Energy Optimization through a Metso Outotec Process Control Optimizer in Fluid Bed Alumina Calciner at CBA

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Abstract

The Metso Outotec Calciner Optimizer is an advanced real-time digital solution to optimize production tradeoffs and pushing the calcination plants to its optimum performance. Today, Metso Outotec has developed a complete tailored Advanced Process Control solution called Calciner Optimizer, which is in continuous operation at Companhia Brasileira de Alumínio (CBA) Alumina Calcination plants since late 2020. The core of the Optimizer solution is a know-how-based algorithms including enhanced process models to improve the operational performance. The paper explains the architecture of the Calciner Optimizer. The achieved results at CBA indicate significant energy savings and is showing a use-time of close to 100% when the plant is running in normal operation mode. Achievements with respect to fuel gas savings as well as greenhouse gas (GHG) emissions are discussed. An important factor in a successful implementation of an Optimizer at CBA Calcination plants is the close cooperation between CBA process experts and Metso Outotec digital and process experts. The paper describes how both parties contributed in this project to create a successful outcome. CBA experts provided the specific plant related constraints and requirements, while Metso Outotec digital experts tailored the Optimizer to specific needs. It is further described how modern digital infrastructure is used to achieve a good cooperation. Data driven analyses combined with process understanding were used to identify saving potential in the plant operation. An example is given in the paper.

Keywords: Calciner Optimizer, Energy savings, Advanced process control, Emission reduction.

1. Introduction

The Calciner Optimizer is an advanced process control (APC) based digital solution to support the daily operation of an alumina calcination plant [1]. In Metso Outotec (M:O) digital portfolio, the Optimizer development started in 2017 with the Roaster Optimizer, which are today used in several roasting plants and as well during commissioning of newly constructed plants [2].

From the Roaster Optimizer as a basis, the portfolio was extended to Alumina Calcination plants and tested first in late 2018 at one of the two fluidized bed alumina calcination plants of CBA. In 2019, several performance test runs were done at CBA with the Calciner Optimizer. Today, the Metso Outotec Optimizer technology is as well rolled out to iron ore Pelletizing plants. A reference in Thickening is [3] or in Leaching [4].

This paper describes the use of the Calciner Optimizer at both Companhia Brasileira de Alumínio (CBA) plants in Brazil with the main target to reduce the specific fuel consumption. CBA plants are located in Aluminio, Sao Paulo and is operating two Calciners, Calciner 5 and Calciner 6, with the Optimizer. The plants were built in 1985 and 1990, respectively. Modifications were carried out over the years. Currently, CBA operation is focusing on fuel savings to reduce costs and CO_2 emissions. Thus, the Calciner Optimizer focusses mainly on the reduction of the specific fuel consumption to support these operational targets. The specific fuel consumption is compared to a baseline operation in a period before using the Metso Outotec Calciner Optimizer.

The paper is structured as follows. Section 2 describes the on-site architecture of the Calciner Optimizer. In section 3, the operation of the Calciners with the Optimizer is described. The measured results, energy saving, CO_2 reduction as well as the time the Optimizer is operated at CBA are discussed in section 4. The collaboration between Metso Outotec and CBA during the project execution is described in section 5. The utilization of data analytics in combination with the APC digital solution to identify process bottlenecks and to further improve the operation is discussed in section 6. Conclusion and outlook are given in section 7.

2. Calciner Optimizer Architecture

The setup used on site of the Calciner Optimizer is shown in Figure 1.

