ECM Technology brings efficiency and Economy to Grinding

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The constantly increasing awareness of quality and the environment as well as the general tendency to rationalize have significantly increased the demands made upon grinding and dispersion technology. This is leading to essential changes in the industry. Existing procedures must be optimized in every aspect. New product technologies often require new and efficient manufacturing processes and plants.

To meet these industrial requirements, the development of a new grinding and dispersion concept was required. The main target was to optimize the circulation and modify the conventional passing procedure in the mill.

Within these new parameters, the high throughput necessary for the circulation processes had to be attained, while keeping maintenance and clean-up work to a minimum. At the same time, the applied drive energy had to be converted efficiently into dispersion performance. WAB therefore developed the Efficient Circulation Mill (ECM) distributed by CB Mills in North America and Latin America. At the core of this technology is the Dyno-Accelerator, an essential component in providing the dispersion and power efficiency mandated by the shifting process paradigm.

CIRCULATION PROCEDURES

In circulation milling, the product is driven in a circle through the mill back into the agitation/holding tank. Then it is mixed with the not completely dispersed material until the required product quality has been attained.

Circulation milling allows the use of less capital equipment and the investment of less cleaning labor when compared with traditional discrete pass operation. The efficiency of this procedure, however, requires that high throughputs be run so that a large number of circulations are possible within a reasonable period of time.

Conventional mills are often limited in throughput capacity, since their grinding shells are designed for providing sufficient residence time to effect dispersion on most materials. The main problem, then, in using a conventional mill in a circulation operation is hydraulic packing.

High-quality products are sometimes run in several fast passes, called the pendulum procedure. In this case, it is viscosity that often limits the throughput.

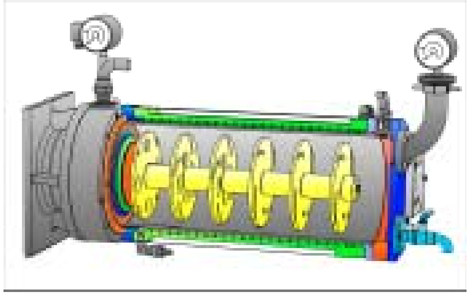


Figure 1: the conventional ball mill has the disadvantage of concentrating the mill media near the separation sites, and creates backmixing, which broadens the size distribution.

The agitator ball mill (Figure 1), which is well known on the market and intended for single pass operation, has a cylindrical horizontal milling container in which an agitator shaft with several coaxial agitator disks are arranged. The milling container is filled up to 85% with hard spherical grinding media (0.3-3mm), which are set into motion by the rotation of the agitator discs.

With circulation and one-passage high-performance processes, the grinding media are dragged along by the strong product current caused by the product feed pump and the stickiness of the product in the direction of the separating device, where the grinding media accumulate. Increases in the milling container pressure, product temperature and mechanical wear in the outlet area are the result of this hydraulic packing. Recirculation bores in the agitator discs create some relief but have the disadvantage of heightened backmixing and therefore create a broader product net particle distribution.

To prevent these drawbacks, an agitator element has been developed that stabilizes the grinding media in the milling container. It does this in axial direction and also prevents backmixing in the milling container through its operating principle, which leads to a tighter dwell time distribution and a higher specific energy density. This agitator element is called the 'Dyno-Accelerator' (Figure 2a), and is employed in the ECM DynoMill.(Figure 2b).

