Dispersing without grinding media

Efficient tool for dispersing pigments and other material can save energy

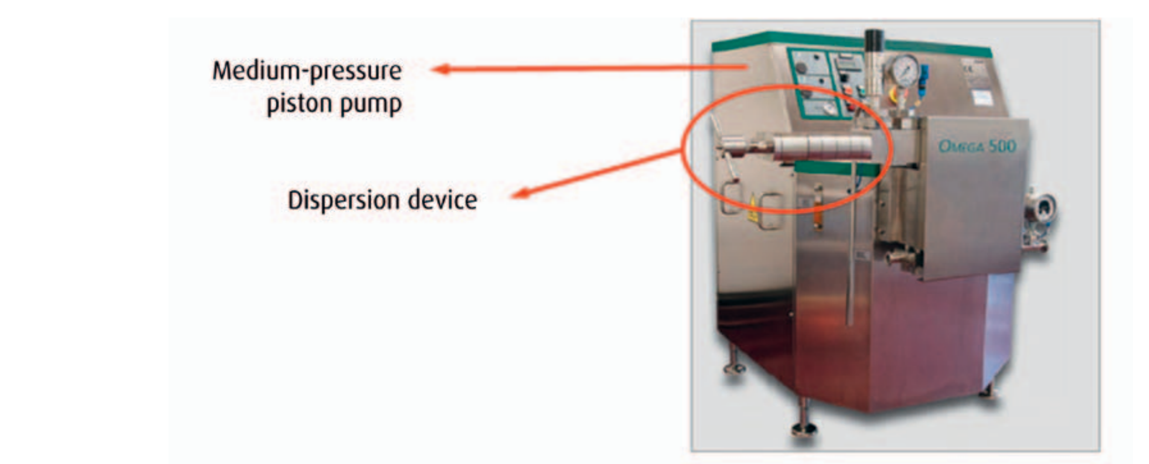

Figure 1: Design of the economic dispersion device

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Grinding or dispersing processes are used in the manufacture of many different products. For some applications, where the goal is to achieve deagglomeration, disaggregation or delamination, manufacturing technologies are often applied for which optimisation is both desired and necessary. A new production technology enables optimisation for such applications in terms of power requirements, output and service life of the production machinery, as well as ease of cleaning and operation.

Results at a glance

››› The economic dispersion device represents an advance over conventional manufacturing technologies with respect to energy requirements and output as well as ease of cleaning and operation.

››› The economic dispersion device operates in a similar way to commercially available high-pressure homo-genisers, which can be run at pressures up to 3000 bar, but due to the unique modular construction of the dispersing unit the tool operates with a maximum pressure of 700 bar.

››› The application range of the machine lies in the area of deagglomeration and light disaggregation tasks, but also the delamination of flaky particles, the defibration or unbundling of natural fibres or carbon nanotubes, as well as emulsification. Examples include the dispersion of titanium dioxide pigment.

››› Feasibility tests can be carried out on both the laboratory and pilot plant scale in applications laboratories. In addition, comprehensive, modern analysis is available for determination of the success of the dispersion process and the change in the product viscosity.

The function of the Economic Dispersionizer "Omega" is similar to that of a high-pressure homogeniser. Due to the unique modular construction of the dispersing unit, the essential difference is that the tool operates with a maximum pressure of 700 bar. Compared with agitator bead mills or high-pressure homogenisers, savings in energy of more than 50 % can be achieved for some applications.

Comminution processes

The various methods of producing ultra-fine particles by crushing coarse particles are referred to as dispersion methods or 'top-down' processes. For this crushing task, high energy densities such as those realised in agitator bead mills, for example, must be made available. These are used in many branches of industry for the crushing of raw materials as well as the dispersion of ultra-fine pigments and products from 'bottom-up' processes. In contrast to the 'bottom-up' processes, wet grinding in agitator bead mills creates particles that deviate from a spherical shape. The product is in the form of primary particles stabilised in a suspension. For many applications, the product can undergo further processing directly, without additional preparation.
While during true comminution of coarse primary particles, the individual primary particles must be subjected to compressive and impact stresses in order to trigger fractures, these direct stresses often damage agglomerated nanoscale primary particles during dispersion. This is due to the change in the mechanical properties of the product particles from brittle-elastic to plastic with decreasing size. Material structure transitions from crystalline to amorphous, or mechanochemically-triggered reactions, can have a negative effect on product properties. Agglomerates of nanoscale primary particles should therefore be stressed primarily through shearing.
The use of extremely small grinding media at very low peripheral speeds in an agitator bead mill can accomplish this task. However, in most cases, turbulent shear flows combined with high differences in speed and cavitation stresses lead to more energy-efficient dispersion processes. This is the basis for the economic dispersion device that is the subject of this paper. Through the optimal

