Fines Production for Aluminium Anode Manufacturing
With Resultant Cost Reductions

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Introduction

For anode production in the Aluminium industry, 20%-30 % of the petroleum coke is used as dust in the "fines" fraction.

This presentation describes the operation of a vertical type mill with an integrated classifier for the anode industry, that was originally introduced in the coal and mineral industry. With this mill, dust can be produced of every fineness and quantity during full time operation, which leads to consistent dust characteristics and minimum storage silo capacity.

The design characteristics of the mill, the control algorithms and the product quality of the production process are the subject of an applied patent.

By use of a vertical ball race mill for production of the fines, may influencing factors can be adjusted during operation and negative influences can be reduced to a minimum.

In addition, this new concept for the anode industry offers further advantages such as:

- Reduced investment costs
- Reduced operating costs
- Reduced metallic impurities in the fines
- Reduced environmental impacts
- Reduced grinding losses
- Increased lifetime of the grinding elements

In the following the principle structure of a vertical ball race mill as well as the process is introduced and the control concept and the advantages of this process are described.

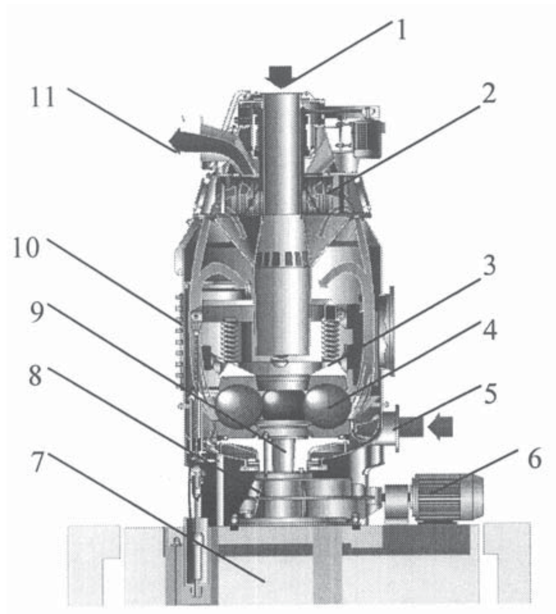

Figure 2. Sectional drawing of a Virtical Ball Race Mill with integrated, dynamic hig-efficiency classifier

Advanced Fines Production for Anode Manufacturing

In other industries the vertical ball race mill, state-of-the-art-technology for several decades now, has been used in particular for the processing of hard and abrasive bulk solids due to its special characteristics. In domains where operational flexibility regarding varying physical characteristics of the grinding material and frequently changing requirements on the ground fines are made, vertical ball race mills are generally used today.

Principal Structure of a Vertical Ball Race Mill

Figure 2 shows the principle structure of a vertical ball race mill with integrated, dynamic high-efficiency classifier.

The vertical ball race mill is a machine where grinding, drying, classifying and conveyance are effected in one single compact unit. The mill operates continuously.

The material to be ground is fed centrally (1) to the mill, falls on the rotating mill yoke (9) and is moved under the grinding balls (4) by means of centrifugal force. It is ground and leaves the grinding area via the exterior circumference of the mill yoke. Here an ambient gas flow (5), which is moving upwards, takes over the material and conveys the ground material to the integrated, dynamic high-efficiency classifier (2). In the classifier the oversized grain is separated and is led back to the grinding area. The ground material of end fineness leaves the mill with the gas stream (11).

The grinding fineness can be readjusted during operation by means of a frequency-controlled motor at the classifier and by adjusting the grinding pressure.

Foreign matter, which reaches the mill (such as stones, steel particles, etc.), is automatically separated during grinding and is collected in a reject gate. The grinding area in the mill is constructed in a way that no dust will accumulate. The grinding pressure in the coke mill is generated by means of a hydraulic pressure device. The hydraulic cylinders which are arranged at the circumference of the mill draw at the tensioning ropes via the piston rods. The tensioning ropes transmit the traction force to the spring tensioning frame. The frame distributes the complete grinding pressure via springs evenly on the pressure ring (3), the upper grinding ring and the grinding balls (4). The grinding pressure is supported by the gear (8) via the mill yoke (9) and is conducted to the foundation (7).

The mill jacket (10) is equipped with two large doors for replacement of the grinding elements as well as a large access opening. The grinding elements can easily be mounted and dismounted by means of a dismantling device .

