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BOOST OF ANODE PRODUCTION AT VOERDE ALUMINIUM BY ADVANCED AND INTEGRATED CONTROL STRATEGIES

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Abstract

Voerde Aluminium GmbH (Voerdal) is operating a 36 section Kaiser type furnace for the production of anodes since more than 40 years. Due to the continuous amperage incease in the potline, the baking furnace capacity had to be increased by 10% in the given boundary conditions of the furnace size and government permission for the maximum flow gas volumes and emissions.

Voerdal and the system designer jointly developed new control strategies to ensure the boost of anode production. This was achieved mainly by implementation of new control modules which integrate the FTC (fume treatment centre) feedback values into the overall control strategy.

This paper explains the functional principles of these control strategies and describes the implementation phases. Finally, it outlines the actual results achieved.

Introduction

Now part of the BaseMetGroup, Voerdal is a primary smelter put into operation in the early 1970's by Kaiser Aluminium. The original aluminium output of 75.000 t/a has been continuously increased during the decades. A new amperage increase project was executed in 2010 to operate the pots at 185 kA for a total metal output of 94.000 t/a. For this boost in production it became necessary to increase the production of anodes from approx. 53.000 t/a to 66.000 t/a. The Kaiser type anode baking furnace as shown in Fig. 1 was originally designed for 49.000 t/a only.

Figure 1 Anode Baking Furnace at Voerdal

Voerdal has an operation permission to produce in Voerde, which includes special limitations in emissions and maximum volume flow rates for the FTC serving the anode baking furnace. These values are supervised by government authorities, whereby the Carbon Plant is connected on-line to the regulating institution. Any exceeding values are reported instantly and may lead to an immediate shut down of the plant.

The challenge therefore is in boosting the anode production without exceeding the boundary conditions and especially the maximum permitted emissions and volume flow rates.

Details of the baking furnace

The baking furnace consists of 36 sections, each with 7 flues and 6 pits. During the decades of production, the furnace and particularly the flue size were continuously modified to accommodate the changing and improving anode sizes. Voerdal operates 3 fires on this furnace in a special fire configuration. This configuration includes 3 sections in the preheat area, 2 sections in the firing area and 4 sections on the cooling area. Fig. 2 shows the actual fire configuration.

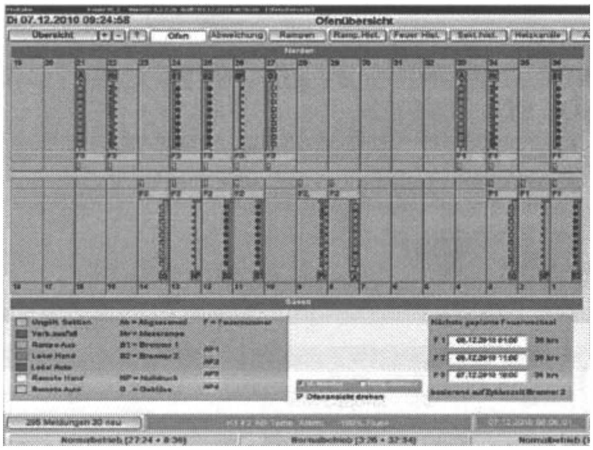


Figure 2 Fire configuration

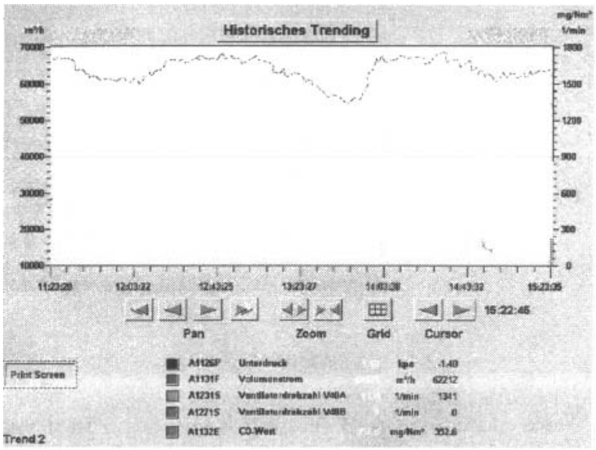
The fire cycle time can vary between 32 – 38 h , depending on the production necessities.

