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NEW DEVELOPMENTS OF ANODE COKE GRINDING USING A VERTICAL MILL TECHNOLOGY

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Abstract

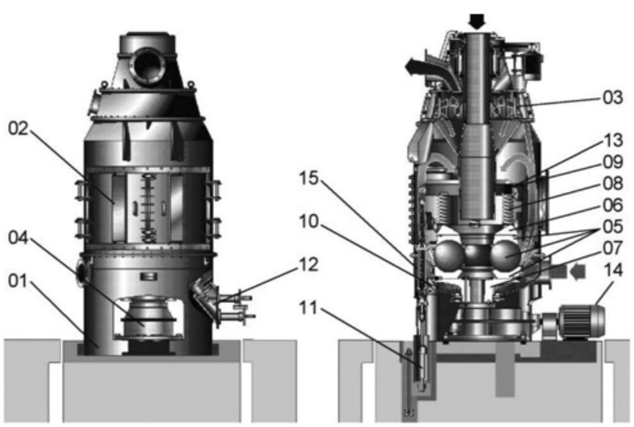
The use of a vertical mill for the grinding of anode coke is well accepted in the Aluminium industry. One of the raw materials, calcined petcoke (CPC), is sourced from different parts of the world with different properties. As the ground product must have constant properties, the grinding process must be adjusted accordingly.

Adding of crushed butts into the grinding mill is a process step which may become more important in future. In this paper these implications on the grinding process using the vertical mill are described.

Introduction

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 [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.



01 Mill Foundation	02 Mill Jacket	03 Dynamic Classifier
04 Gear Box	05 Grinding Elements	06 Pressure Ring
07 Yoke	08 Springs	09 Tensioning Frame
10 Nozzle Ring	11 Hydraulic Cylinder	12 Reject Box
13 Supports	14 E-Motor	15 Gas Channel

Figure 1: Claudius Peters EM Mill with Dynamic Classifier [2]

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.

The advantages of this new grinding principle in comparison to the traditional horizontal tube mill are:

<u>Product Quality of Fines</u>
The product quality of the fines - defined among other things by the median d50 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 homogeneous mixture the consistency of the grain size distribution and the specific surface are decisive. If the fines are too coarse after the grinding process, the specific surface is reduced and the amount of pitch required during anode formation would become too large. If the fines of the ground product are too small, however, the pitch quantity would not be sufficient to produce a homogeneous green anode paste.

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.

<u>Fines Grain Size Distribution</u>
The properties of the fines, characterized by the average grain diameter d50 and the grain size distribution or Blaine number, influence the production process of the green anode paste and thus the quality of the anodes.

<u>Continuous Operation of the Vertical Spindle Mill</u>
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.

Further Effects

In addition to reaching the target fineness and the required specific surface of the fines in continuous operation, the vertical spindle mill offers further technical and commercial advantages over the conventional grinding process with a tube mill.

Investment costs:

Due to the compact design and the lower noise level, compared to conventional tube mills, the building for the grinding plant is relatively small and the insulation measures to be carried out at the building for noise protection are also far fewer. Further, neither a primary crusher, since the wide range of raw material size is acceptable, nor a filter dust silo with all the corresponding equipment is needed since all dedusting points can be connected directly to the main filter. In other industries, e.g. power, steel and cement, the vertical spindle mill has almost completely replaced the horizontal tube mill for coal grinding.

Operating Costs:

Maintenance requirements are minimized due to the long service life of the grinding elements. During the service life it is not necessary to replace or install grinding balls. The low specific drive capacity of the total plant and the low maintenance requirements make this process much more economical.

The power consumption for a grinding plant including a vertical spindle mill will be in the range of 32 to 36 kWh per tonne of CPC while the horizontal tube mill system consumes 55 to 60 kWh/t [3].

Metallic Impurities:

The use of wear-resistant grinding elements reduces the metallic impurities in the fines and thus in the end product aluminium to a minimum. For iron we found that the contamination related to the fines grinding was reduced from a +200 ppm level in the horizontal ball mill down to 60 ppm with the vertical spindle mill ball with ball type grinding elements. This rate can be reduced further by using highly abrasion resistant materials for the grinding elements, i.e. these materials provide a life time which is 70 percent higher than the life time of the standard material [4].

Dust Emissions:

The partial recirculation of the process gas in the grinding plant limits the exhaust gas quantity to the amount of false air from the individual apparatuses, this way reducing the dust emission into the atmosphere to a minimum.

Grinding Losses:

Continuous operation requires a low quantity of calcined petcoke in the mill during the grinding process and the simplest monitoring of the product quality can reduce the grinding losses caused by changes in the input material or in the requirements made on the finished product. Further, the required silo capacity for the fines is reduced, which leads to a reduction of the segregation in the fines silo and optimizes the quality and the consistency of the fines.

