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ELECTRODE TECHNOLOGY FOR ALUMINUM PRODUCTION

Paste Plant Operations

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A GREEN ANODE PLANT PERFORMANCE ANALYSIS TOOL FULLY EMBEDDED IN THE PLANT CONTROL SYSTEM

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Abstract

AMELIOS is an advanced software used to analyze the performance of green anode plants during operation. It helps the plant operators to perform root cause analysis of production breakdowns and guide the process engineers to optimize the anode quality.

Because such a tool had also the potential to be used during the commissioning of new green anode plants, the original version was enhanced to fulfill the needs of start-up engineers during the production ramp up and plant fine tuning.

It now provides data extraction features that aggregate system recorded parameters with conditional events and has been fully embedded into the green anode plant control system based on state-of-the-art control and information technologies used by most smelters.

This paper gives the details of the implementation and beneficial use of AMELIOS during the recent start-up of a new green anode plant in the Gulf.

Introduction

Measuring and evaluating the performance of the green anode plants are common objectives for aluminum producers and plant suppliers. During the start-up, suppliers want to monitor their equipment and estimate the quality of the production of anodes to meet contractual performance. Producers seek thereafter to maintain high performance of their production throughout the life cycle of the plants.

Achieving these goals requires the implementation of practical tools for operational teams, commissioning experts, and process engineers. These tools should allow real-time monitoring of plant performance and evaluation of production quality.

The relevance of these tools will be characterized by their ability to:

- Collect and gather from different sources heterogeneous data which can either be in the form of time series data recorded cyclically and automatically by control systems or be event type recorded automatically or entered manually,
- Properly handle raw data process during the manufacturing process of the anode paste to associate process parameters with properties that characterize the anodes produced.
- Appropriately return the raw data with a more or less detailed level of analysis. KPIs will quickly assess the performance of the facilities. The monitoring of the production, process section faults and equipment tuning will refine the diagnostics to measure the performance of the plant. The influence analysis and the automatic root cause of breakdowns will help the users in their diagnostics.

The original version [1] already included all of these features. As part of a recent green anode plant commissioning, it has been expanded to refine the monitoring of equipment performance. It is fully integrated into the control system control architecture and is accessible to operations teams, as well as process engineers. The system is configurable andscaleable. It can be deployed on green anode plants with a single line or multiple lines.

The paper first presents the principles of treatment and analysis of production data of a green anode plant. It shows how the green anode plants are modeled. It then describes the implementation of the standardized tool. Finally, it discusses case studies in the recent start-up of a green anode plant in Saudi Arabia.

Main Features

<u>Data Collection</u>

The tool collects data from different sources.

- Raw process data in time series format is sampled by the control systems, and stored in a historian. These data are classified into two categories:
  - Process data from sensors (temperatures, pressures, speeds, vibrations, powers, positions …). They are also used on time based trends displayed in the supervision system.
  - Useful information for the reconstruction of mass balance like measured material flows, measured weights on some equipment, and soft sensors recalculated by time shifting from raw data.
- Conditional data or events are automatically stored in a relational database. These data include faults raised by the system in case of equipment failure.
- Further information can be entered manually in relational database by the commissioning or operation

teams. It includes the granulometry analysis results, manual records or mechanical settings on the process equipments.

This set of data is kept over a period of several months. It is the source of information useful for the data processing performed by the algorithms.

Data Processing

This feature belongs to the core of the system. Its goal is to preprocess the raw data to produce a reduced set of data that will form the basis for the analysis. This knowledge base is then used to analyze the performance of the installation. It includes three types of data.

- Anode Data Sheets containing the properties of each anode produced including the process parameters which were used to produce it.

- KPIs

- A history of faults and operating states of the process sections of the paste plant.

Algorithms have been developed to build these data.

Anode Data

A specific algorithm is implemented to produce consistent data. This algorithm consists in re-synchonizing the data time series into anode based data for each produced anode. It is based on a real time tracking of the complete paste plant mass balance, in order to determine the residence times of material fractions that constitute the anode in each plant area.

▪ Process Flow Modeling

This algorithm uses a generic modeling process flow sheet of the Rhodax process.

- The tower is divided into several units. Each unit consists of one or more equipment with their own sensors. Each unit retains a quantity of material. Flows of material shall exchange with each unit.

- Each material flow, each unit mass is assigned to a measurement of physical or soft sensors to provide a complete mass balance.