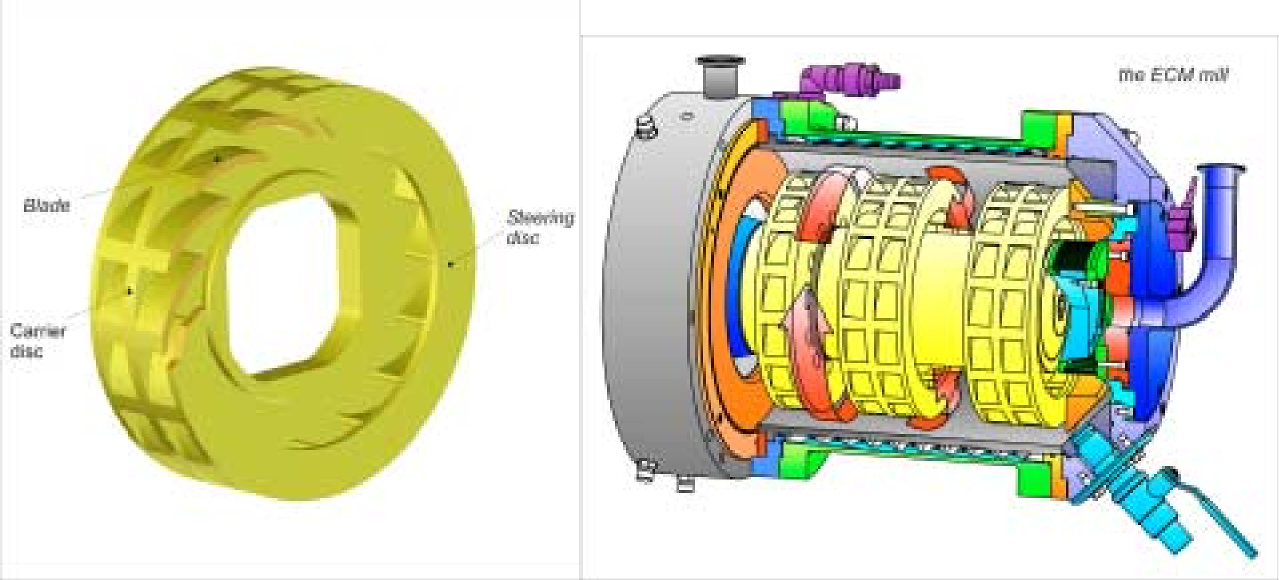
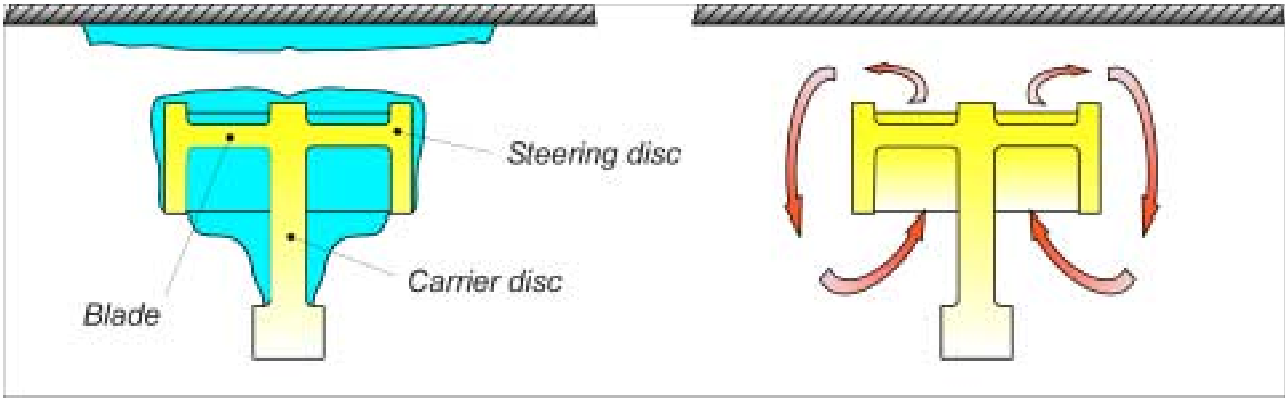


Figure 2: the Dyno-accelerator (2a) is the primary component of the ECM (2b). The grinding path is shown below in (2c).



THEORETICAL BACKGROUND

The energy density in the mill is directly proportional to the degree of fineness that can be expected from the product flowing through it. According to Blecher[1], the crushing in agitator ball mills with disc agitators occurs in two zones with high energy density.