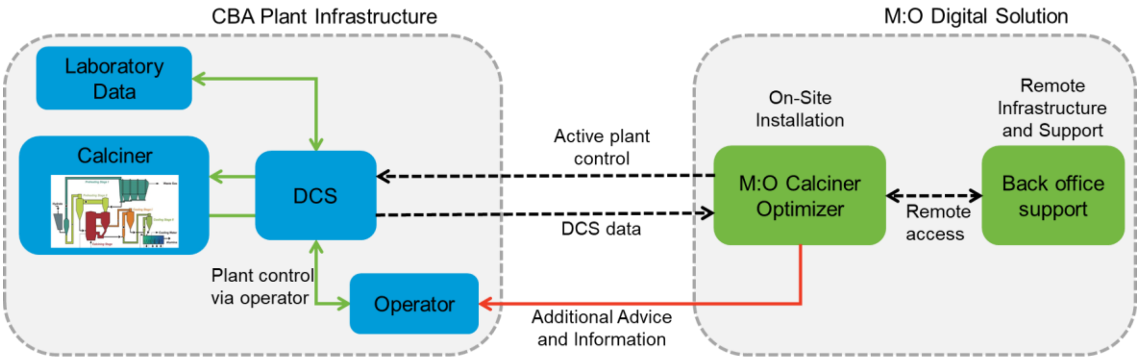

Figure 1. Architecture and integration of the Calciner Optimizer on site.

The left side is showing, in blue, the classic plant automation based on a distributed control system (DCS) and operator controlling the plant. Despite the Optimizer integration, the main setup of the plant DCS is entirely untouched. This means, all relevant safety functionalities like warnings, alarms, or emergency sequences remain and are in place when the plant is controlled via Optimizer.

The right side of the architecture graph shows the M:O Digital Solution. Firstly, it shows the M:O Calciner Optimizer. The Optimizer is connected to the plant (DCS) via an Open Platform Communications (OPC) interface. The Optimizer is installed locally within the plant premises. The setup allows the Optimizer to read the plant process data and to send set points back to the DCS controllers. Thus, the Optimizer actively controls significant parts of the calcination process. The set points are calculated continuously within the advanced process control scheme in the Optimizer or via further additional logics, simulations, mathematical operations etc. The connection between DCS and Optimizer is realized using an OPC interface.

M:O experts can connect remotely via secure internet protocol to the Optimizer on site. This allows M:O digital experts and process experts to fine-tune the Optimizer and to apply updates and new functionality. In addition, the remote infrastructure allows for data analysis to identify the best operational practices or to identify the most suitable settings for the Optimizer.

The Calciner Optimizer itself is implemented in M:O own APC software ACT, which is entirely developed and maintained by M:O and used in various APC and monitoring solutions worldwide. The platform can connect to any DCS system. It can execute many mathematical operations, simulations, create user interfaces, etc.

Currently, the Optimizer is controlling the following parameters of the CBA calciners:

- Hydrate flow rate
- Fuel flow rate
- Additional air blower 1 speed
- Additional air blower 2 speed (dependent on Calciner blower setups)
- Primary air blower speed
- Discharge device opening

The control of these parameters is mainly used to optimize different temperatures in the in the fluid bed furnace and the oxygen and lambda level as well as to keep up the differential pressure in the furnace. Further, control of the hydrate flow rate allows for stable and automated load changes.

2.1 Process Understanding and Simulation in M:O Optimizer

A strong focus of M:O Optimizer development in general and Calciner Optimizer development in particular focusses on a strict utilization of process understanding and mathematical process modelling. That means, the Optimizer is not limited to classic advanced process control (APC) logics. Instead, the APC implementation is strongly improved by various aspects of in-depth process modelling. Such process modelling can either be used to improve the controller performance by online calculations related to the control or by monitoring capabilities to improve the situational awareness. Such features are continuously improved throughout the CBA project execution.

One example can be given when looking more into the operation of an alumina calcination plant. Whereas many M:O process plants operate typically at a very low feed rate variation, a calciner operates between approximately 40% and 100% of full load. Naturally, some aspects of the process behavior depend on the plant load. The Calciner Optimizer thus uses mathematical process models in the background to calculate the plant behavior dependent on the load case and other process parameters. This allows a smooth operation over a wider load range.

3. Calciner Optimizer Implementation at CBA

In this section, the Optimizer interface used at CBA will be discussed. The operator interface for the Calciner Optimizer is shown in Figure 2.

Figure 2. Control screen of the Calciner Optimizer at CBA.