New Development

Following the successful introduction of this new grinding technology further questions arise regarding further new applications. A specific task was: Is it possible to grind butts or mixtures from butts and CPC.

Until now, the re-use of the fine material of the butts as feed for the fine material for new anodes has been a controversial topic.

The main concern has been that the recycled butts may reduce the quality of the anodes. The fines of the butts of these anodes are then re-used again, resulting in an even poorer quality of the anodes. In other words a so called "Vicious Cycle" has been created although it should be noted that the quality of butts can be influenced by the anode plant during the cleaning process of the butts.

The task was now to investigate the technical feasibility of grinding of butts. A further question is what affects the grinding capacity of the mill. It was expected that the butts have a considerably lower Hardgrove index compared to virgin calcined petcoke. If the grindability of butts is worse than CPC, the energy consumption would be higher and the maximum grinding capacity of a mill would consequently be lower.

Trimet Aluminium kindly provided us butts and calcined petcoke for test purposes.

The Hardgrove Test

For performance determinations of a mill it is usual to determine the Hardgrove [5] index. This test procedure is also used for calcined petcoke. The test begins with the preparation of a sample of the given calcined petcoke: pre-drying at ambient air, soft pre-crushing and sieving a narrow fraction close to 1 mm. A portion of 50 g is fed into a small batch-operated ball race mill (8 balls with 25 mm diameter), the so-called Hardgrove mill.

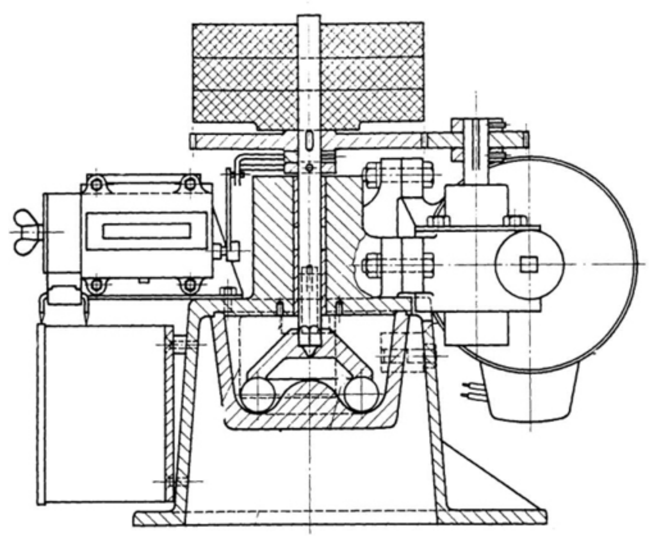


Figure 2: Hardgrove Mill

After 60 revolutions of the grinding mechanism, the 50 g sample is sieved. The amount passing the 75 µm sieve is used to derive the Hardgrove Grindability Index HGI from the calibration chart. In general, the HGI of calcined petcoke that we have tested is in a range between 35 and 40.

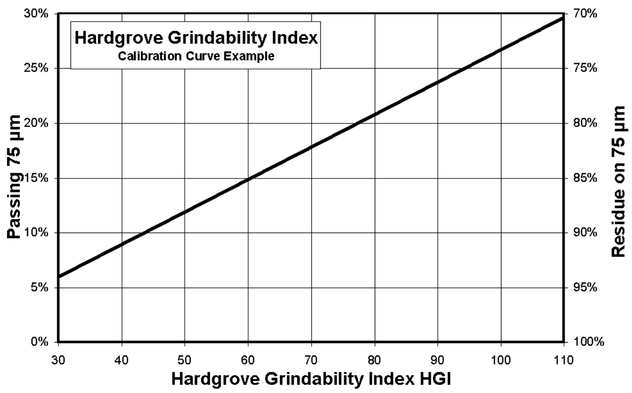


Figure 3: HGI Calibration Graph / Hardgrove Mill

The Hardgrove index was determined in Claudius Peters' laboratory as well as in two further external laboratories.

The result is shown in Table I.

Table I: Results of Hardgrove Tests

	CPC	84/16 mixture	Butts
Institute 1	36		36
Institute 2	42	42	39
Institute 3	46		47

All three institutes calculated nearly the same Hardgrove value for CPC (calcined petcoke) and butts. However, the absolute values of the individual institutes vary between 36 and 47 HGI. This is important because normally a lower maximum throughput, by approximately 30 percent, is achieved in the roller mill as the grindability decreases from 47 to 36 HGI [4].

