The Revolution in Ultrafine Grinding

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The E_{max} is an entirely new type of ball mill which was specifically designed by Retsch for high energy milling. The impressive speed of 2,000 min^{-1}, so far unrivalled in a ball mill, in combination with the special grinding jar design generates a vast amount of size reduction energy. The unique combination of impact, friction and circulating grinding jar movement results in ultrafine particle sizes in the shortest amount of time. Thanks to the new liquid cooling system, excess thermal energy is quickly discharged preventing both sample and mill from overheating, even after long grinding times.

The high energy ball mill E_{max} is ideally suited for continuous grinding. The mill does not require cooling breaks which reduces the grinding time significantly compared to conventional planetary ball mills. The extremely high energy input at 2,000 min^{-1} together with the unique liquid cooling system provides perfect conditions for mechanical alloying and colloidal grinding down to the nanometer range.

Figure 1. High Energy Ball Mill E_{max}

Functional Principle

The novel size reduction mechanism of the E_{max} **unites the advantages of different mill types:** high-frequency impact (mixer mill), intensive friction (vibratory disc mill) and controlled circular jar movement (planetary ball mill) allow for unrivalled grinding performance. This unique combination is generated by the oval shape and the movement of the grinding jars. The grinding jar brackets are mounted on two discs each which turn in the same direction. As a result, the jars move on a circular course without changing their orientation. The interplay of jar geometry and movement causes strong friction between grinding balls, sample material and jar walls as well as rapid acceleration which lets the balls impact with great force on the sample at the rounded ends of the jars. This significantly improves the mixing of the particles resulting in smaller grind sizes and a narrower particle size distribution than achieved in ball mills.

Faster – Finer – E_{max}

Benchmark test: fineness and grinding time

Grind sizes on a nanoscale can only be achieved by wet grinding. For this method a large number of grinding balls with diameters of 0.1 mm to 3 mm is used to create as much friction as possible. **The resulting grinding energy is extended even further by the high speed of 2,000 min^{-1} in the E_{max}.** The high energy input is fully exploited as the unique liquid cooling system quickly discharges the frictional heat. Without effective cooling both sample and mill would overheat. Depending on the sample characteristics and grinding mode, cooling breaks of approx. 60% of the total grinding time are recommended for conventional planetary ball mills to prevent overheating. The E_{max}, on the other hand, is suitable for continuous grinding without breaks thanks to its efficient liquid cooling system.

In a comparative trial, the pigment titanium dioxide was pulverised in the most powerful planetary ball mill and in the E_{max} (50 ml grinding jar of zircomium oxide, 110 g matching grinding balls 0.1 mm Ø, 10 g sample, 15 ml 1% sodium phosphate).

After 30 minutes the d_{90} value of the E_{max} sample was 87 nm. The planetary ball mill achieved a grind size of only 476 nm after this time (excl. cooling breaks). Consequently, the E_{max} provided a 5 times higher final fineness than the planetary ball mill *(Figure 2)*.

Grinding of titanium dioxide in the E_{max} and in a planetary ball mill

	d_{10}	d_{50}	d_{90}
E_{max} (after 30 min.)	57 nm	69 nm	87 nm
Planetary ball mill (after 30 min. excl. cooling breaks)	66 nm	105 nm	476 nm

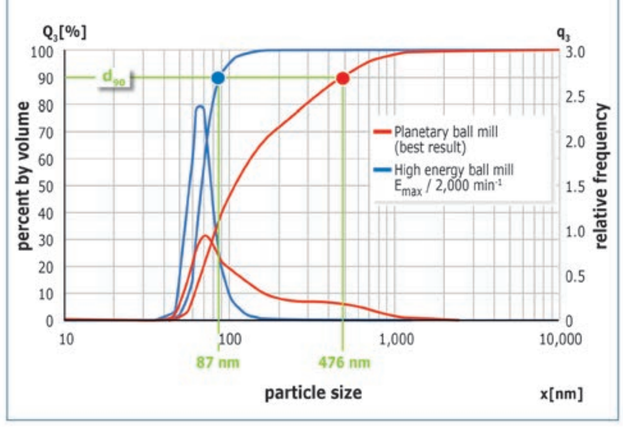

Figure 2. The E_{max} pulverises the sample not only faster and to a finer size, it also produces a significantly narrower particle size distribution.

Comparison of grinding time and fineness in the E_{max} and in a planetary ball mill

Grinding time E_{max}	1 h	2 h	4 h	8 h
Final fineness	13.0 µm	8.2 µm	5.5 µm	1.7 µm
Planetary ball mill (excl. cooling breaks)	**1 h**	**2 h**	**4 h**	**8 h**
Final fineness	25.0 µm	20.3 µm	16.2 µm	12.6 µm

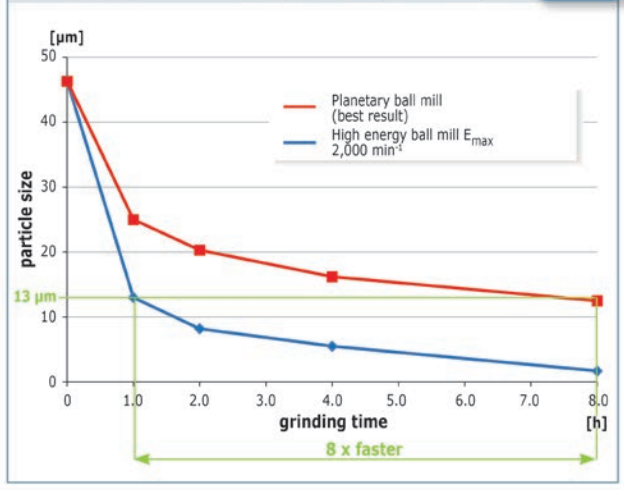

Figure 3. Pulverisation of graphite. The water-cooled Emax is highly superior to the planetary ball mill without cooling system both in speed and achieved final fineness.