The main operator interface screen is separated into multiple functionalities:

- **Status information**: Providing overall status information, mainly whether Optimizer is running or not.
- **Controlled Tags**: Interaction screen for operations team to adjust the Optimizer settings. Here, the process targets and limitations are defined, for example the target feed rate, temperature targets or minimum allowed oxygen value.
- **Manipulated Tags:** Showing the process parameters which are influenced by the Optimizer. Operators have the option to provide limits (minimum/maximum) for these parameters, for example, if an equipment cannot operate in the full range.
- **Trends of important process values:** Some very important process parameters are shown via trend in the Optimizer interface. These trends allow for a quick assessment of the Optimizer operation as well as for checking the process stability.
- **Advice:** The advice screen is used to indicate process advice to the operation team. Such advice is for example, to start or stop additional blowers in case of low/high oxygen levels. The advice screen is a simple opportunity for interaction between the Optimizer and the operators.
- **Analysis:** The analysis screen shows real-time process assessment for selected parameters. It shows mainly the specific energy consumption. Further, some important laboratory results are indicated in this section of the screen.

At CBA, the most important process parameter targets are entered by the operations team via DCS. The Optimizer reads these values via the OPC interface. This simplifies the use of the Optimizer for the operations team, as no inputs are required any more inside the Optimizer screen. Similarly, important advice is shown on the DCS, easily visible by the operators.

4. Calciner Optimizer Results at CBA

This section shows the results at CBA, using the Calciner Optimizer during daily operation. A comparison is based on a reference period before operation with the M:O Calciner Optimizer.

4.1 Savings in Energy Consumption

The following results show the statistical evaluation of daily average specific fuel consumption values. The data for the statistical evaluation is filtered as follows:

- **Outliers** are excluded: abnormal data points typically due to start-up, ramp-down or otherwise strongly disturbed operation are excluded.
- **Feed range** is filtered: data points outside of the typical load range are excluded. All load ranges operated at CBA calcination plants are included.
- **Moisture correction** is applied. This is due to specific energy consumption of an alumina calcination plant being strongly dependent on the hydrate moisture. A correction is applied to make data points of different moisture comparable.

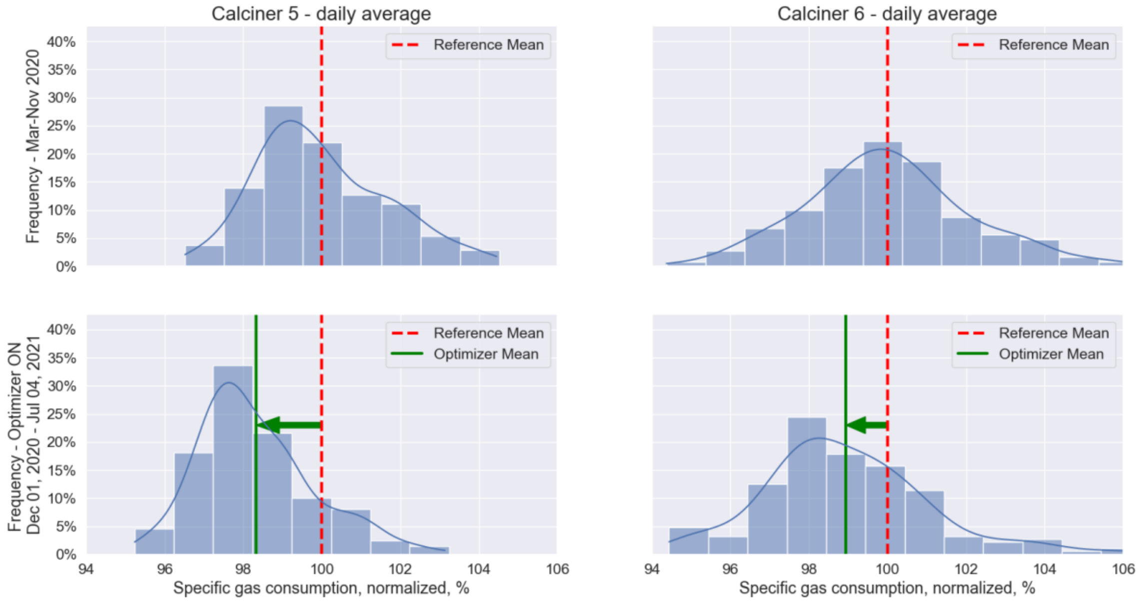

Figure 3. Specific energy consumption in reference period (top row), compared to Optimizer operation (bottom row) for Calciner 5 (left) and Calciner 6 (right).