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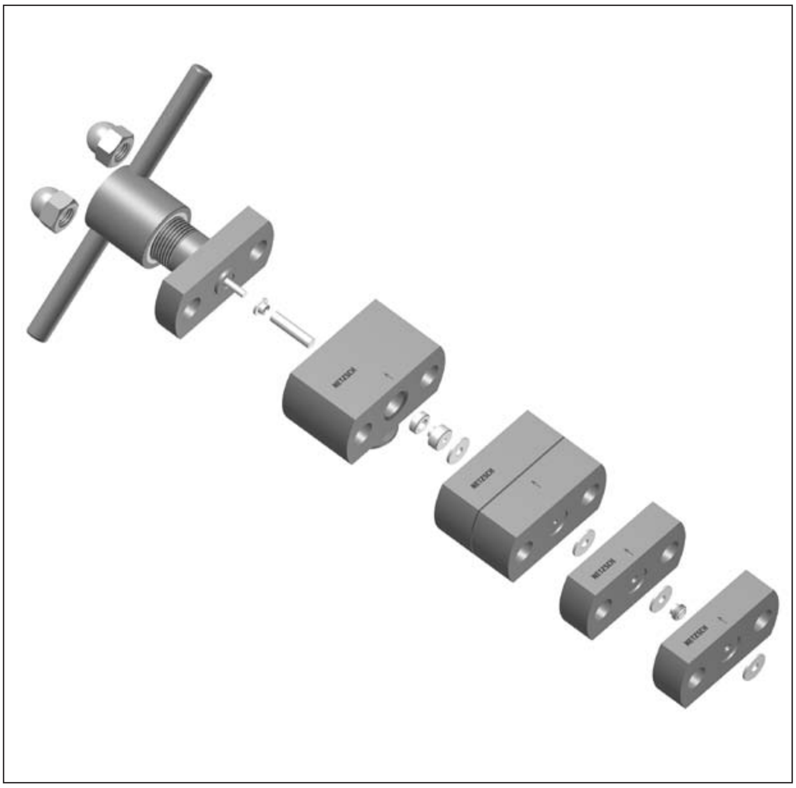

Figure 2: Design of the dispersion device with valve (1), turbulence (2), nozzle (3) and filter module (4)

Figure 3: Titanium dioxide suspension after one pass

use of factors, including turbulence, cavitation and shear forces, the machine guarantees the greatest possible reproducible product quality with considerably reduced energy expenditure and maintenance and minimal heat generation during dispersion.

Operating principle

The economic dispersion device operates in a similar way to commercially available high-pressure homogenisers, which can be run at pressures up to 3000 bar. Major differences relate to the modular construction of the dispersing unit. The product dispersion is pumped at a constant flow rate through the dispersion device, as shown in *Figure 1* and *Figure 2* by means of the medium-pressure piston pump. In the process, the filter module retains contamination such as fibres, hair or coarse particles in order to prevent clogging or damage to the nozzle module. In the nozzle module, the dispersion is accelerated to speeds up to 350 m/s, which is why the first shear and elongation stresses appear at this stage. The latter can be understood as an expansion of the material in the dispersed phase due to the high accelerating force and is relevant primarily for emulsification. In the turbulence module, the product dispersion experiences combined stress, caused by the turbulent shear flow and the cavitation after exiting the nozzle. In the production of emulsions, the deformation in laminar elongational flow into, and upon exit from, the nozzle is responsible to a great extent for atomisation of the droplets of the dispersed phase. For applications in the paints and coatings industry, this laminar elongational flow provides for effective incorporation of additives into the formulation. The pressure drop across the nozzle, and thus the level of active forces, can be regulated via the nozzle diameter and the flow rate.
In a second pressure stage, the homogenisation gap in the valve module can be adjusted by means of spring resistance after the turbulence module. Thus, pressure can be built up again independent of the pressure drop across the nozzle. This pressure is converted to kinetic energy in the homogenisation gap, whereby the combined stress of turbulent flow, shear and impact forces acts in this component. With the independent control of the pressure drop in the nozzle and valve, the effective forces can be optimised for each product and application through selection of the operating parameters.