No sealing air is required due to the simple and solid construction without bearing and lubricating points in the grinding area.

Mill support: The mill support is a welded construction, the lower half of which is embedded in the concrete mill foundation.

A reject gate for falling foreign matter is situated on the side. Foreign matter in the grinding material falls through the nozzle ring and is transferred by the scrapers, which rotate with the grinding yoke, to the reject gate. The foreign matter may be easily removed during operation. A safety device ensures that the reject chamber may only be opened when it is sealed off from the grinding chamber.

If a mill operates under pressure, the passage openings to the grinding chamber must be sealed with an airlock.

The hot air for grinding drying flows through two air inlets into the mill. The zones fed with air are made of heat-resistant material.

Hydraulic cylinders are used in order to produce grinding pressure in the coke mill and these are secured in the foundations. The piston rods are connected by ropes to the spring tensioning frame.

Mill jacket: Mill doors, larger than the diameter, are set in the mill jacket to facilitate installation and removal. The mill jacket is connected above the mill support. Guides with the relevant wear plates are included in the mill jacket to absorb the rotary forces of the spring tensioning frame and pressure ring. The clearance should be readjusted periodically when wear increases.

Integrated, dynamic high-efficiency classifier: The particle/gas mixture flows from the outside to the inside through the guiding blades in the high-efficiency classifier and ends in a tangential flow located between the guiding blade ring and the rotor.

The dividing limit of the classification is determined by the peripheral speed. During operation the fineness can be adjusted without problems by means of a rotor drive with speed-controlling device.

The fine material flows through the rotor bars and leaves the mill together with the gas flow. The oversize particles fall outside the rotor into the course material cone and are transported back to the grinding chamber for further grinding.

An especially adapted sealing, with low wear, located between the rotor and the classifier housing avoids a short-circuit flow and consequently the appearance of oversize particles in the fine material.

Heavy and central lubricated rolling bearings take over the bearing of the rotor. The lubrication is electronically adjusted and controlled. The temperature of each bearing is supervisioned. The calculated design for the roller bearings is made for a continuous operation of more than 10 years.

Gear box: Spiral-toothed bevel spur gears are mainly used. The drive is designed in a way that it may be quickly restarted following an emergency stop of the grinding plant, without the grinding chamber having to be cleared.

The axial forces are taken up by a rocker-segment bearing in the upper part of the housing. By selecting the optimum ratio between segment-bearing diameter and supporting housing walls, only very small bowing stresses occur. The fresh oil enters by way of nozzles between the segments. During operation, oil pressure, oil temperature, flow and differential pressure in the filter are constantly monitored. The amount of gear oil is checked by way of an inspection glass in the housing.

The gears are equipped with an electric oil heater, which is activated when the temperature drops below 15 °C. The mill cannot be started if the oil temperature is lower than 15 °C.

The calculated design for the bearings is made for a continuous operation of more than 60.000 h, the design calculation is based on an AGMA factor of 2,5.