The results of specific energy savings are shown in Figure 3. The graphs show the results for CBA Calciner 5 on the left and for CBA Calciner 6 on the right. The specific energy consumption is normalized with the average specific energy consumption for the reference period being set to 100% for each Calciner. The top row in this graph shows the results for the reference period (March to November 2020, before the Optimizer was in use). The bottom row of figure 3 shows the results using the Optimizer for the period from December 2020 until July 2021. Energy savings are clearly visible for both plants. The results show a reduction in specific energy consumption for Calciner 5 of 1.7% and for Calciner 6 of 1.1%. Further, the graphs show the kernel density estimation for the fuel consumption in all distributions. The kernel density estimation is a probability density function of the expected energy consumption in the respective scenario.

The Calciner Optimizer was improved over the time through collaboration between CBA process experts and Metso Outotec experts (process, digitalization, and APC) which could reduce further energy consumption over time.

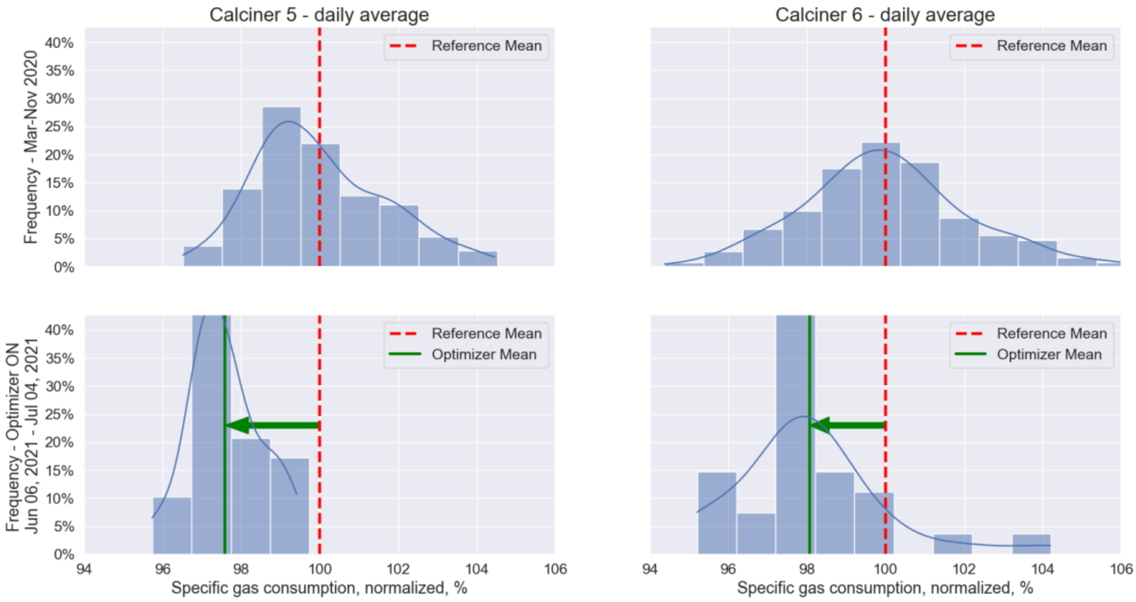

Figure 4. Specific energy consumption in reference period, compared to Optimizer operation after several months' operation.

