

Superfine Grinding of CPC with Ball Race Mills – Challenges and Solutions

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Abstract

Claudius Peters did supply several Ball Race Mills to Aluminium Smelters worldwide. The standard application is fed by a calcined petroleum coke with a size <10mm and produces a fine material with a specific surface of 4000 Blaine. In order to develop the system, further tests have been made to identify parameter for a finer finished product. The challenge was to provide CPC dust with 6000 Blaine with similar equipment as the 4000 Blaine material. Such high fineness can be managed following basic rules of grinding in air swept mills. Tests have been done on an industrial scale to verify the effect of such a change of the parameter. The specific power consumption rises from 100 % to 200 % and the iron contamination rises accordingly. Due to the fineness the mill power decreases from 100 % to 67 %. At the end, the mill capacity decreases significantly, but all challenges found a safe and sound solution. The different target could be met without modification to the equipment.

Keywords: Grinding, material handling, energy efficiency, fine grinding.

1. Introduction

Claudius Peters did supply meanwhile 17 EM Ball Race Mills to Aluminium Smelters worldwide. For standard applications mills are available as shown in Figure 1.

The mill shown in Figure 1 is a modern vertical ball ring mill with a dynamic classifier. The material to be ground is fed to the ball ring mill centrally from the top where the material falls down onto the rotating grinding yoke. The yoke and the lower grinding ring are driven by the mill gear. The upper fixed grinding ring, pressed down by the hydraulic system, holds down the grinding balls.

The calcined petcoke is now crushed between the grinding elements and grinding rings and then transported out of the grinding track by centrifugal forces. An air flow directed upwards captures the now ground petcoke and directs it to the classifier integrated in the mill. The excessively large particles are separated from the other particles inside the classifier and return back to the grinding mechanism for renewed grinding. The other particles leave the mill together with the transport gas. The use of a dynamic classifier makes it possible to produce the highest fineness and steepest particle size distribution lines.

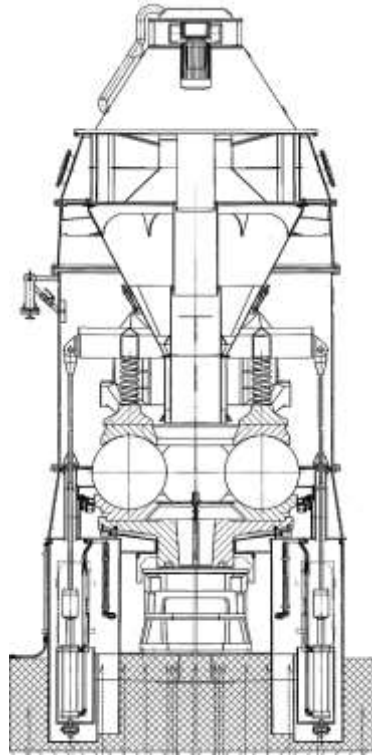


Figure 1. Claudius Peters EM-Mill

The introduction of the vertical spindle mill for production of the fines for the anodes has improved the consistency and quality of the anodes remarkably.

The advantages of this new grinding principle in comparison to the traditional horizontal tube mill amongst other are [2,3,4]:

Product Quality of Fines

The product quality of the fines - defined among other things by the median d_{50} and the range of particle size distribution, the specific surface according to Blaine and the metallic matter from the wear of the grinding elements which come into contact with the product - has a main influence on the production of the green anode paste.

For the production of a consistent anode the consistency of the grain size distribution and the specific surface are decisive.

Metallic components determine the quality of the anode, this way having a negative influence on the quality of the aluminium since they enter the molten metal when the electrodes are burnt during the electrolysis.

Fines Grain Size Distribution

The properties of the fines, characterized by the average grain diameter d_{50} and the grain size distribution or Blaine number, influence the production process of the green anode paste and thus the quality of the anodes.