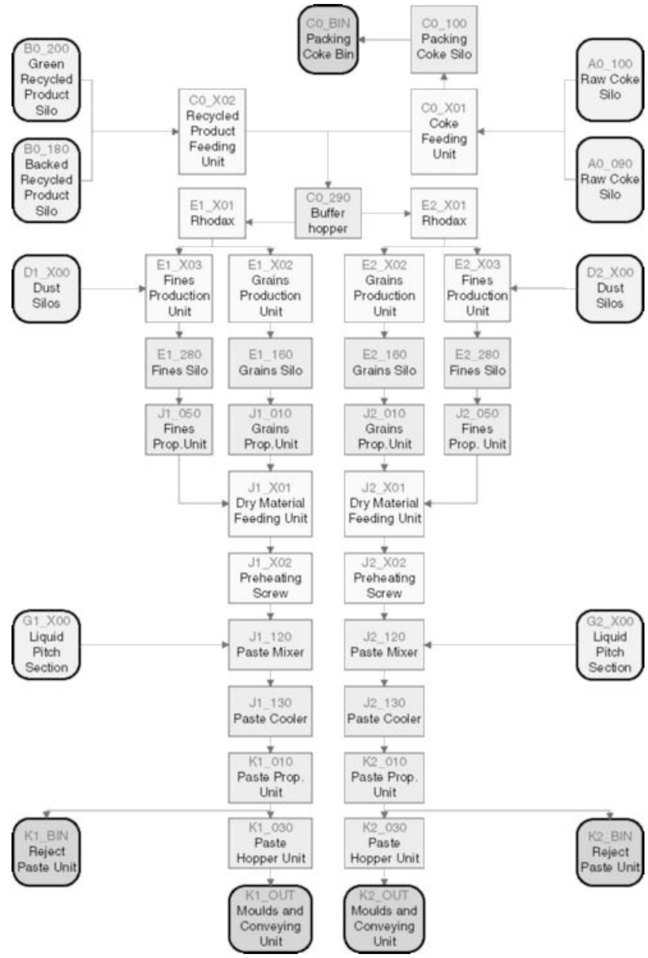

Figure 1: Modeling of a Green Anode Plant with two Lines

The components which constitute the anode are modeled. They are associated with a material flow.

▪ Computation

Each time an anode is produced the algorithm looks back in the history of mass balances up to the previous produced anode. The mass balances are adjusted by data reconciliation [2] to minimize all possible inconsistencies. After corrections, the algorithm browses the history of mass balances to compute the residence time in each unit for each of the components that constitute the anode. With these residence times, the algorithm aggregates the process measures stored as time series to associate them to the produced anode.

This approach is generic. Any measurement linked to a unit in the modeled process can thus be taken into account and provide an additional property of the anode data.

KPIs

A dedicated algorithm uses the raw data to calculate standard KPIs for every hour of production. KPIs quantify the efficiency of the plant, the quality of the production, the reject rates, and the availability of the installation.

Downtimes

This algorithm records in real time production stops of the paste plant. At each stop, it initiates a root cause analysis using a particular logic to navigate through the system fault history.

Data Analysis

This feature is to periodically analyze the evolution of plant efficiency on different time scales (from a few hours to several weeks). The algorithm performs a correlation between the evolution of the anode density and series of anode data previously selected. The algorithm then determines the most influential process parameters on the evolution of the density for the time period analyzed.

Data Visualization

This feature allows the users to seamlessly share all information gathered during the production as well as data from the analysis. These data are accessible through a common web interface.

The interface is designed and structured to provide quickly relevant information on the plant performance. Navigation allows the users to browse the process knowledge base to analyze production periods.

The users can quickly explore the history of all the KPIs of the paste plant and have an overview of the key process parameters through the dashboard for the production in progress.

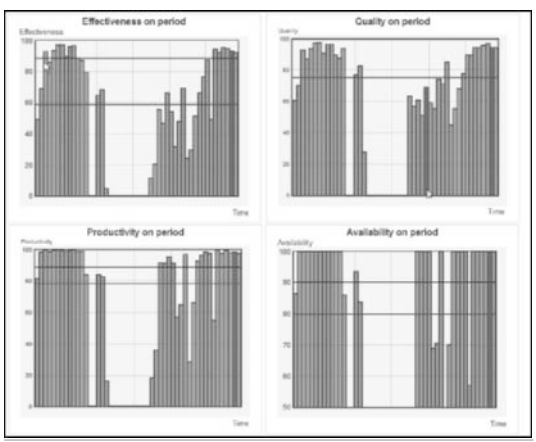

Figure 2: KPI History

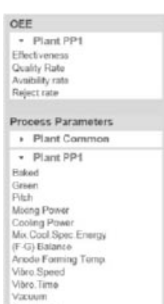

Figure 3: Dashboard, Key Process Parameters

They can deepen the analysis by focusing on the root cause analysis of breakdowns or the influence analysis of the production. Anode based trends allow the users to correlate production process parameters. Additional export facilities allow the users to extract information from the knowledge base to spreadsheets.