The energy consumption in a later period, 2021, June 06th until July 04th, is compared to the reference period in Figure 4. The graph shows the full potential of using the Calciner Optimizer. The left column shows Calciner 5 highest energy consumption on daily average basis below the reference period average consumption. The right column shows Calciner 6 specific energy consumption with Optimizer almost entirely below the average consumption of the reference period. The savings in this period were 2.4% for Calciner 5 and 1.9% for Calciner 6.

Improvements of the specific energy consumption using the Optimizer, compared to the reference period, is summarized in Table 1. In summary, significant energy savings were achieved using the Calciner Optimizer in both CBA plants. The strong performance in the recent data indicates that the Optimizer was improved over time. This improvement was the result of close cooperation between CBA and M:O.

Table 1. Reduction of specific energy consumption.

Time period	Fuel savings, Calciner 5	Fuel savings, Calciner 6
Full Optimizer period, 2020, Dec. 01st – 2021, July 04th	1.7%	1.1%
Recent Optimizer period, 2021, June. 06th – 2021, July 04th	2.4%	1.9%

4.2 Fuel and CO_2 – Savings Calculation

A reduction of specific fuel consumption leads to a reduction in CO_2 emissions. The absolute amount of energy and CO_2 reduction is dependent on a calcination plant throughput and thus naturally on the size of the plant. In this section, a fictive example (not related to CBA operation) on CO_2 savings for different production facility sizes is given. The following assumptions are made:

- Assumed reference consumption 3000 $kJ/kg_{Alumina}$ (approximately 81 $Nm^3_{natural\ gas}/kg_{Alumina}$)
- 1 $Nm^3_{natural\ Gas}$ results in 2 kg CO_2 emissions
- 330 production days per year

Table 2. Reduction of specific energy consumption.

Refinery production rate, tph	Yearly production, t	Fuel savings, %	Yearly CO_2 savings, t
100	792 000	2 %	2569 t
150	1 188 000	2 %	3853 t
200	1 584 000	2 %	5138 t
300	2 376 000	2 %	7707 t

4.3 Optimizer Availability

A trend of both calciners, indicating the uptime of the Optimizer, is shown in Figure 5. The trend demonstrates that the Optimizer is ON (orange) most of the time except for periods of fast ramp-up or ramp-down procedures and for periods when plant is shutdown. The operation of the plants under normal conditions is easier and more reliable with the Optimizer being online. The energy consumption is lower and the plant operates with a higher degree of automation with the Optimizer. It can be concluded, that during normal operation, CBA uses the Optimizer without interruption.

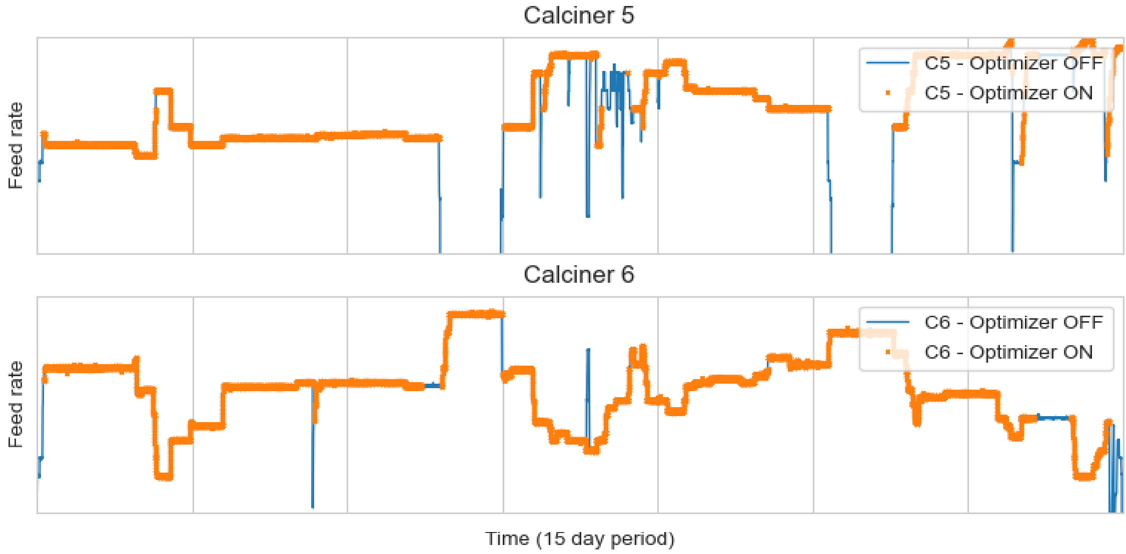

Figure 5. Optimizer use-time.