Continuous Operation of the Vertical Spindle Mill

Conventional grinding processes using a horizontal tube mill with very limited turn-down ratio must be operated in start / stop modus in order to meet the production requirements. With the vertical spindle mill, however, the actual capacity can be turned down by between 100 and 25

percent and the required grain size distribution of fines is obtained in continuous mode without having to stop the plant.

2. Test Setup

To identify the effects of the different material parameter, grinding test in an industrial scale are necessary. The Claudius Peters Technical center has a small EM17-525 installed to do such testing (Figure 2).

This central grinding system is equipped like an industrial plant with all process elements and control systems to simulate a real production situation.



Figure 2. EM 17-525 Test Mill with Control System

The standard application is fed by a Calcined Petroleum Coke CPC with a size smaller than 10 mm and produces a fine material with a specific surface of 4000 cm²/g acc. to Blaine method. The special super fine application is fed by a mono-sized CPC of approx. 1 mm and produces approx. 6000 cm²/g.



**Figure 3. Mill feed - left: standard with natural size distribution < 10 mm
right: feed for super fine grinding mono-size of approx. 1mm**

In order to develop the system, further tests have been made to identify parameter for a finer finished product. The challenge was to provide CPC dust with 6000 cm²/g using similar equipment as for the 4000 cm²/g dust [1].

3. Results from Test operation

In the following all sieve residues were measured with the Alpine Air Jet Sieve and all specific surfaces were measured with the Blaine method using a Tonindustrie device. The power consumption is monitored regularly at the operator screen of the test plant.

3.1. Product Fineness

Figure 4 shows that the given CPC leads to a sieve residue on 32 μm of 25% (= 25%R32) and a median particle size x_{50} of 22 μm , when the specific surface is 6000 cm^2/g . Further on we will focus on these 6000 cm^2/g resp. 25%R32. Results of other finenesses are shown for orientation and for understanding of trends.

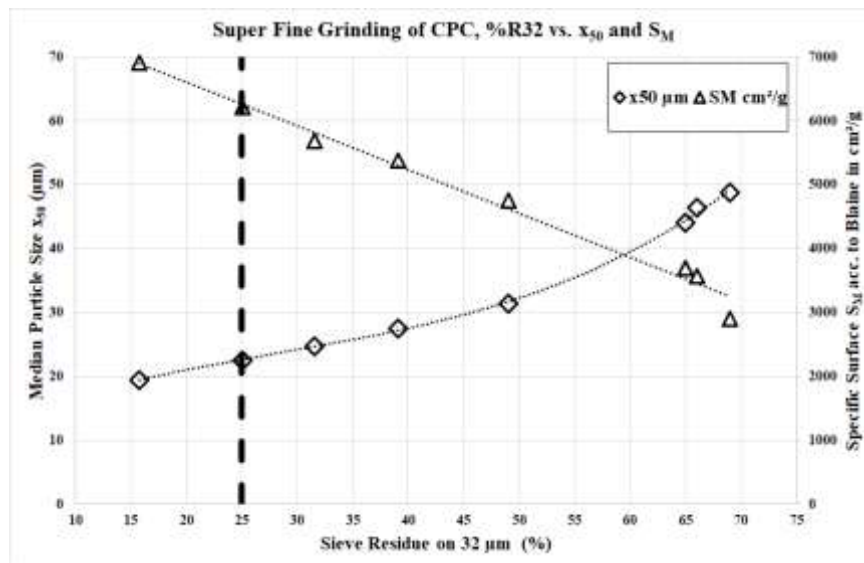


Figure 4. Trends of median particle size x_{50} and specific surface S_M vs. sieve residue on 32 μm

Figure 5 shows that 25%R32 is such fine that the residue on the 90 μm sieve and the residue on the 75 μm sieve is less than 0.1%. Even the residue on the 63 μm sieve is still below 1%. Our reference point in the right corner of Figure 4 is valid for the very typical fineness of 25%R75, which is 75% passing 75 μm . A comparison with Figure 3 shows that this special CPC has a specific surface of 3500 cm^2/g and an x_{50} of 46 μm .