The first zone almost encompasses the agitator disc and the second lies at the grinding shell wall. Within the area of the agitator disc, the grinding media are accelerated among others in the direction of the shell wall and during that process absorbs kinetic energy.

This energy can be used for crushing the particles when impacting on other grinding media or onto the grinding shell wall. There is a strong shear rate at the agitator disc. In addition, the grinding media collide with one another due to differential tangential velocity and can release their potential energy into seized particles. During turbulent flow, 90% of the energy input into the grinding chamber is used for dispersion and crushing in these zones, which makes up approximately 10% of the grinding volume.

Blecher's calculations also indicate that the grinding media are not being circulated all the way into the area adjacent to the agitator shaft. Unground product can be found in these areas, product which upon recirculation destroys the uniform particle size distribution of the product. This phenomenon is sometimes called bypassing.

This inefficient distribution of the energy density and the unfavorable circulation behavior necessitates the construction of big mills with many agitator discs and a high filling volume of grinding media to attain the required performance.

HIGH ENERGY DENSITY STRESS ZONES

If ones takes a look at the Dyno-Accelerator, four main stress zones with high energy density can be identified. These are in the area of the accelerator carrier disc, between the blades, at the grinding cylinder wall and at the steering disc (Figure 2c).

The mixture of the grinding media and product is drawn into the area of the agitator shaft and because of the Dyno-Accelerator construction it is rapidly accelerated to the outside by the multitude of blades in the Dyno-Accelerator.

An internal circulation is built up at the radial-axial level through the pressure differential between the intake and outlet of the impeller. This force is locally much greater than the axial product current. The missing external effect area of the agitator shaft when using conventional discs is created through this forced flow when using the Dyno-Accelerator. The energy input into the grinding chamber is used for crushing in zones that take up around 30-40% of the milling volume, as opposed to 10% for a conventional mill.

Figure 3 illustrates the influence of the Dyno-Accelerators on the grinding result in comparison to the conventional agitator disc. The product used is a 70% calcium carbonate suspension. This also shows the particle size distribution using identical specific energy input. The distribution indicates a better dwell time distribution in comparison to the conventional agitator ball mill (Figure 4).

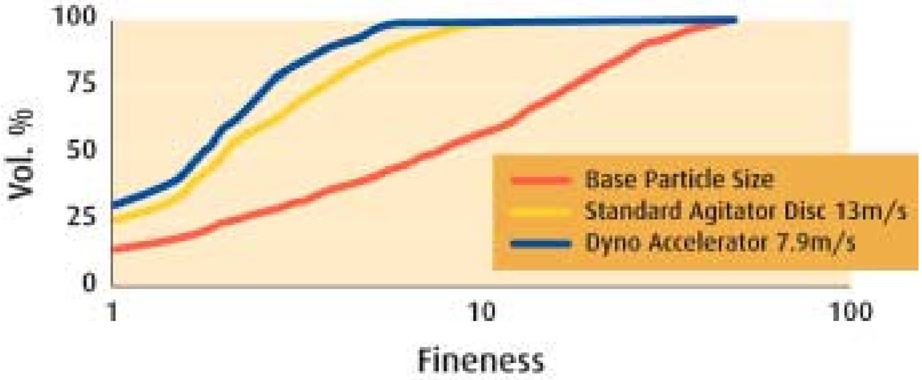


Figure 3: particle size distribution during identical specific energy input.