Actual limitations of the equipment

The actual FTC flow rate allowed is limited to 44.480 Nm3/h including all necessary auxiliary process air inside the FTC. Based on this flow rate, the emissions are taken and reported to the governmental authority.

The baking facility consists of 2 major equipments: the baking furnace and the fume treatment plant. Each equipment was operated independently as stand-alone units. The only connection between the two is the ring main duct for the exhaust gases from the furnace. If the firing and control system of the baking furnace has a demand for more draft, the dampers of the exhaust ramp open and the flow rate rises in an uncontrolled manner. Due to a strong demand of draft at a specific fire during the baking cycle the maximum flow rate was achieved or even slightly exceeded resulting in a drop of draft at the other 2 fires on the furnace. In these cases furnace operators often took over control of this fire for a certain time. This manual intervention led to a decrease of the operation time in "automatic mode" which had a direct impact on the long-term sustainability of the process and negatively influenced the productivity.

On the other hand it was also observed that at certain intervals the actual flow rate was far below the maximum allowed values. This fact indicated "unused" spare capacity which could be utilized to boost the furnace output capacity. Figure 3 shows a typical trend of the "uncontrolled" flow rate at the FTC through the firing cycle.



■	A1126P	Unterdruck	kpa	-1.40
■	A1131F	Volumenstrom	m³/h	62212
■	A1231S	Ventilatordrehzahl V40A	1/min	1341
■	A1271S	Ventilatordrehzahl V40B	1/min	0
■	A1132E	CO-Wert	mg/Nm³	352.6

Figure 3 Flow rate at FTC during the fire cycle

Problem description

The problem was how to achieve a boost in anode production within these limitations. More production would be possible by better utilization of the pits and sections and by faster fire cycles. However, this immediately generates more fuel gas and more pitch load into the furnace. Fuel gas and pitch volatiles can only be combusted if enough oxygen is available. The utilizable oxygen is limited by the maximum volume available. All controls have to be directed towards an optimization of the fuel efficiency of the individual fires of the entire furnace. All operating situations of the fire, which also includes cross-over positions have to be examined and taken into consideration. Fig. 4 illustrates the typical volume versus production curve.

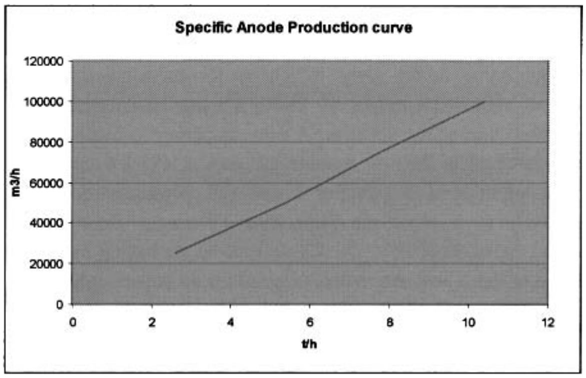


Figure 4 Volume versus production curve

The first idea was to stay within the boundary conditions. Therefore the actual volume flow rate and emission values of the FTC have to be established also for the firing and control systems. These values of the FTC have to be linked to the Firing Control System. Now an advanced control strategy has to be developed and implemented to utilize the maximum allowed flow rate for the baking process.

Strategies for production boost

Strategy no. 1 Volume Flow Control between FTC and Firing

Strategy no. 1 to reach the higher anode production is the implementation of an overall volume flow control. The basic control of the volume in the furnace is done by a cascaded Temperature-Draft PID control loop as shown on the left part of Fig. 5. The main setpoint for the control of the preheat area is the flue temperature in peephole no. 4 of the first section. But this control is only capable to react within the given limits of the dynamics of the draft. The actual volume flow of the FTC has to be used as a feedback signal for the firing control system.