For the first half of 2021, the Optimizer of Calciner 5 was online 92% of the time during normal operation. Calciner 6 Optimizer was online 91.2% of the time. In the middle upper graph of Figure 5, the Optimizer was offline for a long period on Calciner 5 due to the plant ramping up/down, which explains why the Optimizer was offline. This further bears a risk for increased energy consumption due to not using the Optimizer and having unstable process conditions. In addition, data analyses show that the Optimizer is sometimes not in use at very low production rates.

4.4 Product Quality

An important product quality parameter for an alumina calcination plant is the loss-on-ignition (LOI). It is typically measured frequently at the site laboratory. For the operation in January to June 2021 with the Optimizer, the LOI is shown in Figure 6. The green line indicates the product specification, which is an upper limit to the LOI. The blue line shows the laboratory measurement of the LOI. Note that for Calciner 5, some LOI values in the beginning are missing. The LOI specification was met throughout the entire operational period of the Optimizer. Due to the accurate set point tracking with the Optimizer, the product quality was very stable. In the early stage in January 2021 some tuning effect was seen in the results on Calciner 6 (lower graph). The LOI results improved afterwards and results were consistently very low. There was, however, a short period in April/Mai with slight increase in the results while remaining below specification limit. In conclusion, the product quality specifications were always met with the Optimizer and the operation ensures a high-quality alumina product.

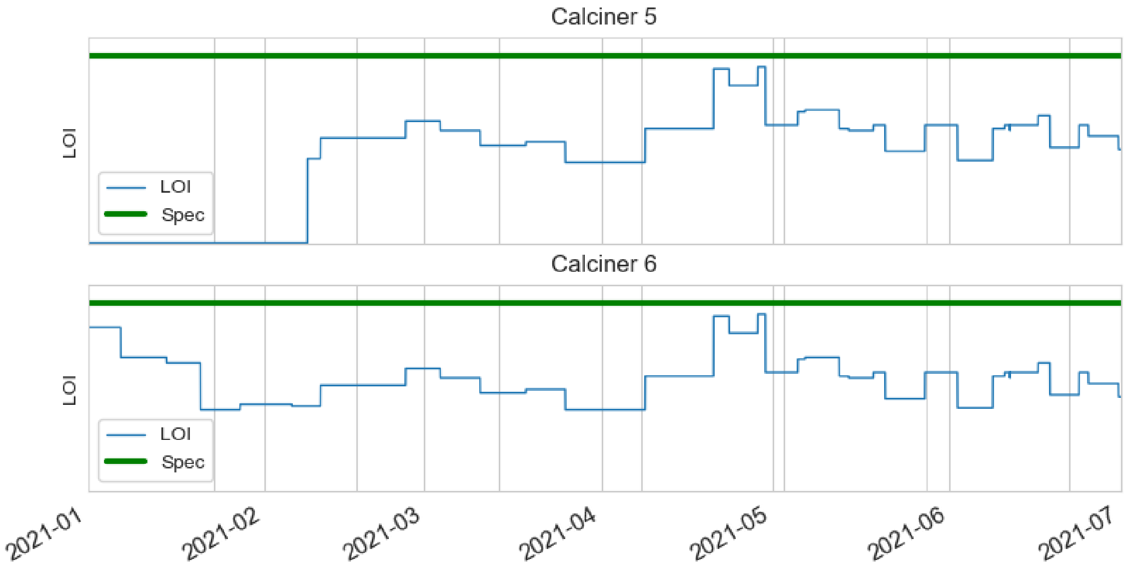

Figure 6. LOI trend for first half year 2021, compared to product specification.