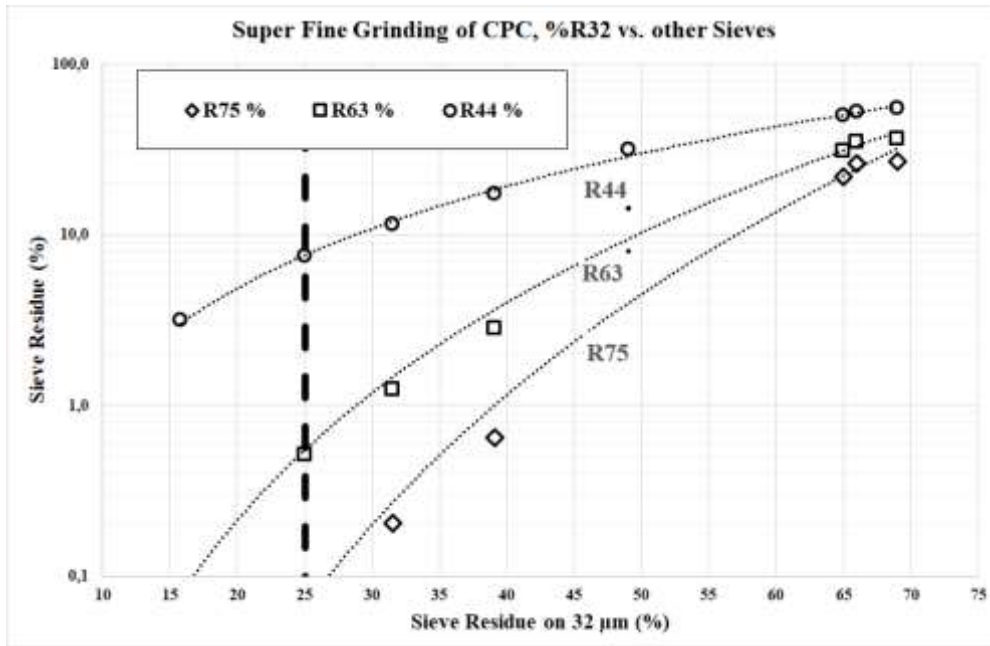


Figure 5. Trends of characteristic sieve residues vs. sieve residue on 32 μm

3.2. Fineness and Mill Capacity

Figure 6 shows the capacity resp. the maximum throughput versus the fineness of the produced dust of the test mill, which is a ball race mill type EM17-525. It has 5 balls of 250 mm diameter. This is the smallest industrial size of Claudius Peters EM-Mills. As bigger industrial CPC mills produce so far not more than 30 t/h the EM17 test mill allows precise predictions with a rather low scale-up factor of usually less than 100. Figure 6 shows, that a standard fineness leads to 0,6 t/h = 600 kg/h, while the capacity at 6000 cm²/g is only in the range 200 kg/h.