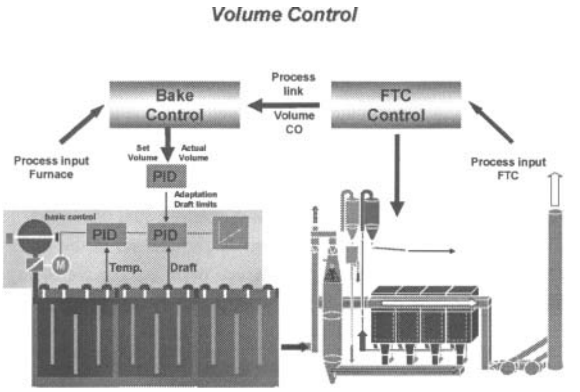
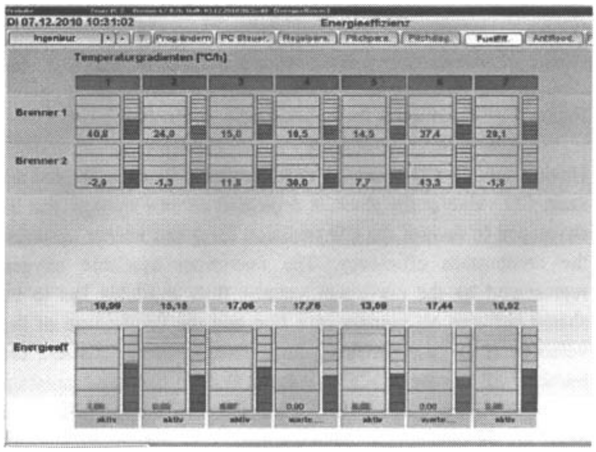


Figure 5 T-P and volume flow control

Now the volume flow control strategy can be designed as an adaptive control which influences the max. allowed draft level of the PID. For each 1000 m^3 below the limitation value (i.e. 67.000 Bm^3/h) the draft level will be increased by 5 Pa. For each 1000 m^3 above the limitation value, the max. allowed draft level will be decreased accordingly. This ensures, in a first general approach, that any "spare" volume available can be utilized by any of the 3 fires. On the other hand it guarantees that the max. allowed volume flow will not be exceeded at any time. Having these spare volumes now available, further advanced strategies can be implemented to optimize the flow, i.e the control of the oxygen demand for each fire according to their individual requirements.

Strategy no. 2 Fuel efficiency Control

Normally the maximum permitted burner capacity for each burner is individually limited by a fixed parameter. There is no interconnection to other burners firing into the same flue. There is also no relation to the actual volume available in the specific flue. Lack of oxygen resulting in flooding situations [1] are not recognized or prevented. With the knowledge of the actual volume, an actual maximum burner capacity can be calculated for the active burners per flue. The total "allowed" burner capacity is shared between these burners, where priority is given to the burner in the section where the highest deviation between temperature setpoint and actual temperature occurs. Figure 5 shows the results of the calculated fuel efficiency, the actual temperature gradients achieved and the split of the total burner capacity at the 2 burner ramps.



	1	2	3	4	5	6	7
Brenner 1	40,8	24,0	15,0	16,5	14,5	37,4	28,1
Brenner 2	-2,9	-1,3	11,8	30,0	7,7	43,3	-1,8
	10,09	15,15	17,06	17,76	13,09	17,44	16,92
Energieeff	[illegible]	[illegible]	[illegible]	0,00	[illegible]	0,00	[illegible]
	aktiv	aktiv	aktiv	warte...	aktiv	warte...	aktiv

Figure 6 Fuel efficiency control and monitoring

Strategy no. 3 CO control

CO is a direct indicator of the combustion quality. In the anode baking furnace, CO is mainly generated if the pitch burn in the preheat area is incomplete. In this case the burners are consuming all the available oxygen, and there is no or only little oxygen left for the combustion of the volatiles. CO is primary measured at the stack of the FTC. For the development of a CO control, each exhaust ramp of a fire has to be equipped with an additional CO analyzer unit as shown in Fig. 7.

