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NANONISATION BY DRY GRINDING

Steam is power

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A new method of grinding for jet mills that allows finenesses in the submicron range to be obtained was described in the April 2010 issue of cpp in an article headed "Economical using steam". Such finenesses had until then been unattainable with dry grinding. This established process, known as the s-Jet system, is meanwhile operating successfully in numerous applications.

Dry fine grinding of solid matter was previously understood to mean size reduction down to about 2 to 200 µm (d97). As the need for considerably finer products has increased steadily in the last few years, a technology which effectively enables dry grinding down to the submicron range has now been developed. The difference between the s-Jet system (Figure 1) and conventional dry grinding processes with jet mills is that in the former superheated steam is used as grinding gas instead of compressed air. The maximum jet speeds with steam are around 1200 m/s and thus approximately double those with compressed air. As a result, the discrete energy input is practically quadrupled, facilitating final finenesses that used only to be possible with wet grinding.
However, in addition to increasing the energy input for grinding solids to the above-mentioned final finenesses, precise monitoring of the grinding process is also necessary, i.e. the particle dwell time in the mill up to the desired final fineness must be carefully controlled. An air classifier integrated in the mill separates the particle sizes in the s-Jet system exactly. This is a fundamental difference compared to other steam mills employed in specific branches of industry. These older systems, which are usually based on spiral jet mills, operate without an air classifier and are therefore not capable of producing clearly defined particle sizes in steam operation.
As steam has a considerably lower dynamic viscosity and a correspondingly higher sound velocity than air, the maximum peripheral flow rate within the classifier wheel increases and with it the acceleration forces which influence the product to be classified. For example, if the peripheral speed goes up from 200 to 300 m/s, the effective centrifugal force of the particles increases 2.25-fold. Centrifugal force is mass x acceleration. The centrifugal force therefore increases in line with the centrifugal acceleration. This is the decisive factor which enables particles to be classified down to the submicron range by dry grinding.

Figure 1: The s-Jet system uses superheated steam as grinding gas instead of compressed air

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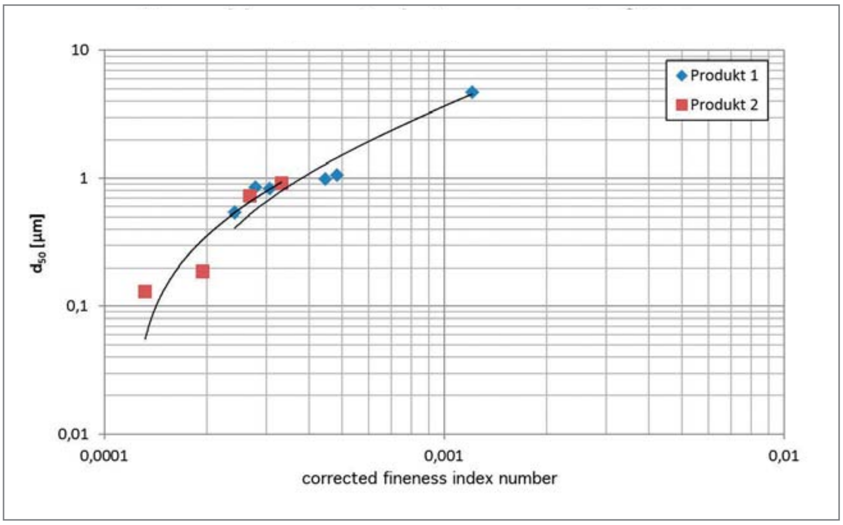

Figure 2: Grinding colour pigments with the s-Jet system

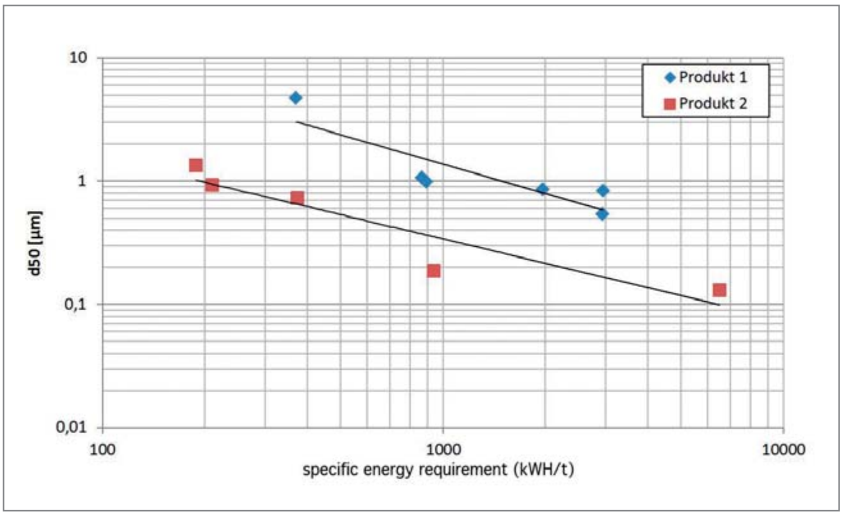

Figure 3: The s-Jet system's specific power requirement for grinding colour pigments

The s-Jet system also has a few interesting economic aspects. If steam is used, the total energy input is approximately 2.6 times higher depending on the steam pressure. The output of a mill can accordingly be increased by a similar factor compared to conventional air operation with the same particle size.