5. Digitalization to Enhance Collaboration between M:O and CBA

A digitalization project, which is directly affecting the operation of a process plant, is seen as a journey of improvements. As was already shown in the previous sections, energy savings increased during the project execution period. The cooperation between CBA process experts and M:O digitalization and process experts was exceptionally effective throughout the Optimizer operation. Both achievements as well as opportunities to improve were openly discussed and solutions applied remotely by M:O to the Calciner Optimizer.

One example of such an improvement journey is the integration of the Optimizer closer to the DCS operator interface. In the beginning, feed rate target and temperature targets were adjusted only on the Optimizer screen. In addition, warnings, and advice to operating personnel were as well only shown on the Optimizer screen. This topic was discussed between CBA and M:O and agreed to closer integrate these points to the DCS screen. The communication protocol both for feed and temperature set points as well as for the warning and advice flags between DCS and the Optimizer were agreed. Today, this integration allows the CBA operating team to have the important information directly on the DCS as well as on the Optimizer screen.

A crucial success factor of the Optimizer implementation and utilization at CBA alumina calciners is the cooperation and open contact between the stakeholders. The project team uses a dedicated communication platform to report and interact. It allows to store results, share quick process analyses, address challenges in operation despite being in different locations and time zones. The digital project brings closer the CBA operating and process team with M:O digital and process experts. It enables a clear and very quick communication, giving shortest reaction times both for Optimizer and process discussions.

6. Data Driven Process Analytics

Besides the Advanced Process Control Scheme within the Optimizer and the process simulation models, M:O is using state-of-the-art data driven analytics to improve the operation. One advantage for M:O to provide the process plants and the digital Optimizer solution is that the data driven findings can normally be explained from a process perspective. In other words, if data analytics identify a finding there is normally a good process reason for it. The digital Optimizer allows easy in-depth data analytics and provides a good basis for process related discussions between CBA and M:O.