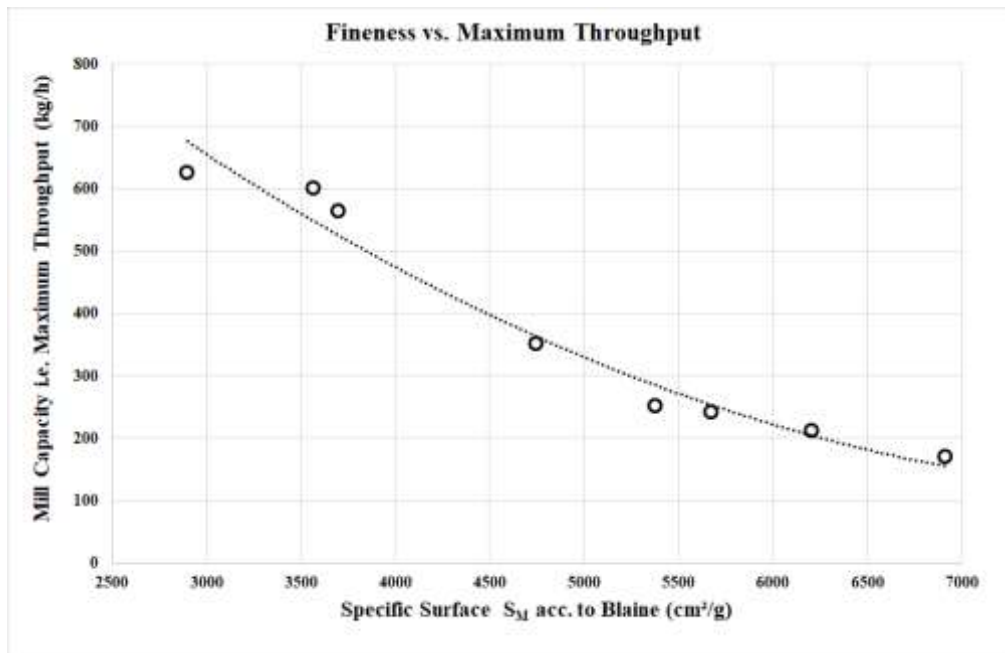


Figure 6. Mill capacity vs. specific surface S_M acc. to Blaine

3.3. Fineness and Power consumption

Figure 7 shows the relative power consumption of the test mill versus the fineness of the produced dust. It is an experimental finding, that the power consumption is lower than in standard applications and lower than expected.

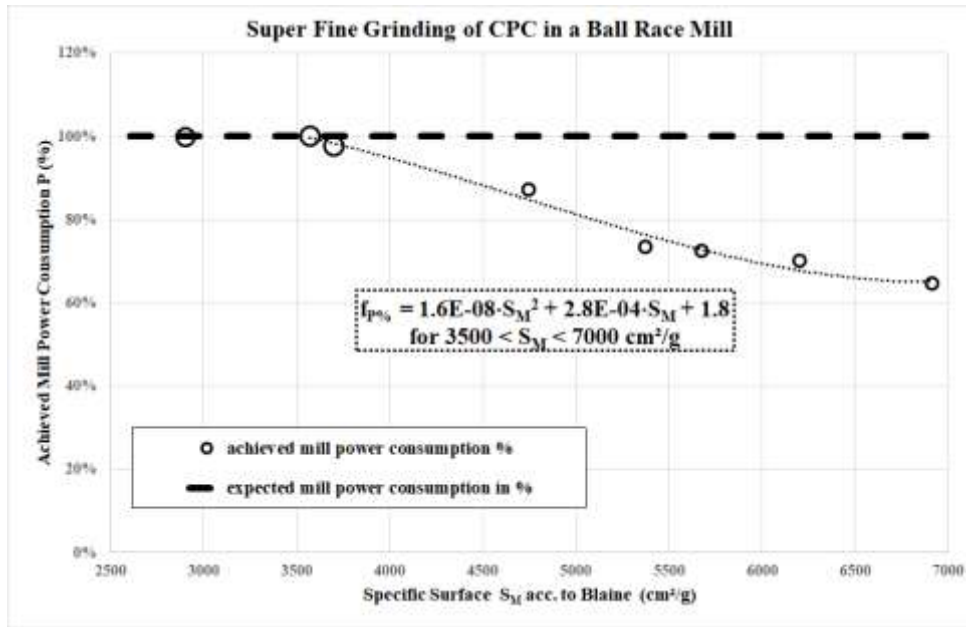


Figure 7. Relative mill power consumption vs. specific surface S_M acc. to Blaine

4. Evaluation

Actually the power consumption is in the range of only 67% when grinding to 6000 cm²/g. Equation (1) describes this behaviour in a regression formula, called power factor $f_{p\%}$.

$$f_{p\%} = (0,000000016 \cdot S_M^2 - 0,00028 \cdot S_M + 1,8) \quad (1)$$

where:

f_p Power factor, %
 S_M Specific Surface, cm²/g

and

$$3500 \frac{cm^2}{g} < S_M < 7000 \frac{cm^2}{g} \quad (2)$$

The mill power consumption is lower than in standard applications, because the mill feed, the mill product and the material circulating inside the mill are much finer than usual. This advantage in power consumption is a disadvantage in mill capacity, as it will be shown later.