Pressure ring: The pressure ring

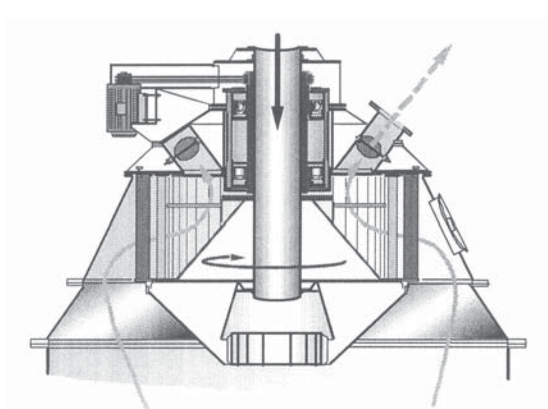

Figure 3. Sectional drawing of dynamic high-efficiency classifier

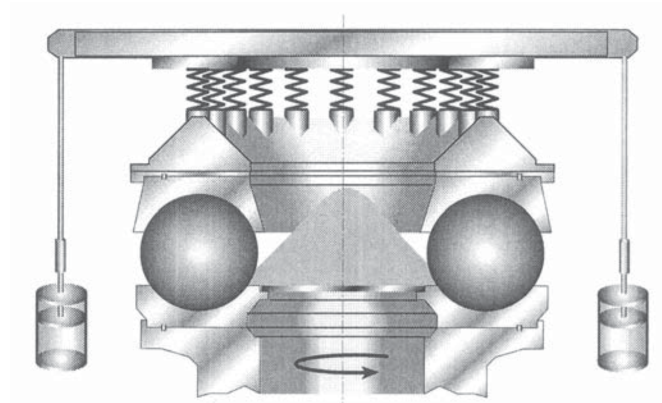

Figure 4. Sectional drawing of grinding zone

(Figure 4.) is a cast body for holding the upper grinder ring, with arms located on the circumference, which are supported on the jacket in the direction of rotation. The pressure ring is connected by springs to the spring tensioning frame. The pressure ring guides the upper grinding ring and absorbs the torque at the mill jacket. The pressure ring can move freely vertically in the guides on the mill jacket, in order to compensate for oscillations in the mill bed. This prevents foreign matter blocking and thus damaging the grinding elements.

Mill yoke: The mill yoke (Figure 4.) represents the connection between the lower grinding ring and the segment bearing in the gear. The grinding pressure is supported by the mill yoke in the gear and conducted to the foundation.

Compressing springs: The springs are centered in the guide pipe sockets between the pressure ring and the spring tensioning frame as a flexible connection. The springs have the task to conduct the tension from the spring tensioning frame to the grinding elements as pressure. Additionally, the springs ensure a uniform grinding pressure on the grinding elements.

Spring tensioning frame: The spring tensioning frame (Figure 4.) is a welded construction, running in the mill jacket like the pressure ring. The frame has the same function as the pressure ring. The spring tensioning frame is connected by traction ropes to the hydraulic cylinders in the mill support.

Grinding elements: The grinding elements (Figure 4.) consist of the lower grinder ring, grinding balls and the upper grinder ring.

All the parts are made of diecast metal, highly resistant to wear. The grinding balls are formed as hollow spheres. The grinding elements are maintenance free. A measurement of the wear needs simply to be carried out at certain intervals, in order to deduce the expected standing time of the grinding parts and to place the operators in the position of being able to plan spare part orders over longer periods.

The lower grinder ring is centered over a recess in the grinding yoke and secured by driver pins. The grinding yoke is attached to the gear output flange. To this extent, the neck of the yoke protrudes from out of the mill support. The grinding is sealed off from the outside by a labyrinth.

Nozzle ring: The nozzle ring is positioned between the lower grinding ring and the mill jacket and seals off the grinding chamber from the hot gas inlet. The nozzle ring is designed as a cast part in the segment construction. The hot air required for drying the ground material enters the grinding chamber via the nozzle ring. In order to prevent ground material falling out, the nozzle ring is set to a minimum airflow speed. Foreign matter in the ground material is able to fall into the reject gate through the nozzle ring.

Hydraulic system: The grinding pressure in the mill is produced by a hydraulic pressure device. The hydraulic cylinders positioned on

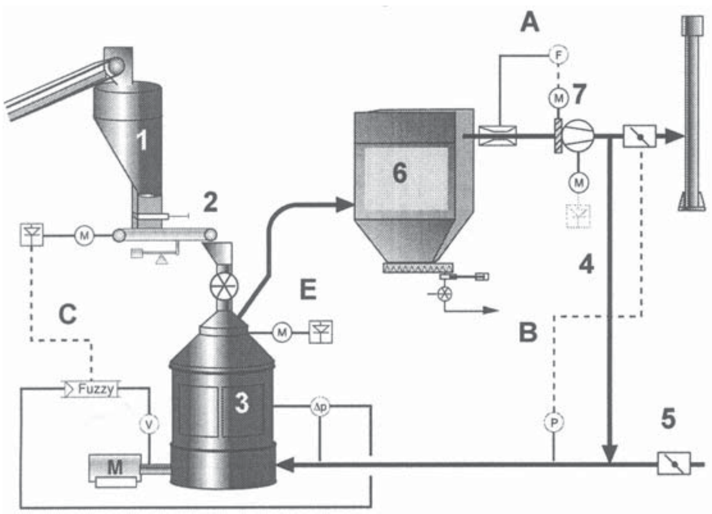

Figure 5. Schematic flowsheet of a grinding plant for calcined petcoke with a vertical ball race mill and integrated high-efficiency classifier

the circumference of the mill pull on the tensioning ropes via their piston rods. The tensioning ropes transmit this tension to the spring tensioning frame. This then evenly distributes the total grinding pressure via springs over pressure ring, upper grinding ring and mill balls. The grinding pressure is then supported by the gears via the grinder yoke and is conducted to the foundation.