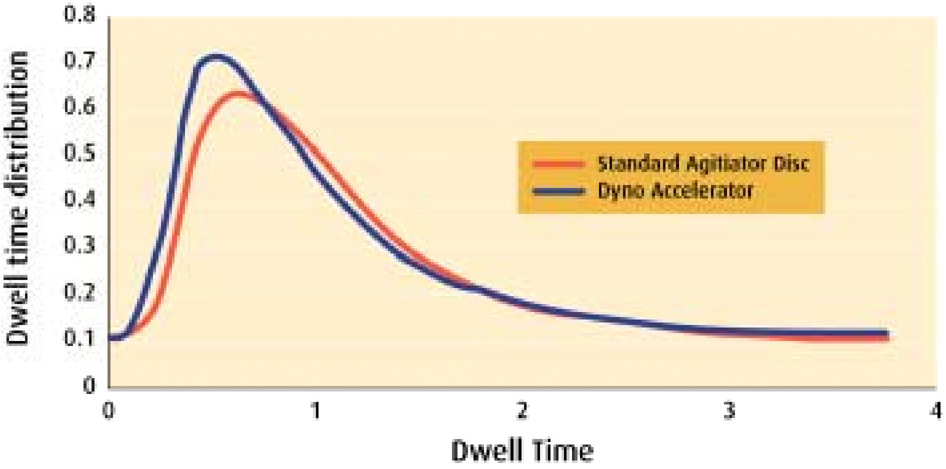


Figure 4: comparison of agitator discs

As Bunge[2] shows, the specific energy can also be understood as a product of the stress intensity and the stress frequency.

$$E_v\text{-} \quad \frac{M_d}{V_5} \; .w.t$$

E_v = Specific Energy
M_d = Intensity of Stress
V_s = Volume in liters
w = Frequency of Stress
t = Time

The movement of the grinding media causes the crushing. The higher the torque $\mathbf{M_d}$ the higher are the forces causing the crushing that is found where higher stress intensity results.

The probability of particles reaching the active crushing space increases with increasing rotational speed ***w*** and longer crushing duration ***t***. The result is the stress frequency. Here, it can be seen that the stress intensity in the Dyno-Accelerator is high because of the stress frequency through the forced internal circulation.

FLOW RELATIONSHIPS IN THE DYNO-ACCELERATOR

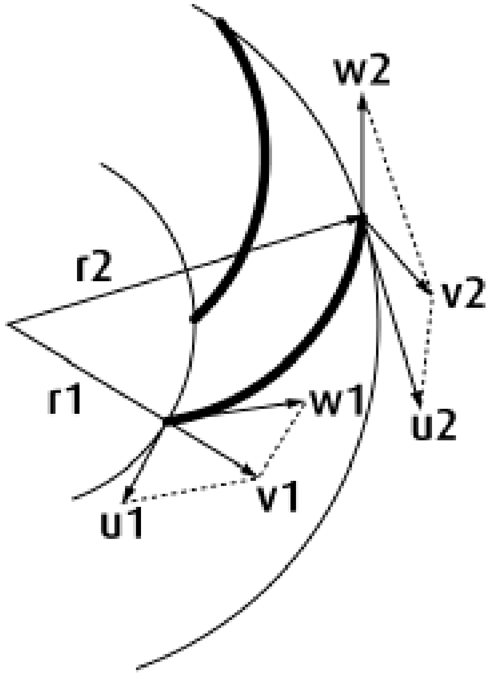


Figure 5: movement and speed relationships of the mixture in the Dyno-Accelerator
r1, r2 - interior and exterior radius of the impeller;
u1, u2 - circumferential speeds;
w1, w2 - relative velocity of the mixture;
v1, v2 - absolute speeds of the mixture.

Figure 5 shows the relationship between the movement and speed of the delivery medium on a blade of the Dyno-Accelerators.

The mixture of product and grinding media that enters axially in the center is diverted from the turning Dyno-Accelerator in a radial direction through the blade channel to the exterior circle. The centrifugal force supplies the mixture with energy on the way through the internal channel.

The speeds ***u1*** and ***u2*** determine the centrifugal force. Because the channel cross-section in the exterior circle is larger than in the internal circle, ***w1 > w2*** applies according to the continuity equation.

The blade forces cause the speed changes that occur in the Dyno-Accelerator. The angular momentum increase between the internal and external accelerator perimeter determines the energy transferred to the mixture in the blade channel. To keep pressure loss as low as possible, the mill mixture enters the Dyno-Accelerator radically with an absolute speed of ***v1.*** The exit angle determines the stress intensity.