Figure 8 brings fineness and spec power consumption together. It follows the “Law” of Rittinger [8]:

**The specific power consumption for grinding W_M
is proportional to the newly created
specific surface S_M .**

$$W_{M,R} \approx (S_{M,p} - S_{M,f}) \quad (3)$$

Where

$W_{M,R}$ Specific Power consumption, kWh/t

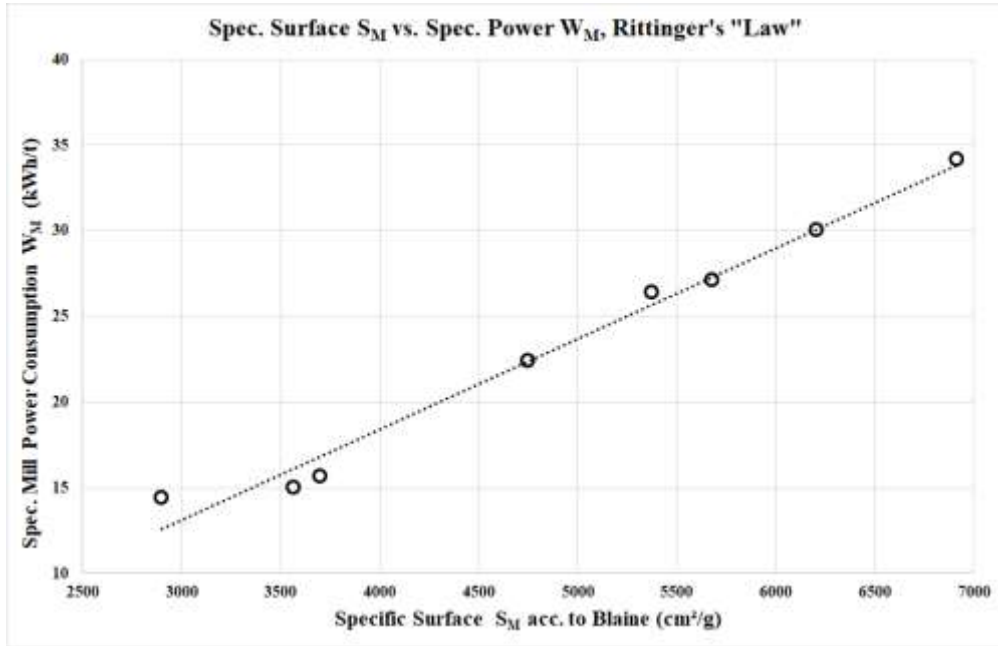


Figure 8. Specific mill power consumption vs. specific surface S_M acc. to Blaine

As the spec. surface of the feed $S_{M,f}$ is much smaller than the spec. surface of the product $S_{M,p}$, Rittinger's "Law" can be simplified to

$$W_{M,R} \approx S_{M,p} \quad (4)$$

Equation 3 describes the straight line in Figure 8.

Rittinger's "Law" can be also written as:

$$W_{M,R} \approx \frac{1}{X_{50,p}} - \frac{1}{X_{50,f}} \quad (5)$$

As the median particle size of the feed $x_{50,f}$ is much bigger than the median particle size of the product $x_{50,p}$, Rittinger's "Law" can be simplified to

$$W_{M,R} \approx \left(\frac{1}{X_{50,p}} \right) \quad (6)$$

The hyperbola shown in Figure 9 has an exponent of -1.04, which is very close to -1.