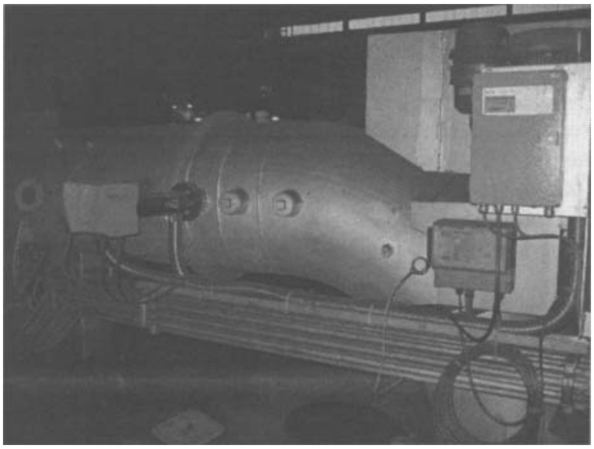


Figure 7 CO sensor at the Exhaust ramp of the fire

Having now the CO emission levels available for each fire and the main CO value at the stack, a dedicated control strategy can be developed to control the CO emission level and further optimize the combustion efficiency. The maximum available oxygen represented by the maximum volume flow available has to be shared between all burners in a flue and the combustion of the volatiles. If the setpoint firing curve (baking curve) is static, the burners will use the available volume flow to keep and maintain the target values. Exceeding CO emissions during the pitch burn phase are the unavoidable consequence.

The solution that was developed is a dynamic adaptation of the firing curve in relation to the CO emission values. Both CO values – the CO value from stack of the FTC (CO_f) and the CO value from each individual fire (CO_b) – will be used in a 2-step strategy. CO_b adapts the firing curve for each fire whereas CO_f will decrease the firing curve of all fires in a second step. This strategy will ensure enough oxygen for the volatile combustion as defined within the legislation permits of the environmental government. Fig. 8 shows the loop diagram for the CO control strategy.

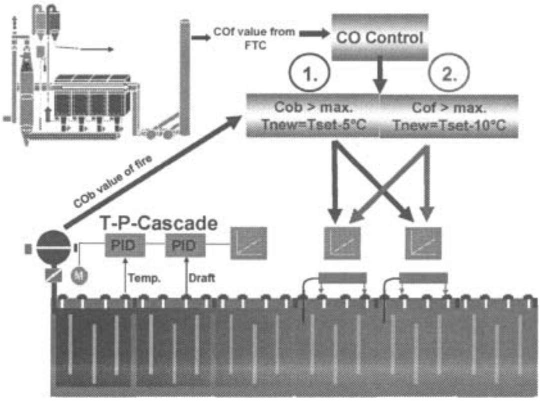


Figure 8 CO Adaptive Control

Deviations in the temperature curve, which may occur by the CO adaptive control, are compensated by the Firing Index Module at a later stage as earlier described [1] [2].

Results

The implementation of the volume flow control, fuel efficiency control and CO control enabled increased production in the carbon plant while remaining in the given permits. The following graph illustrates the corresponding production data.

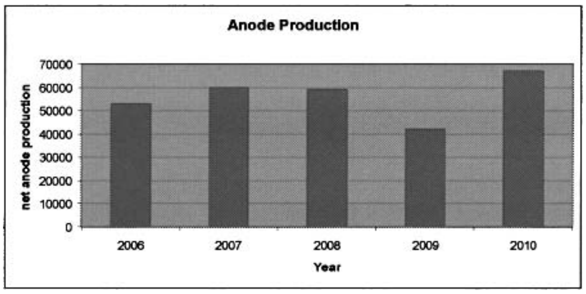


Figure 9 Anode production

As a second result, the volume flow rate of the FTC is stabilized which indicates that all available volume flow will be utilized for the combustion in the 3 fires as shown in Fig. 10.