CONSTRUCTIVE SOLUTION

The geometrical proportions of the grinding chamber and the Dyno-Accelerators determine the efficiency of the crushing and dispersion, the throughput, wear and heat development.
The proportion of the suction, pressure and exit face velocity must be in an optimum relation since otherwise the pumping effect and therefore internal circulation are disturbed.

With regard to this, the position and shape of the blades play an important role. Blades that are too flat do not grind and blades that are pitched too much cause movement that is far too aggressive, which is expressed in excess wear and inefficient grinding.

The geometry of the Dyno-Accelerators is the result of many laboratory tests and an extensive cybernetic examination.

All of the results and realizations of recent years have been incorporated into the 'ECM Models'. The high energy density created with the Dyno-Accelerator enables a compact design.

Zones with low energy density have been avoided. The employment of ceramic and other high-grade materials ensure high cooling performance and low abrasion despite the high energy density. The media charge level, which can reach 90% in conventional mills, has been reduced to as low as 55% through the function of the Dyno-Accelerator. Table 1 shows some practical examples of test data.

With the ECM, the stress intensity can be adjusted in such a way that the principle proves itself in particular in a wide variety of wet milling applications. Here it is not so much genuine crushing that is required but the breaking down of agglomerates and aggregates. Strong hydraulic movement through the Dyno-Accelerator also leads to high shear forces.

While the ECM has demonstrated superior performance in the recirculation process, discrete mill operation is successful also. Benefits to the ECM are increased production capacity with less energy, less floor space and less labor.

The efficiency of the new agitator blade geometry for dispersion and crushing is successfully realized in the ECM. There are many possible uses of the Dyno-Accelerator, successful trials have been run on calcium carbonate, digital ink, flexographic ink, minerals, ceramic milling, automotive paints, architectural paints, magnetic oxides, to name a few .

References:

[1] L. Blecher, Flow processes in agitator ball mills, article.
[2] F. Bunge, Mechanical cell break down in agitator ball mills, article.

Product	**Demand**	**Mill**	**Grinding capacity**	**Specific energy**	**Temp (º C)**
Alkyd Resin, Inorganic pigment	<15 µm	ECM (18l)	500 kg/h	0.05kWh/kg	50
Nail Polish	Gloss color	*ECM (18l)* *15 l mill*	*125 kg/h* *30 kg/h*	*0.2 kWh/kg*	*54*
Industrial finish, TiO_2	<12 µm	ECM (18l) 45 l mill	1500 kg/h 6.5 kg/h	0.13 kWh/kg 0.3 kWh/kg	60 70
Automotive top coat, iron oxide yellow	<5 µm color	*ECM (18l)* *15 l mill*	*170 kg/h* *6.5 kg/h*	*0.13 kWh / kg* *0.3 kWh / kg*	*55* *60*
Flexo-printing Solvent based	Gloss/Color Strength	*ECM (18l)* *17 l mill*	*120 kg/h* *50 kg/h*	*0.12 kWh / kg* *0.19 kWh / kg*	*50* *40*
Flexo-printing water-based	Gloss/Color Strength	*ECM (18l)* *17 l mill*	*120 kg/h* *40 kg/h*	*0.12 kWh / kg* *0.19 kWh / kg*	*55* *40*
Tint paste,	10-15 µm	*ECM (18l)* *15 l mill*	*150 kg/h* *10 kg/h*	*0.12 kWh / kg*	*42* *45*
Coating varnish	<20 µm	ECM (18l)	800 kg/h	0.25 kWh / kg	60
Inorganic pigment	Color strength	ECM (15l)	600 kg/h	0.05 kWh / kg	45
Pigment paste for printing ink	Gloss/Color Strength	*ECM (28l)* *200 l mill*	*100 kg/h* *60 kg/h*	*0.26 kWh / kg* *0.12 kWh / kg*	*55* *45*

Entries in *italics* denote 3 circulation process

Table 1: milling characteristics of different products are listed together with bead types and bead geometrics.