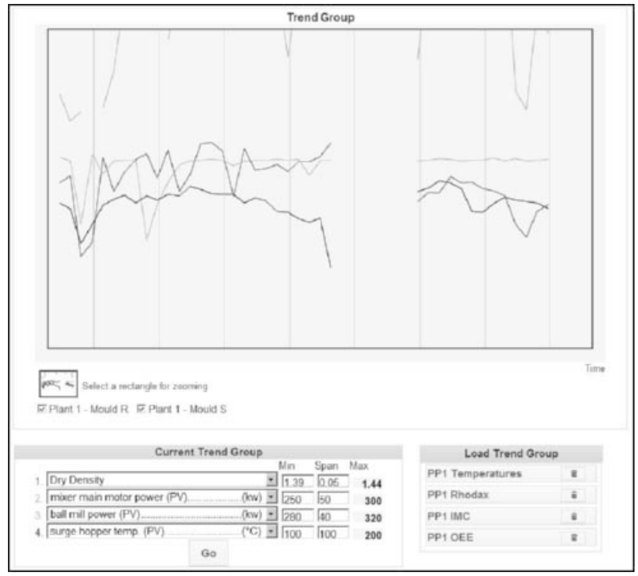

Figure 4: Anode Based Trend History

Figure 5: Root Cause Analysis Results, Pareto Chart

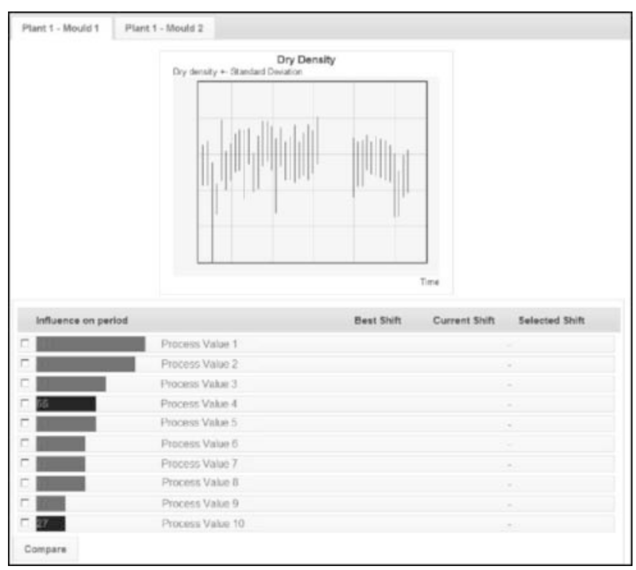

Figure 6: Influence Analysis, Pareto Chart

Implementation

The original version of this advanced tool has been adapted for a better integration within the plant control system of a greenfield project recently delivered.

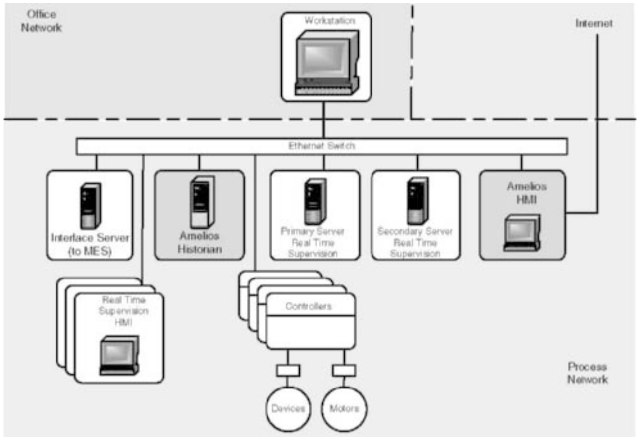

Figure 7: Simplified Control System Architecture

It uses a dedicated PC server to host a historian commonly used in the aluminium industry. The historian acts as a shared database for usual trend displays based on time-series and as input source for the software algorithms. It also hosts SQL databases to store system faults, production, process, and analysis data. A web server provides the access to the HMI and data export facilities to any computer connected on the local network. The system robustness is increased as its features prevent system and communication failures with the hardware/software redundancies and data buffering.