After the grinding system was introduced on the market and the first production-scale s-Jet plant installed at Netzsch-Condux in Hanau, many different products were tested and several more systems installed in industrial production. The results are altogether convincing and speak for themselves.

One s-Jet system already in place at a customer's facility is used to grind colour pigments. The d50-value obtained during tests is plotted in Figure 2 as a function of the fineness index number. This number considers the geometric and operating parameters of a classifier wheel and is defined as follows:

$$\xi = \frac{D_F}{D_i^2 \times H^{0,5}} \times \frac{\dot{V}_L^{0,5}}{n}$$

D_F describes the diameter at the fines outlet and D_i the diameter on the inner edge of the beater while H_F is the height of the fines outlet on the classifier wheel. This formula also includes the gas volume flow and the speed at the classifier wheel. The fineness of a product ground with steam is calculated using the corrected fineness index number, which takes account of the product viscosity. The smaller this value, i.e. the smaller the D_F or the volume flow and the greater the D_i, H_F or classifier speed, the finer the ground final product.

The speed of the classifier wheel, the diameter of the immersion tube and the nozzle size were each varied in grinding tests on the s-Jet 500 steam jet mill. The 40 bar, 320 °C superheated steam was produced separately in a steam generation plant. The fineness measurements were carried out on a Cilas measuring device in a wet medium.

The particle sizes of both feed materials achieved on an air jet screen were very coarse with residues of 29.5 % larger than 500 µm and 22.2 % larger than 1000 µm. However, d50 values of less than 1 µm were obtained for product 1 using the s-Jet process. An even finer result was obtained for product 2, which was ground using a different type of nozzle and a smaller immersion tube. A lower d50 value means a lower fineness index number with both products.

The specific power requirement indicates the adiabatic energy requirement according to the throughput. The adiabatic energy requirement Ead specifies the grinding efficiency with the selected operating parameters (mill inner pressure, steam pressure, amount of steam and grinding steam temperature) independently of the production efficiency factor (one-step, two-step, cooled, uncooled, etc.).

The specific power requirement per ton of final product is plotted in Figure 3 as a function of the d50 value obtained. A lower steam volume flow was available for product 2 owing to the different parameters, leading to a reduction in the specific power requirement for the same range of finenesses (0.5 to 2 µm). On the other hand, both curves show an increase in the power requirement as the fineness increases.

Fine and economical

To ensure the best possible energy and fineness values, products were ground both in steam operation and with compressed air in a low-pressure process (e-Jet system). The e-Jet (e = economical, energy-efficient and ecological) is a grinding system developed by the same manufacturer which cuts energy costs by up to 30 % compared to classic jet mills thanks to its customised grinding conditions and optimised process. It does this using a low-pressure compressor, which compresses the air in a single step to a maximum of 3.5 bar(g) at a maximum temperature of 225 °C. No intermediate cooling is necessary, meaning the entire energy is conserved and can be utilised. Providing certain conditions are met, subsequent cooling of the air downstream of the compressor can be dispensed with.