While the static pre-tension in the system may be adjusted and is predefined by the hydraulic cylinders, the intermediate compression springs allow smaller strokes during the grinding process.

By altering the hydraulic pressure in the cylinders, the pre-tension in the springs is also defined. With the wear of the grinding elements and balls, the pistons of the hydraulic cylinders automatically follow the worn path. Thus the same, predefined pressure is always maintained and so the total grinding pressure is also kept constant, independent of the state of wear of the grinding elements.

In order to compensate for pressure inconsistencies in the hydraulic system, the mill is equipped with a hydro- pneumatic accumulator. The bubble tank is filled with nitrogen and is placed under a pressure corresponding to about half that of the known grinding pressure.

When the mill is at a standstill, a heater is automatically activated at temperatures below 20 °C, until the predefined temperature is attained.

Dismantling device: A dismantling device is included for replacing the grinding elements. Following its connection, the pressure ring, mill yoke, grinding balls and grinding ring can be easily removed through large doors in the mill support. The grinding elements are removed using hoisting winches suspended from the removal crosspieces.

Advanced Grinding process for fines production

Figure 5 schematically shows the preparation process for production of the fines. The raw calcined petcoke, with a coarseness of 0,1 - 8 mm, is fed through the raw petcoke bin (1) and the belt weigh feeder (2) as flow control facility to the mill. The presented raw material bin design is a round steel plate silo with eccentric outlet. This form has been well-proven in the past and guarantees a trouble-free feeding to the feeder.

The mill (3) is a continuously operating vertical ball race mill where grinding, classifying and conveying can be executed in one closed unit as described in Figure 2.

The petcoke ground to the required fineness is discharged pneumatically from the mill together with a mixture of recirculated gases (4) from the grinding process and fresh air drawn in from the atmosphere (5) and is then separated in the main filter (6).

The largest part of the fines is separated in prechambers off the flow of gas, the dedusting of the rest is effected by filter bags.

The fines are removed from the filter hopper by a troughed screw feeder and a rotary feeder and are fed to the subsequent process phases for production of the green anode mass.

Less than 10 % of the pure gas separated from the fines are pressed through the fan (7) into the stack. This way more than 90 % of the pure gas are returned to the process.

To achieve constant operating conditions during the grinding process, the control algorithms described below are required.

Control Algorithms of grinding process

The grinding plant is equipped with 4 control loops.

Control of air volume (A): The measuring of the air volume is effected between filter and fan by means of a Venturi nozzle. The set value for the air volume is given. The control is effected by means of an air regulator which can be adjusted by motor or a frequency inverter.

Control of pressure level (B): For operation of the mill in clear pressure relations the pressure in front of the mill is being kept constant. The pressure measuring is arranged in the pipeline in front of the mill. The set value for the pressure is given. The control will be effected by a pneumatically-operated adjusting flap in the exhaust gas pipe.

Control of grinding capacity (C): The grinding capacity, which depends on the requirements in the anode factory with regard to fineness and specific surface area and on the Hardgrove Grindability Index of the calcined raw petcoke which varies from 32 – 40 °HGI, can be regulated by means of the feeder speed, and if applicable by adjusting the grinding pressure, process gas flow and mill motor speed.

The belt weigh feeder is continuously adapted to the speed of the necessary grinding capacity. It is possible to operate the feeder in a range between 25 – 100 % of the maximum capacity.

To avoid an over-charge of the mill and to control the vibration set point the delta p measurement in the coke mill will be taken as parameter as well as the vibrations of the gear box. These values are processed in a Fuzzy-Logic module to control the speed of the belt-weigh-feeder.

Control of particle fineness (E): The quality of the fines is defined by the characteristic grain particle diameter d_{50} at a residue / screenings of 50 % in a range of 32 – 55µm and the specific surface according to Blaine between 2000 – 5000cm²/g. These ranges are reached by adjusting the classifier speed via a frequency converter and by adapting the process gas quantity via an adjustable air regulator or a frequency converter.

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 mass. This green anode mass is mixed — mostly by adding pitch — from different petcoke fractions, butts, green and baked scrap and is then formed into anodes.