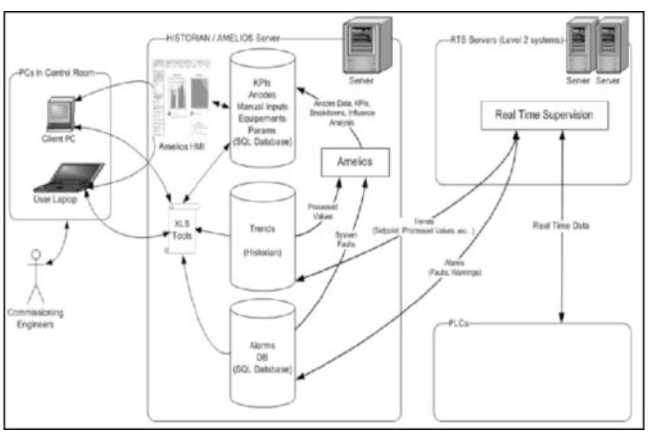

Figure 8: AMELIOS Server – Application Architecture

Case Studies during Commissioning

The system is running at a green anode plant whose production is currently at the start-up phase. The commissioning team uses this tool as the analysis system to provide statistics of the installation.

The process of the green anode plant is split into sections. Although the sections are interlocked between each others, they are independently commissioned. Therefore the performance tool tracks not only the production of paste, the quality of the anodes but also the sections status. Over a selected time period it gives the top 10 of system faults for each section, the production status (running, waiting, faulty). This helps to identify potential recurrent failures on equipments.

Figure 9: Performance Monitoring, Sections Follow-up

Additionally the Breakdowns and Fault monitoring tool collects the breakdown and faults histories to better correlate breakdowns with equipment faults.

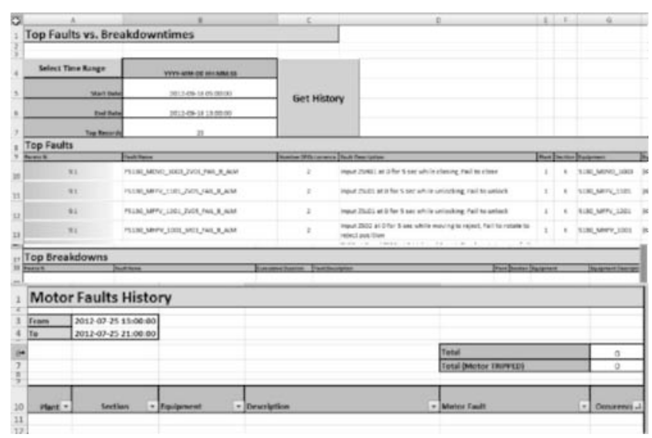

Figure 10: Breakdowns and Faults Monitoring

During the commissioning phase the equipment settings are changed up to the final fine tuning. The commissioning experts perform manual measurements to validate the good operation of the equipment. All this information is manually recorded into the system through the Equipment tool. For maintenance purpose the operation team can find thereafter in the log history the settings which are applied on the equipment.

Figure 11: Equipment Monitoring

In the same way, a tool exists to log measurements which are not recorded by the control system. As an example the operation team can record on a shift basis all the inlet/outlet pump pressures, and motor currents of the HTM-section. This helps to monitor any process disturbance or any equipment deterioration.

The commissioning and process team record information about raw material (coke supplier, sampling data, and equipment settings).

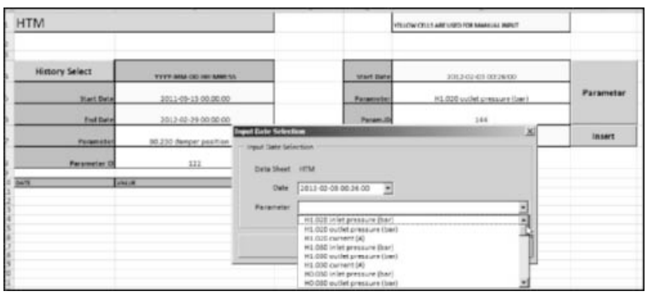

Figure 12: External Process Parameter Monitoring

The process engineers store granulometry data into the system through templates for any sampling point of the green anode plant. The granulometry history is then visible in GSD charts inside spreadsheets. The grain and sand contents of the material components are the followed up as trends.