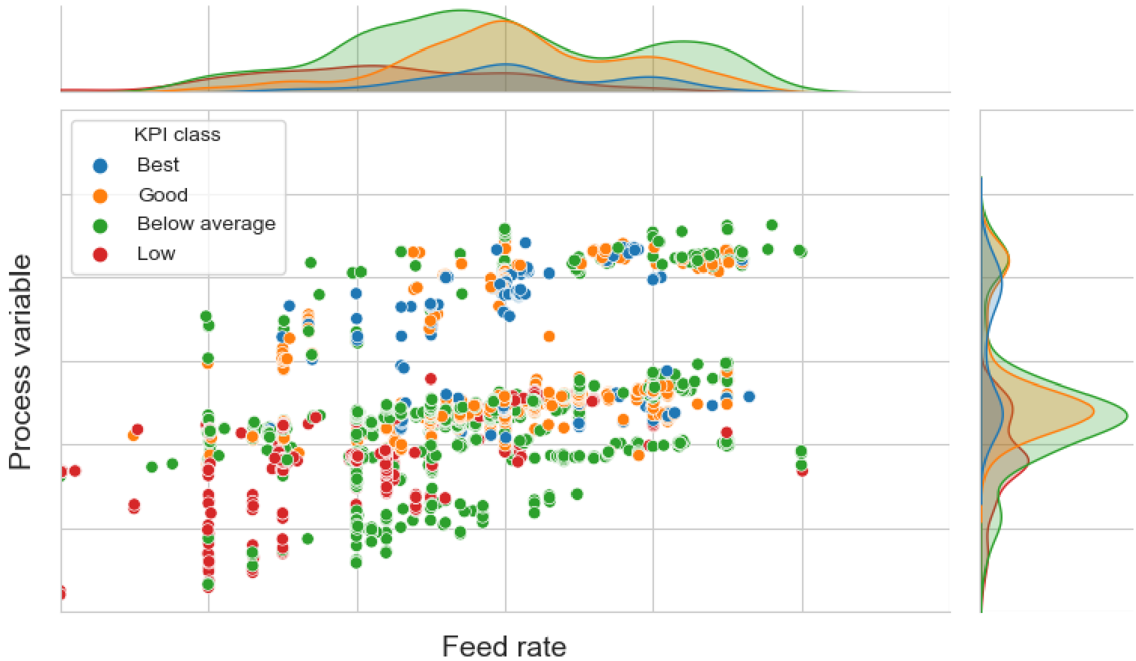

Figure 7. Example of data driven process analytics.

One example is shown in Figure 7. The process variable to be investigated is shown on the y-axis, and the feed rate on the x-axis. Grouping the data into different operational KPI classes using colors gives indication on how well the process is running. In the example, blue data points are the best KPI and red data points poor or low KPI which shall be avoided. This type of graphics led to discussions between CBA and M:O project teams to identify bottlenecks and opportunity for improvement. In this example, a higher process value for this process variable led to a higher probability of getting best (blue) KPI performance. The diagram further shows kernel density estimations (KDE) close to the axes. These KDEs indicate that low (red) data points are more likely at lower values for this process variable.

7. Conclusion and Outlook

The Metso Outotec Calciner Optimizer is a digital solution combining modern advanced process control (APC) techniques with detailed process modelling. It is now in operation since December 2020 at both CBA fluidized bed alumina calcination plants, Calciner 5 and Calciner 6, in Brazil. The Optimizer automatically controls certain process parameters with objective to reduce the specific fuel consumption of the plants.

The specific energy consumption of both plants was compared to a reference period in 2020, where the plants were operated without the Calciner Optimizer. In the period with the Calciner

Optimizer solution between December 2020 and July 2021, the following specific energy savings were observed:

- Calciner 5 – 1.7 %
- Calciner 6 – 1.1 %

Over time, the Optimizer solution was continuously improved. Such improvements and developments were the result of collaboration and constructive communication between CBA process experts and M:O digitalization and process experts. As a result, the Energy consumption was reduced for a period in June 2021 to:

- Calciner 5 – 2.4 %
- Calciner 6 – 1.9 %

The reduction in specific energy consumption also means a reduction in CO_2 emissions of a calcination plant. A calculation assuming a production rate of 100 tons alumina per hour and 2% energy savings results in 2569 tons CO_2 savings per year, combined with a financial benefit in gas savings. The analysis of the product quality during the Optimizer operation shows stable and consistently within specification results.

In the entire period, the Optimizer was almost always used by CBA operations team. The uptime of the digital solution was 92% for Calciner 5 and 91.2% for Calciner 6 during normal operation. The Optimizer is occasionally stopped for very fast ramp-up or ramp-down procedures, during updates or at very low production rates.

The digital solution enables a very close communication between CBA and M:O experts, which extended the collaboration beyond the support of the digital Calciner Optimizer to process related topics. As a result, plant bottlenecks can be found, Optimizer shortcomings identified, and more tailored solution implemented specific to CBA needs. These process related discussions were supported by data driven statistical analysis, which proved very efficient in the identification of energy saving potentials.

7.1 Outlook

As the Calciner Optimizer is based on an advanced process control scheme, it stabilizes the process very well. A more stable process provides opportunity to focus more on the process itself while continue operating the plant with an Optimizer. In conclusion, utilizing a digital Optimizer solution at a process plant is an optimization journey.

Focusing on the process can be two-fold:

- Integrating more process simulation and know-how into the Optimizer
- Assess the process and decide which bottlenecks must be addressed

More process simulation and know-how integration to the Optimizer means, that the focus switches from an APC solution towards more process supporting and debottlenecking tool, while the Optimizer is still running. As a mid-term target, the utilization of a digital process twin is planned. Finally, the current Optimizer experience and the deeper understanding of the CBA process will allow for a clear analysis of the plant instrumentation. Assessment and improvement of process instrumentation could lead to further energy savings.

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