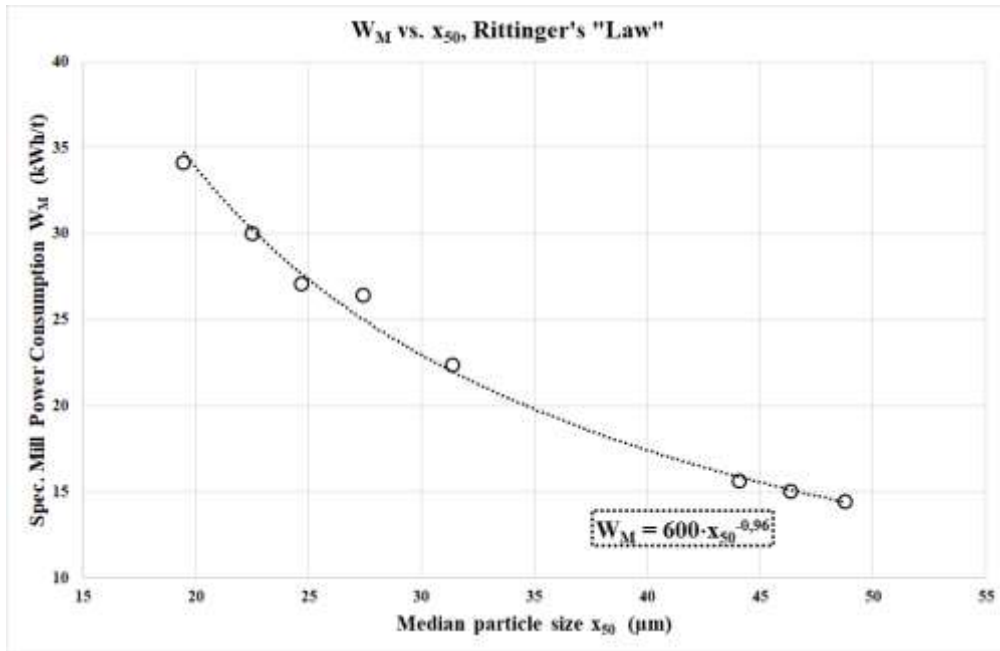


Figure 9. Specific mill power consumption W_M vs. median particle size x_{50}

Figure 10 shows Figure 9 in a reverse way and in double logarithmic scale, as it is often used in general sciences. The straight line proves Rittinger's "Law".

