double walled supply vessel, with integrated pumping- and stirring system

	Type	Milling chamber volume in ml	Power in kW	Voltage/ frequency in V/Hz	Speed in rpm	Recommended millbase volume
DISPERMAT®	SL-M5 EX	50	1,1	230/50	0 - 6000	50 - 500 ml
DISPERMAT®	SL-M12 EX	125	1,1	230/50	0 - 6000	100 - 750 ml
DISPERMAT®	SL-M25 EX	250	2,2	400/50	0 - 6000	200 - 2500 ml
DISPERMAT®	SL-M50 EX	500	3	400/50	0 - 6000	0,5 - 10 l
DISPERMAT®	SL-M100 EX	1000	3	400/50	0 - 3000	1 - 20 l
DISPERMAT®	SL-M200 EX	2000	4	400/50	0 - 3000	2 - 50 l
DISPERMAT®	SL-C5 EX	50	1,1	230/50	0 - 6000	50 - 500 ml
DISPERMAT®	SL-C12 EX	125	1,1	230/50	0 - 6000	100 - 750 ml
DISPERMAT®	SL-C25 EX	250	2,2	400/50	0 - 6000	200 - 2500 ml
DISPERMAT®	SL-C50 EX	500	3	400/50	0 - 6000	0,5 - 10 l
DISPERMAT®	SL-C100 EX	1000	3	400/50	0 - 3000	1 - 20 l
DISPERMAT®	SL-C200 EX	2000	4	400/50	0 - 3000	2 - 50 l

DISPERMAT® SL-C EX, optional: stainless steel double walled supply vessel



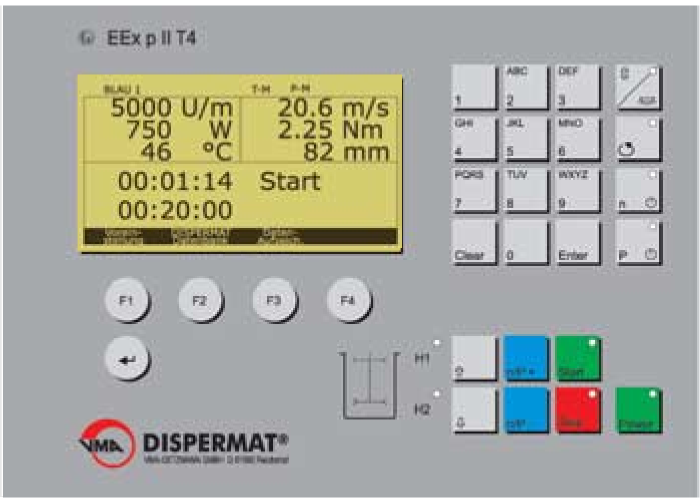
Software WIN-DISP



DISPERMAT®
SL-M EX

The DISPERMAT® SL-M EX explosion proof bead mills have variable speed control.

The compact instrument control box is conveniently mounted at the mill. Speed and product temperature are indicated.



DISPERMAT®
SL-C EX

with process control measurement of :

- Speed (rpm)
- Power input (W)
- Torque (Ncm)
- Work (Wh)
- Product temperature (°C/°F)
- Peripheral speed of impeller (m/s, ft/min)

The DISPERMAT® SL-C EX enables a dispersion at either "constant speed" or "constant power". The measured values are shown on a digatal display. An RS 232 serial port enables the data to be transmitted to a PC for processing with WIN-DISP software (see page 17-22).

Accessories for the DISPERMAT® SL Bead Mill

FP and FP-EX Feeding presses

To process high viscosity and non-flowing materials with the bead mill, the feeding press system is required.

The feeding press with integral control panel uses a pressure piston to force the product through the milling chamber.

The DISPERMAT® SL supply vessel is removed and replaced with a solid stainless steel vessel (capacity 500 ml or 1000 ml).

After pouring the material into the vessel (if necessary, with a spatula), the press is attached to the vessel with a quick clamping ring.
The lifting/lowering speed of the pressure piston can be infinitely adjusted so that the flow rate of the material to be processed can be accurately set. When the piston reaches its lowest point, the press switches off automatically.The piston is raised and the press is moved aside after loosening the quick clamping ring. If a foil is placed between the vessel and piston prior to starting, the pressure piston does not require cleaning.

Feeding press FP 80 EX

Type	Supply vessel volume ml	Flow rate ml/s	Voltage/ frequency in V/Hz
FP 80	500	1 - 5	400/50
FP 80 EX	500	1 - 5	400/50
FP 100	1000	2 - 10	400/50
FP 100 EX	1000	2 - 10	400/50

Bead Mill
DISPERMAT® RS 5

The DISPERMAT® RS 5 is a horizontal bead mill for pilot plant and production applications. The compact, functional design ensures an extreme easy and safe handling as well as outstanding dispersing results.

- infinitely variable speed via modern frequency converter
- stirring shaft with double bearing is hollow for improved millbase heat transfer
- mechanical seal system with integrated cooled thermo-siphon container for lubrication liquid and safety pressure valve.
- adjustable dynamic gap bead separation system
- complete safety device
- simple central operation and control
- pressure control by manometer with electrical contact
- Non explosion-proof on request

DISPERMAT® RS 5 C-EX

- motor power: 15 kW
- speed: 0 - 2600 min^{-1}
- milling chamber volume: 5 l

The DISPERMAT®RS is also available explosion-proof on request