For the production of a homogeneous mixture the constancy 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

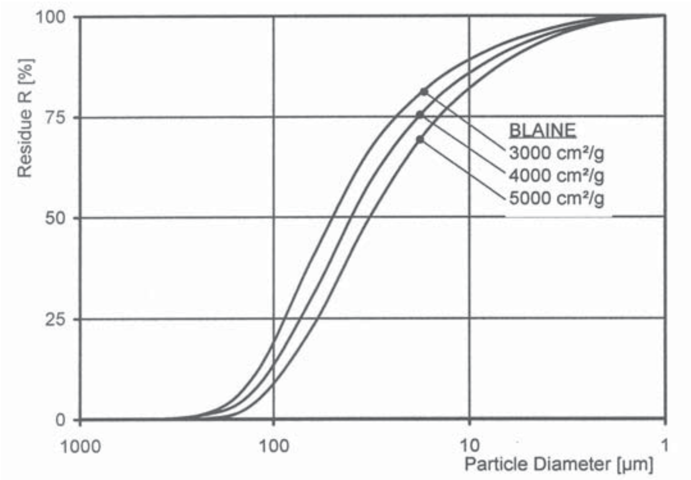

Figure 6. Grain size range of the fines for the production of green anode masses

reduced and the required amount of pitch 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 mass.

Metallic components determine the quality, i.e. purity of the aluminium, this way having a negative influence on the quality of the light alloy since they enter the molten mass when the electrodes are burnt during the fused mass electrolysis.

Fines grain size distribution

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

Figure 6 illustrates the requirements on the characteristics of the fines for production of the green anode mass. The illustration shows the weight-% residue in correlation with the particle diameter.

Conventional processes such as described in Figure 1 must be run in start / stop modus in order to meet the requirements described in Figure 6. With the new system described above, however, the different grain size distributions as shown in Figure 6 are obtained in continuous mode without having to stop the plant.

Figure 7 shows the grain size distributions produced with the new process in continuous industrial operation. The grain size distributions were measured by use of an air-jet screen according to DIN 66 165 part 1/2 [5] down to a mesh width of 32 µm. As one can see, steeper grain size distributions occur which show a lower inclination in the fine range <32µm. The influence of the deviating grain size distributions on the specific surface according to Blaine shall be explained in the following.

Fines specific surface according to BLAINE

The pitch quantities required for the production of the green anode masses are determined depending on the specific surface according to Blaine. The specific surface is reduced / increased by a change of the average grain diameter and the range of grain size distribution. Table 1 shows the required correlation between average grain diameter d_{50} and the specific surface according to Blaine for the production of green anode masses in conventional processes, as described in Figure 1 as well as the average grain diameters d_{50} and screen residue on a sieve with a mesh width of 32µm achieved with the ball race mill process described below.

Specific surface area acc. to BLAINE [cm²/g]	Av. particle diameter in Std. Millsd d_{50} [µm]	Av. particle diameter in Ball Race mills d_{50} [µm]	Residue on 32 µm sieve [W-%]
~3000	~55	~62	~67
~4000	~47	~43	~58
~5000	~32	~35	~50

Table 1. Correlation of the specific surface according to Blaine and the average grain diameter d_{50} in conventional mills and ball race mills

The measured grain size distributions shown in Figure 7 differ in range as well as in steepness from the required distributions illustrated in Figure 6. As a consequence, the required specific surfaces may be too small or too large. The specific surfaces of the measured grain size distributions shown in Figure 7 were determined in accordance with DIN 66 126, Part 1/2.

The comparatively steeper grain size distribution is compensated for by the fine share with a lower inclination <32µm, so that the required surfaces, as shown in Figure 7, are obtained. A correlation between the specific surface according to Blaine and the average grain diameter d_{50} could not be found. In the grinding process with a ball race mill, the specific surfaces depend on the residue on a sieve with a mesh width of 32µm. Figure 8 shows the measured linear correlation between the specific surface according to Blaine and the residue remaining on a sieve with a mesh width of 32µm.