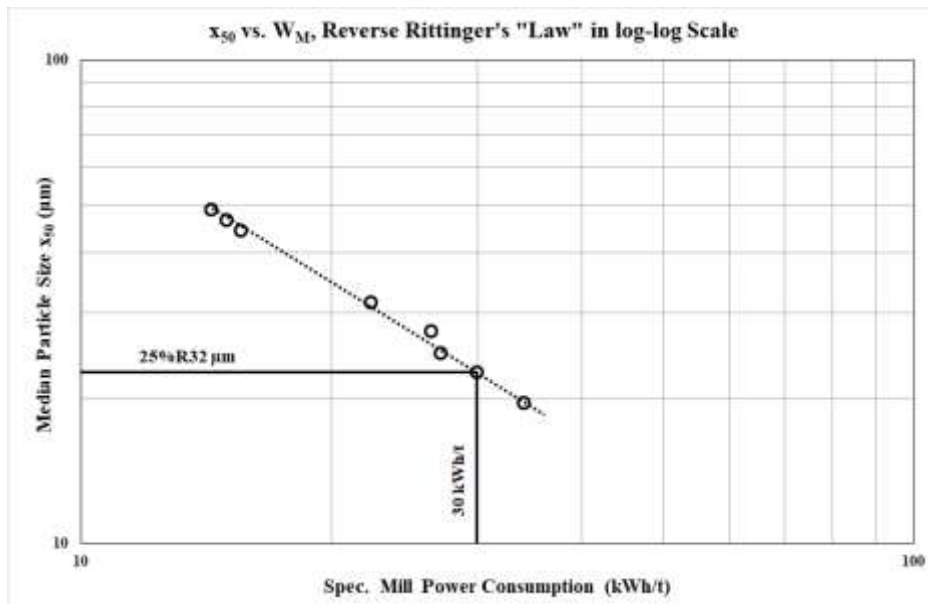


Figure 10. Median particle size x_{50} vs. specific mill power consumption W_M

The specific mill power consumption is not only important for the consumed kWh of electrical energy. It correlates also very well with characteristic numbers like specific wear in g/t resp. iron contamination in ppm. Here we measured that super-fine grinding to 6000 cm^2/g requires twice the specific energy and creates approx. twice the iron contamination of standard application, see Figure 11. However, approx. 120 $\text{g/t} = 120 \text{ ppm}$ is still a moderate value compared to other mill types [5,6].

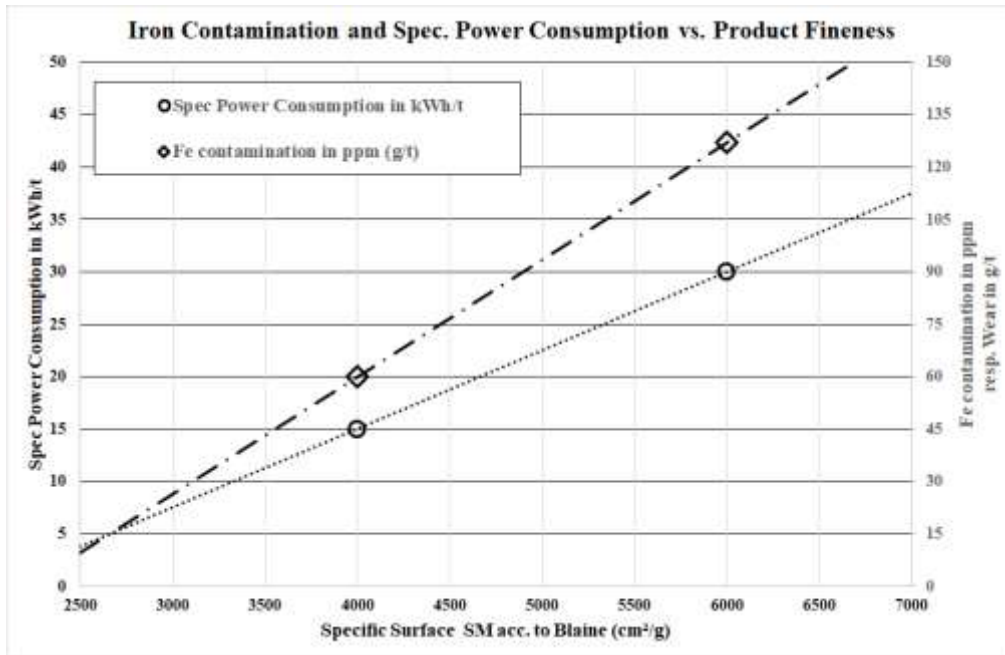


Figure 11. Iron Contamination and Spec. Power Consumption vs. Product Fineness

Figure 12 brings mill capacity i.e. maximum mill throughput and fineness together. Extrapolating experiences of standard grinding applications with ball race mills grown in Claudius Peters since 1906 would lead to the curve called “expected capacity”. Obviously the curve called “achieved capacity” delivers much lower values [7].