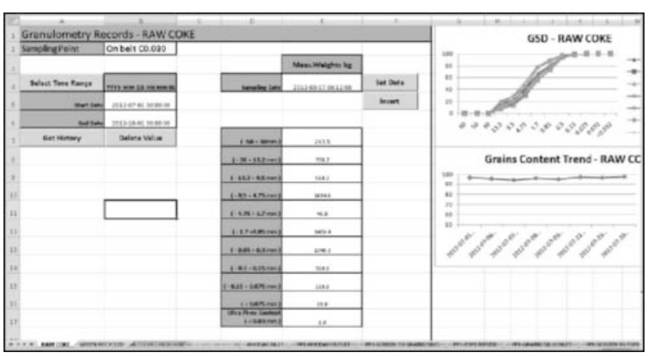

Figure 13: Granulometry Tool

The process engineers use the Process Parameter tool to extract aggregated data of the anode production process by combining process data on the material grinding, paste heating, mixing, cooling, and anode forming with event data like granulometry data, mechanical settings).

PROCESS PARAMETERS

Data Extraction		10/28/2012 16:57			
from		10/27/2012 7:00			
to		10/27/2012 19:00			
Data grouped by		Shift			
Plant		1		from	1
				to	1
	18	Standard Deviation Dry Density	S	g/cm3	
Production	19	Paste Production	S	ton	
	20	Operating Ratio (%)	S	%	
	21	Paste Plant Flow Rate	S	tph	
	22	Paste Plant Start-ups	S	--	
	23	Total Produced Anodes	S	ton	
	24	Total Good Anodes	S	--	
	25	Total Rejected Anodes	S	--	
	26	Rejected Paste	S	ton	
	27	Rejected Anodes + Rejected Paste	S	ton	
	28	Rejected Paste Percentage	S	%	
Formula	29	Coke (A) / Coke (A+B) Percentage	S	%	
	30	Baked Percentage	S	%	
	31	Green Percentage	S	%	
	32	GRAINS Percentage	S	%	
	33	FINES Percentage	S	%	
	34	PITCH Percentage	S	%	
Grain Size Distribution	35	Total Analyzed Samples	S	--	
Dry Aggregate	36	OS 13.7	M	%	
Grinding Data	47	Rhodax Speed	S	%	
	48	Rhodax Gap	S	mm	
	49	Rhodax Power	S	KW	
	50	Rhodax Vibration Amplitude	S	mm/s	
	51	TSV 1 Speed	S	%	
	52	TSV 2 Speed	S	%	
	53	Process Fan Flow	S	m3/h	
	54	Ball Mill Speed	S	%	
	55	Ball Mill Power	S	kw	
	56	Ball Mill Inlet Flow (Ex.180)	S	tph	
	57	Ball Mill Estimated Load (Wear Computation)	S	t	
	58	Added Balls Quantity	M	Kg	
Mixing Data	59	Preheating Screw Speed	S	rpm	
	60	Mixer Power	S	kW	
	61	Mixer Load	S	kg	
	62	Mixer Specific Energy	S	kWh/t	
	63	Mixing Residence Time		min	
	64	Mixer central rotor speed	S	rpm	
	65	Mixer wall side rotor speed	S	rpm	
Vibrocompacting	78	Vibro 1 Speed	S	rpm	
	79	Vibro 2 Speed	S	rpm	
	80	Vibro 1 Compacting Time	S	s	
	81	Vibro 2 Compacting Time	S	s	
	82	Vibro 1 Counter Pressure	S	bar	
	83	Vibro 2 Counter Pressure	S	bar	
	84	Vibro 1 Vaccum Pressure	S	mbar	
	85	Vibro 2 Vaccum Pressure	S	mbar	
	86	Vibro 1 Counterweight Setting	M	mkg	
	87	Vibro 2 Counterweight Setting	M	mkg	
	88	Vibro 1 Suspension Below Pressure	M	bar	
	89	Vibro 2 Suspension Below Pressure	M	bar	
	90	Paste Temperature at Vibro Inlet	S	°C	

Figure 14: Process Monitoring

Other tools allow the commissioning team to record any event into the database that have an importance in the process follow up.

Conclusions

This advanced tool has the ability to monitor the overall performance of green anode plants since the start-up of production. The system is fully embedded in the plant control system and uses the state of the art of IT software. This provides a good inter-operability and eases the system maintenance. All its features make it become a MES for the green anode plant which can run stand-alone and be linked to the global smelter MES.

Using this tool from the start-up of the production brings methodology to the commissioning team as well as operation teams to follow up the performance of the installation.

This software is helpful for the commissioning experts to quickly extract and analyze information from the system and let them focus more on troubleshooting. It allows a precise tracking of equipment mechanical settings as long as operation team record data into the system. It will be more and more used by both commissioning and operation teams during the fine tuning.

Implementing such a tool at this stage will ensure the green anode plant team to have a proven and ready-to-use tool for the nominal production of anodes. The system will also guarantee the producers to have a full snapshot of the green anode plant at the final handover of ownership.

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