Machine sizes

The machine is available in various sizes, as shown in *Table 1*. The flow rate can be varied by means of a frequency converter and the dispersing unit can be customised to the particular product requirements with various nozzle modules and valve settings. A scale-up from test results to larger outputs is thereby ensured.

Advantages

The combination of shear, turbulence, cavitation and impact stress is important for an efficient dispersion process. Compared to commercially available high-pressure homogenisers, analogous, or somewhat bet-

Figure 4: Aqueous CNT suspension (left), aqueous cellulose suspension (right)

ter, dispersion results can be achieved at a maximum pressure of 700 bar due to the unique modular construction of the machine.
The considerably reduced pressure drop across the dispersing unit leads to an energy saving that can potentially exceed 50 %. Additional energy saving results from the lower cooling capacity required, since the reduced pressure drop leads to the generation of considerably less heat in the product. The flow control in the tool's dispersion device results in only minor wear on the nozzle and valve modules.
The construction and short holdup of the dispersion device facilitate easy cleaning and quick product changes without cross-contamination. An exchange of individual modules, disassembly or assembly for cleaning or maintenance requires only a few minutes, as the individual modules are mounted on two bolts and secured with two nuts, as shown in *Figure 2*. Likewise, individual modules can be removed if necessary, such as the filter module when processing fibres or pelletised carbon black.

Applications

Grinding media is not required for dispersion with the machine, so the technology is not, therefore, suitable for true comminution or for difficult disaggregation of particles that are partially connected to one another by solids bridges. In contrast to agitator bead mills, grinding progress and, hence, required colour values cannot be achieved through the selection of suitable operating parameters. The application range of the machine lies in the area of deagglomeration and light disaggregation tasks, but also the delamination of flaky particles, the defibration or unbundling of natural fibres or carbon nanotubes, as well as emulsification.
Prior suspension of the solids or emulsification of the liquids is required in every case for application of the machine technology. Ideally, the dispersed substances are distributed homogeneously in the dispersion medium and perfectly wetted with no air bubbles. Alternative optimised machines for the suspension stage of the process exist.

Titanium dioxide applications

Conceivable applications are, for example, products that are easy to disperse, for which the device would constitute an optimisation of the existing production system. One good example is the dispersion of titanium dioxide, as shown in *Figure 3*. In a specific case, the required target fineness is achieved by the machine in one passage. After measurements based on static laser light scattering, the particle size is reduced from 50 µm to a maximum size of 10 µm. In addition to efficient dispersion, highly viscous suspensions can also be processed, thereby achieving high solids contents.
Further, it is conceivable that the device could be used in a process with products that are difficult to disperse, for which the first step of comminution is predispersion in an agitator bead mill. This would allow the use of smaller grinding beads in the mill, which would increase both the efficiency of the mill and the entire value-added chain.

Defibrillation of natural fibres or unbundling of carbon nanotubes

Other good application examples include the unbundling (separation) of carbon nanotubes (CNT) as well as the defibration (defibrillation) of natural fibres. Both applications usually present two challenges for processing in agitator bead mills. First, these suspensions reach a very high viscosity even with very low solids content, so that safe operation of the mill is often only possible with large grinding media. Second, when stressed with large grinding media in an agitator bead mill, the fibres or tubes are often shortened unintentionally.
In contrast, highly viscous suspensions can be safely processed with the machine as illustrated in *Figure 4*. Here, the defibration and separation of the CNTs or fibres is achieved through the combination of shear forces in the nozzle and turbulent shear forces in the turbulence and valve modules. Since there is no contact with crushing elements such as grinding media, the fibers or tubes retain their original lengths to a great extent.

Table 1: Different economic dispersion tool models

	"Omega 60"	"Omega 500"	"Omega 2000"	"Omega 4000"
Flow rate [l/h]	18 – 60	150 – 500	600 – 2000	1200 – 4000
Operating pressure [bar]	10 – 700	10 – 700	10 – 700	10 – 700
Nominal power [kW]	4	15	55	90
Number of pistons	2	3	3	3
Connections	DN 25	DN 32/25	DN 50/25	DN 70/50
Hold-up [l]	0.7	1.5	2.1	3.5