Based on the findings of Fig-

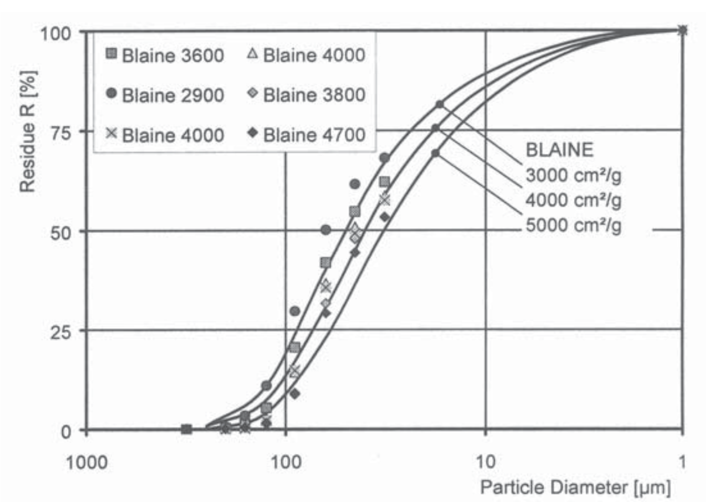

Figure 7. Grain size distributions and surfaces obtained by use of the described process

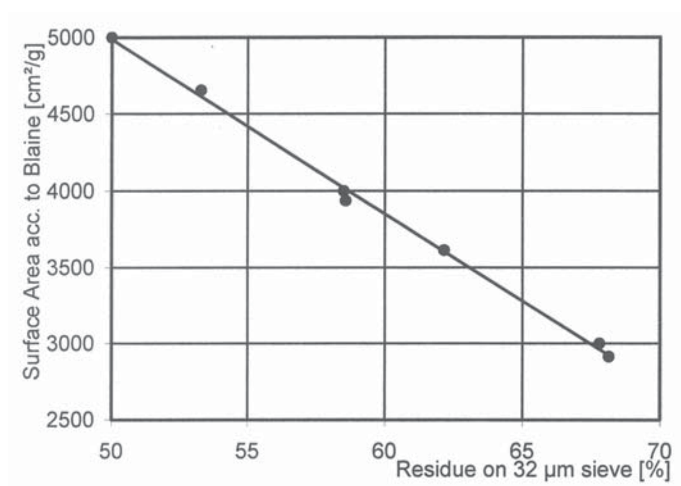

Figure 8. Correlation between the specific surface according to Blaine and the residue on a 32 µm sieve.

Fines Production For Aluminum Anode Manufacturing Continued

ure 8, the quality of the fines can be controlled / monitored by considerably reduced measuring requirements and the process can be adjusted, if necessary, by changing the operating parameters.

Further effects

In addition to reaching the target finenesses and the required specific surfaces of the fines in continuous operation, the new process described above offers further technical and commercial advantages over the conventional grinding process.

Investment costs: Due to the compact design and the lower noise level, compared to conventional 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 led directly to the main filter.

Operating costs: Maintenance requirements are minimized due to the long service life of the grinding elements. During the guaranteed 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 new process much more economical.

Metallic impurities: The use of highly wear-resistant grinding elements reduces the metallic impurities in the fines and thus in the end product aluminium to a minimum.

Dust emissions: Recirculation of the process gas in the grinding plant cycle 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, low quantities of calcined petcoke in the mill during the grinding process and the simplest monitoring of the product quality reduce the grinding losses caused by changes in the input material or in the requirements made on the finished product. Further, the 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 constancy of the fines.

Conclusion

A continuous production of defined dust quantities of any fineness desired from calcined petcoke of different grindabilities by a simple adjustment of operating parameters and a simultaneous minimization of the segregation in the finished product silo is achieved by use of the verticle ball race mill grinding plant concept.

This innovative process is characterized by the use of

- a proven vertical ball race mill
- an integrated dynamic high-efficiency classifier
- an adjusted control concept

This process developed for the aluminium industry is based on long years of experience of CLAUDIUS PETERS in the processing of coal, petcoke, gypsum and other bulk mineral solids. The process is predicted to result in cost reductions which will be significant in the raw material supply context for anode production. A more detailed paper is anticipated in 2005 in conjunction with The Minerals, Metals, and Materials Society (TMS).

Societies NEWS

Pennsylvania Society of Professional Engineers

The Pittsburgh Chapter of PSPE will sponsor a refresher in Spring 2005 for both the Professional Engineer (mechanical, civil, and electrical disciplines) and the Engineering in Training (E.I.T./F.E.) exams. Courses meet one evening per week at the University of Pittsburgh and are scheduled to complement the semiannual examinations administered in the Commonwealth of Pennsylvania. The Spring 2005 Refresher Course is now scheduled for 9 sessions beginning Feb 7, and running through April 11 (no class on March 7), and provide 22 ½ hours of instruction. The deadline for course registration is Jan 28, 2005. A minimum of 10 students is required for each class. Applications for enrollment can be found at www.pittsburghpe.org.

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