To explain the different Hardgrove values of the three institutes the sample pre-treatment can be applied. The raw material has to be pre-crushed to a narrow fraction by 1 mm (correct 0.6 up to 1.18 mm). The higher the contact force during pre-crushing, the more cracks are generated into the 1 mm size particles which are later easier to be ground in the Hardgrove tester and consequently supply higher Hardgrove values.

Since such "small details" are hard to control during test preparation, a mill supplier cannot rely on Hardgrove values measured externally. The Hardgrove test does not supply sufficient results to determine the required mill size, especially if the test has been carried out by an external institute. Therefore, the grinding tests have been carried out at Claudius Peters' technical center on an industrial scale.

Grinding Tests

The calcined petcoke, the butts as well as their mixture (84 %: 16 %) were ground in a spindle mill type EM17-525 (Figure 4) with the aim to determine the maximum throughput of the mill and to understand the grinding behaviour of these very hard materials. During the tests the desired product fineness of 18 % R 90 µm was considered - corresponding to a specific surface of 3700 cm²/g according to Blaine based on the measuring procedure of this technical centre and laboratory.

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

Figure 4: EM 17-525 Test Mill with Control System

A series of tests have been carried out in order to determine the maximum capacity of the mill [6]. The results are shown in Table II.

Table II: Results of Grinding Tests

Share of Butts	max. mill capacity	fineness	max. mill capacity conv. to 14%R90	max. mill capacity conv. to 14%R90	Equivalent grindability of bituminous coal
%	kg/h	%R90	kg/h	%	HGI
0	600	18.0%	540	100%	36
16	525	15.1%	509	94%	34
100	380	16.7%	353	65%	26

It therefore appears that despite the same Hardgrove test results between CPC and butts the maximum grinding capacity of a roller mill might be very different. From these results the Hardgrove index was recalculated for CPC to be 36 and for butts to be 26.

As shown in Figure 5 the achievable grinding capacity for mixtures of CPC and butts interpolate linearly between these two values. Contrary to the original fears, dramatic reductions of the grinding capacity by enrichment of the hard components in the mill did not materialize in this test. However, this phenomenon will require checking for specific applications.

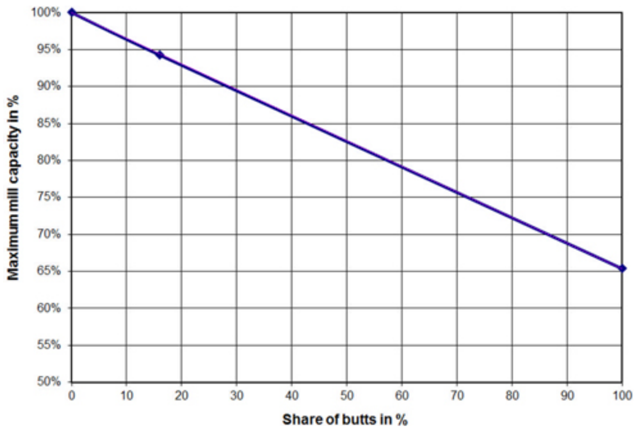


Figure 5: Dependency of the maximum Mill Throughput regarding the Proportion of Butts contained in CPC

Conclusion

The test results show that the grinding of butts and mixtures of CPC and butts are possible.

Despite having nearly the same grindability according to the conventional Hardgrove procedure, the behaviour of CPC and butts is very different in the mill. Such relations cannot be derived theoretically nor are they explainable from the usual material values such as the Hardgrove Index.

Grinding tests with a sufficient large and continuous operating roller mill are necessary. Claudius Peters uses a pilot scale mill with a nominal capacity of 1000 kg/h for this kind of test.

References

[1] Stefan A. Gosau, Andreas Wolf; "The Vertical Ball Mill for the Grinding of Calcined Petroleum Coke to improve the Quality of the Anodes in the Aluminium Industry"; TMS 2011, Claudius Peters Projects GmbH, Buxtehude, Germany

[2] N.N; Presentation documents, Claudius Peters Technologies GmbH, Buxtehude, Germany, 2001

[3] Nolde, Hans-Dieter; "Vertical Mill for Anode Coke Grinding", Aluminium Open Day Buxtehude, 02 October 2014; Claudius Peters Projects GmbH, Germany

[4] N.N.; Internal Mill Handbook, Claudius Peters Projects GmbH, Buxtehude, Germany, 2014

[5] ASTM-Standard D 409, DIN 51742 and ISO 5074

[6] Dr.-Ing. Thiel, Jens-Peter; "Results of Grinding Tests with Anode Coke"; unpublished report 2014; Claudius Peters Projects GmbH, Buxtehude, Germany