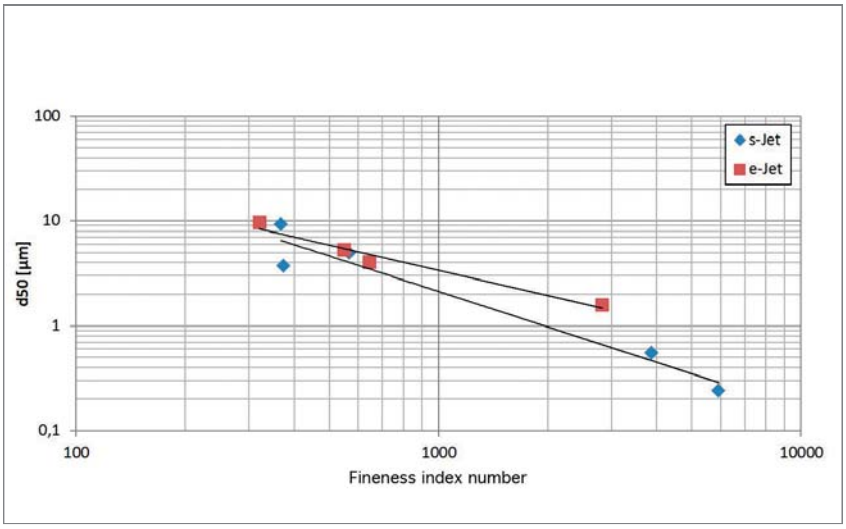

Figure 4: Grinding of silicium carbide with the s-Jet and e-Jet systems

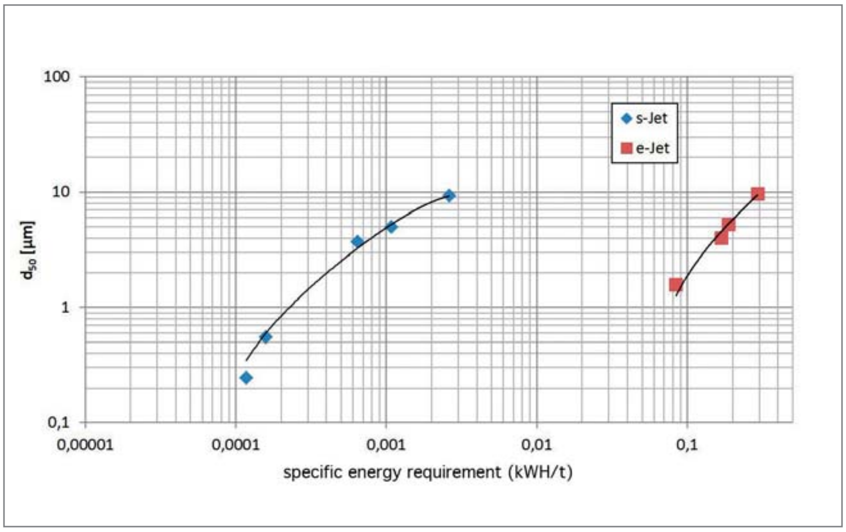

Figure 5: Specific power requirement of the grinding process in Figure 4

Fine-grinding of silicium carbide

Figures 4 and 5 present the results of tests carried out on an existing plant for fine-grinding silicon carbide (SiC). Figure 4 shows that particle sizes in the submicron range (smaller than 1 µm) can be produced using steam as the grinding medium. The same product can be ground much finer with the s-Jet process. Within the same range of finenesses (1 to 10 µm) the index number in steam is lower than with the e-Jet by a factor of 10^{-2}.

An increase in the specific power requirement was noted in both processes at higher finenesses of the final product (Figure 5). Between 2 and 10 µm (d50) the requirement was almost identical in the low-pressure and s-Jet processes.

Conclusions

The production of nano-scale particles in steam operation has passed its baptism of fire. The s-Jet grinding process opens up promising options for dry production with an exact particle size distribution. The results confirm that particle sizes which were previously only attainable with wet grinding can now be produced by dry grinding. The traditional drawback of subsequent product drying, which used to be unavoidable in many applications, no longer applies.

The requirements of industry – both the presentation of new, product-specific applications and the technical design of the machines – are thus now met by process machinery manufacturers.

SUITABLE FOR THE LAB

Grinding process with superheated steam

Following the successful launch of the s-Jet grinding process, detailed discussions with various customers showed that there was also a demand for this new technology in laboratories or for small-scale production. A compact steam-jet mill plant was therefore developed for this purpose. The s-Jet 25 system integrates all the necessary components such as dosing, milling, product separation, control, valves and steam generation on a single skid. The space required for this system is only 3 m² and the maximum height a mere 2450 mm.

During the development phase, great care was taken to ensure that the system was especially suitable for manufacturing very small amounts and product samples. An ergonomic design was a further requirement along with the condensation of the waste steam vapours produced during the process. This in turn allows flexible installation of the system (available as an option). The product is fed via a gravimetric dosing system and an injector. The filter cloth used in the product separation filter is ideal for hot-steam applications and guarantees a residual dust content of <1 mg/m³.

The steam generator is a compact unit installed on the skid in a separate cabinet next to the grinding plant. All the components necessary for superheated steam production are combined in this cabinet. Grinding steam pressures up to 11 bar(g) and temperatures up to 300°C are possible. The maximum amount of steam which can be generated is around 25 kg/h.

The electrical control system for the plant is also integrated in the skid. An automatic operating mode ensures a high degree of safety and reproducibility. The operator panel features a graphic display. The plant is completely assembled and delivered after internal testing. The central connection points for compressed air, electricity, water and drains permit rapid installation and commissioning.