Benchmark test: grinding time

The superiority of the E_{max} is even more visible when looking at the grinding time. *Figure 3* shows the results of grinding graphite in the E_{max} at 2,000 min^{-1} (50 ml grinding jar of zirconium oxide, 110 g matching grinding balls 0.1 mm Ø, 5 g sample, 13 ml isopropanol) and in the most powerful planetary ball mill. Graphite is a lubricant and therefore requires a particularly high energy input for size reduction. **After only 1 hour of grinding 90% of the E_{max} sample possessed a fineness of 13 microns. This grind size was achieved by the planetary ball mill only after 8 hours of grinding (excl. cooling breaks).** Regarding the final fineness achieved in the E_{max} after 8 hours of grinding, its superior performance again is quite apparent: With a d_{90} value of 1.7 µm the grind size is 7 times finer than the one achieved in the planetary ball mill (12.6 µm).

Highly Efficient Liquid Cooling

The grinding jars of the E_{max} are cooled by an integrated water cooling system. To further reduce the temperature, the mill can be connected to a heat exchanger or the tap. Figure 4 shows the cooling circuit of the E_{max}. The grinding jars are cooled via the jar. The cooling system is very effective because heat is more easily discharged into water than into air. The E_{max} software allows the user to carry out the grinding process within a defined temperature range, i.e. he can set a minimum and a maximum temperature.

When the maximum temperature is exceeded, the mill automatically stops and starts again upon reaching the minimum temperature. Cooling can be an essential advantage, especially if heat-sensitive samples are processed or if isopropanol has been added to the sample. Isopropanol evaporates at 82°C which makes the pressure inside the jar rise considerably. If the temperature remains below this value, the pressure inside the jar and the stress on the sealing are reduced. Moreover, the grinding jar can be opened shortly after the grinding is finished.

Maximum Safety

During product development of the E_{max} special attention was paid to operational safety. The position of the grinding jar is automatically monitored, so that the mill cannot be started if the position is not correct. No counterweight is required to operate the E_{max}. Possible imbalances are controlled at all times. If they become too strong the mill automatically stops. The remaining grinding time is displayed and the process can be re-started once balance has been restored.

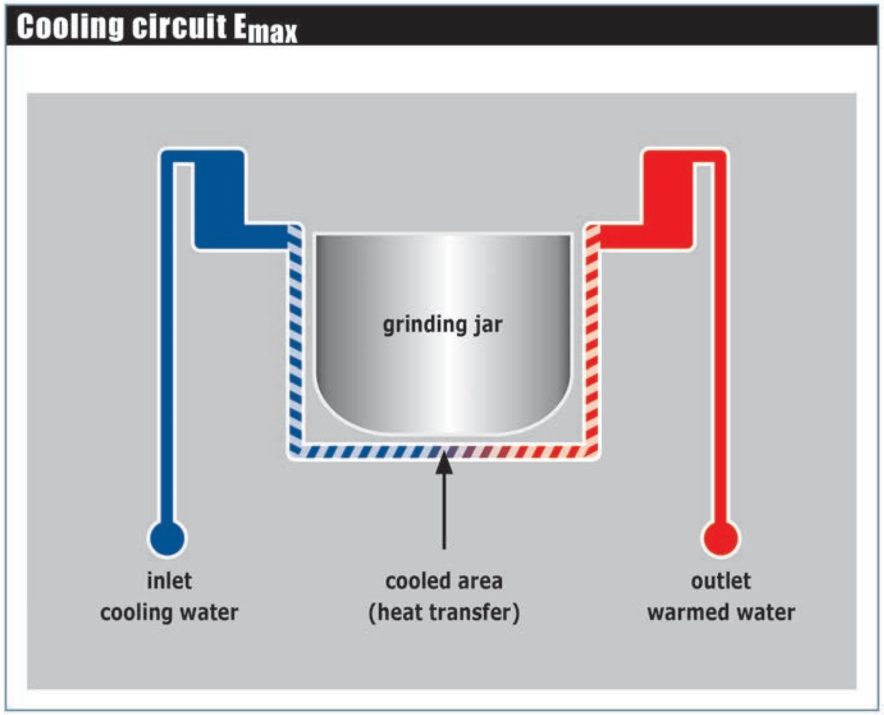

Figure 4. Cooling Circuit inside the E_{max}

Conclusion

The E_{max} opens up a new dimension in high energy milling. The unique combination of friction and impact as well as the revolutionary speed of 2,000 min^{-1} permit the production of ultrafine particles in the shortest amount of time. Thanks to the unrivalled liquid cooling system the E_{max} generates substantially more grinding energy than conventional planetary ball mills – without overheating. Moreover, the water cooling allows for a significant reduction of the grinding time compared to ball mills without cooling that require grinding breaks. The examples shown in this article impressively demonstrate that the E_{max} achieves the desired grind sizes in a fraction of the time required by comparative ball mills.