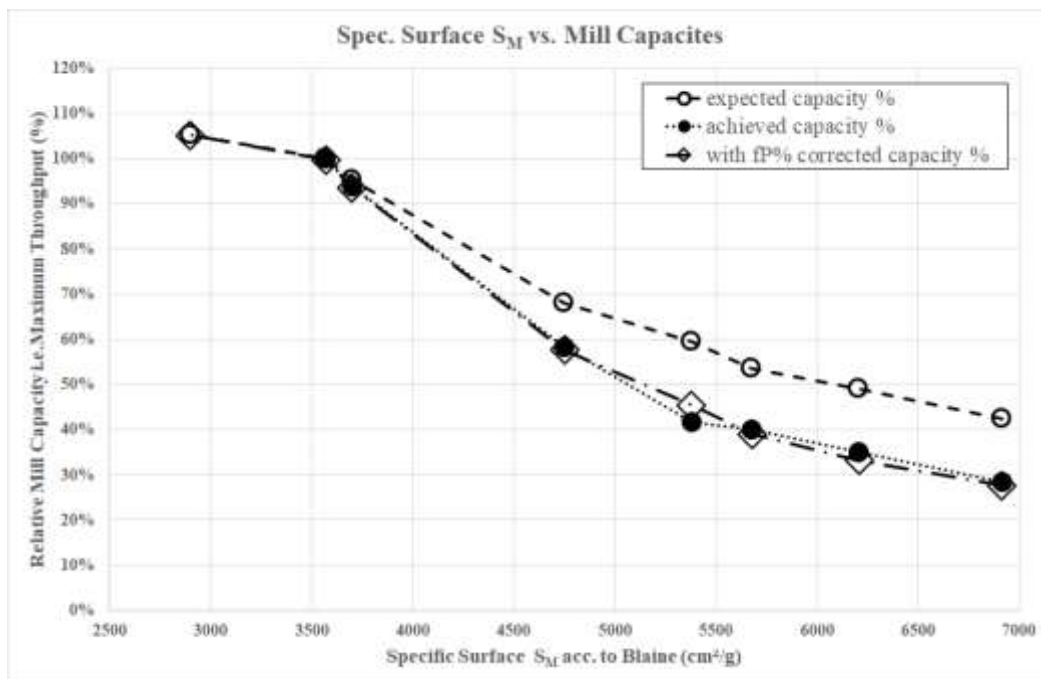


Figure 12. Comparison of relative mill capacities: expected capacity, achieved capacity and with f_p % corrected capacity vs. specific surface S_M acc. to Blaine

However, we have to remember that the power consumption at super fine grinding is lower as in standard applications. We can correct the expected mill capacities using the power factor $f_{p\%}$ of Equation (1).

$$\dot{m}_{rel,corr} = f_{p\%} \cdot \dot{m}_{rel,expect} \quad (7)$$

with

$f_{p,\%}$ Power factor, %

Example:

With:

$S_M = 6200 \text{ cm}^2/\text{g}$

$\dot{m}_{rel, expected} = 50\%$

$$f_{p\%} = (0,000000016 \cdot 6200^2 - 0,00028 \cdot 6200 + 1,8)\% = 68\% \quad (8)$$

$$\dot{m}_{rel,corr} = f_{p\%} \cdot \dot{m}_{rel,expected} = 68\% \cdot 50\% = 34\% \quad (9)$$

5. Conclusion

We see, that the curve called “corrected capacity” fits very well to the curve called “achieved capacity” in Figure 12 and we can estimate quite exact the mill capacity for a fineness in the range between 3500 and 7000 cm^2/g (see Equation 2) with this method.

This proves the well-known rule that vertical mills prefer coarse feed. With reasonable coarser feed the mill power consumption and the maximum mill capacity are higher. This is opposite to horizontal mills, usually called ball mills, which prefer fine feed. Therefore, it is in general not good to exchange in plants a horizontal mill against a vertical mill without changing the fineness of the pre-grinder.

6. Outlook

Grinding tests for a material quality with a very high fineness have been carried out in the industrial scale grinding plant. The same equipment as for coarse grinding has been used. Only the operating parameter have been changed. The tests did prove that only with small adjustment changes, completely different qualities can be achieved.

If a high rate of fines is requested, the ball race mill is a vertical mill which suffers from fine feed only in a moderate way, the mill capacity is reduced. And this moderate suffering can be estimated quite exact after the a.m. tests.

During service life of the grinding elements the grinding balls will keep its shape and the capacity of a ball race mill will not decrease, which is very different compared to other vertical mills.

7. References

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