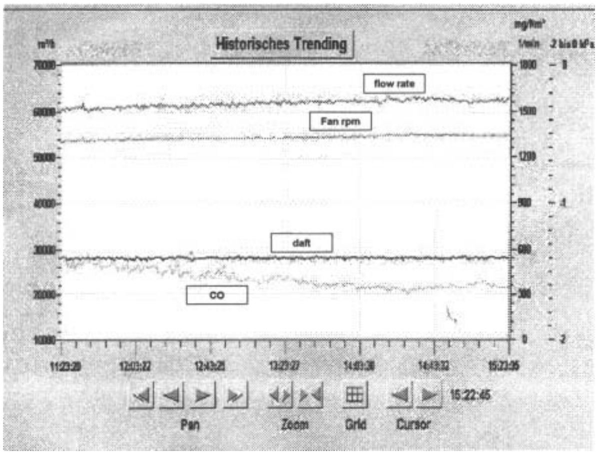


Figure 10 Flow rate at FTC after implementation of flow control

The results of the CO control at each fire are shown in Fig. 11

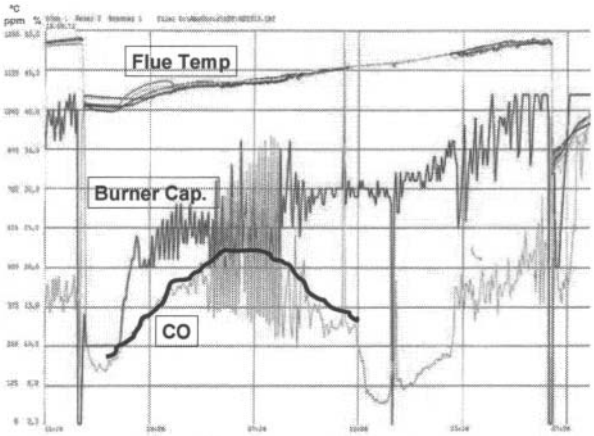


Figure 11 CO control

The graphs show the reaction of the dynamic adaptation of the flue temperature setpoints. The capacity output for the burner decreases automatically and the CO average can be kept below 550 ppm. As a result the CO value at stack (from all 3 fires) can be maintained (ref. Fig. 10) within the emission permits.

As already mentioned in the beginning, the productivity is directly influenced by the degree of automation of the entire plant. At Voerdal, the degree of automation is continuously recorded and monitored as shown in Fig. 12.

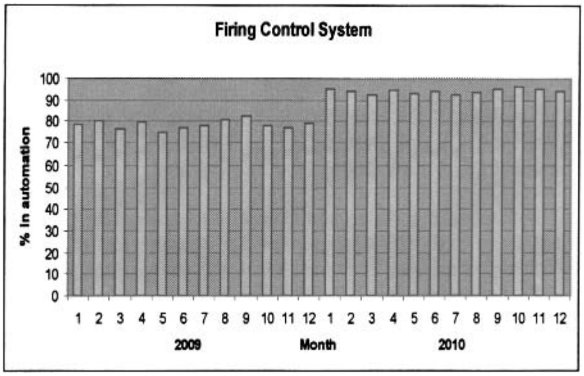


Figure 12 Degree of automation

After implementation of the new control strategies. the degree of automation increased in average from 78 % to 94 %. The increase of the operation time in "automatic mode" has a direct impact on the long term sustainability of the process and influences the productivity in a positive manner.

Specific gas consumption

The specific gas consumption is a strong indicator for the efficiency of the anode production. After commissioning and fine tuning of the new integrated control strategies, the specific gas consumption could be lowered by 7 % at a peak production output of 67.000 mt / anno. This led to an annual saving of approx. 210.000 m^3 of natural gas per year, which had a positive impact on the operational production costs.

Conclusions

This paper discussed possibilities of increasing the anode production in an existing baking furnace. The results demonstrate very impressively the reached targets and further improvements that have been achieved.

The anode baking process is normally the bottleneck in the production chain for the production of anodes. These new strategies for the baking process to gain more production output provide additional space for the actual and even further potline amperage increase in the future.

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