ABB Cement Fingerprint - A Holistic Approach for Cement Industries

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Abstract:
ABB’s Cement FingerPrint is a new service approach to cement customers that aim to assess the status of a cement plant, right from stock pile making to cement grinding, to identify process and energy efficiency improvement opportunities. Cement FingerPrint is intended to analyze the total installed equipment base and relate these installations to the overall production process.
For this purpose, the historical plant data is collected to study operational practices and process variability. Plant sensitivity tests then are conducted to understand the dynamics of the different areas of the plant. This same data is used to build process models. Both historical data and process models are used to analyze the current plant performance and identify process and energy improvement opportunities.

With this paper ABB will explain the different steps of the Cement FingerPrint concept, from data collection to plant modeling, and will discuss the results of one specific audit.

1. Cement FingerPrint

1.1 What is Cement FingerPrint?

Cement FingerPrint is a holistic approach that aims to assess the status of a cement plant from stock pile making to cement grinding, finding process and energy efficiency improvement opportunities.

For this purpose, the historical plant data is collected to study operational practices and process variability. Plant sensitivity tests are then conducted to understand the dynamics of the different areas of the plant. This same data is used to build process models. Both, historical data and process models are used to analyze the current plant performance and identify process and energy improvement opportunities (see Fig.1).

1.2 What happens during a Cement FingerPrint project

The main tasks in the investigation of each designated area are as follows:

- Conduct process study and observe operation
- Collect and analyze process data
- Conduct plant sensitivity tests and develop process models
- Analyse benefits

To execute a FingerPrint analysis, the effort expected (per area!) is one of five days on site, and five days in the office, for one ABB FingerPrint engineer. Synergies can be realized if several areas are analyzed simultaneously. Fig.2 represents a typical project execution plan.

Special attention is paid to the base automation. Indeed, base controllers such as material, pressure or flow controllers play an important role in the overall process stability; If the actuators do not obey tightly then self induced oscillations will propagate throughout the whole plant. These assets represent a constant challenge for the automation engineers not only due to their large number, but also for their tendency to performance degradation.

In a cement plant there are a number of critical PID loops whose performance is crucial for operational excellence. These are (see Fig. 3):

- Raw mill: limestone and additives feeders
- Precalciner and kiln section: kiln feed, coal feeder
- Cooler: under grate pressure controllers
- Cement grinding: Temperature controllers.

Activities in this area can be summarized as follows:

- Collect historical data for critical PID loops
• Perform PID setpoint changes to generate data related to dynamic conditions
• Analyze data with ABB’s PID performance assessment tools
• Make a diagnosis of generation and report writing

1.3 How will Cement FingerPrint improve your operation?

Depending on the plant situation the expected benefits are achieved by implementing (see Fig. 4):

• Variable-speed drives for specific applications
• Additional measurements such as online gas analyzers and feed and/or cement quality analyzers
• PID loops tuning services and continuous loop monitoring systems to preserve performance improvements into the feature
• Multi-variable controllers using techniques such as Fuzzy Logic and/or Model Predictive Control
• Energy management systems to monitor energy consumption, but also to manage the complexity inherent to power grid capacity constraints, own generation capacity and optimal production scheduling
• Heat Recovery Power Plants

The following Chapter describes the audit, where Cement FingerPrint was conducted for a precalciner area. Furthermore, it points out where business excellence can be achieved, summarized as recommendations.
2. Process area precalciner

2.1 Process Description

The pyro-processing system at the plant investigated, consists of a five stage preheater with Low NOx in line precalciner equipped for staged combustion, kiln and cross bar cooler. Design rating of the system is 3200 tpd of clinker, but it is currently working at 3750 tpd. At the moment specific energy consumption appears to be in the order of 800 Kcal/kg of clinker, which appears to be high for the plant layout. Coal is introduced through an indirect firing system on both, the kiln and the precalciner with 55-60% of the fuel being introduced in the precalciner.

The signals available appear to be sufficient to control, monitor and optimize the process. The combustion conditions are assessed using an oxygen probe that is reliable. There is no CO meter in the precalciner area, which is possibly an area for improvement of the combustion efficiency. Measurements of the precalciner outlet temperature and the cyclones are in place. An overview of this area can be found in the Fig.5.

2.2 Process Analysis

Historical Data Analysis

Raw data was gathered during these activities and Fig. 6 gives a representative sample of it. The graphics on the left column represent a time series. The horizontal axis is the time, while the vertical axis depicts the value of the magnitude in question at the given time. The graphics on the right column represent so called histograms. This means that in the horizontal axis we have the natural scale of the magnitude (e.g. oC), while in the
vertical axis we have an indication on how often the particular value of the magnitude was measured. These graphs give a visual clue as to how variable the process magnitude is. Additionally, the average and standard deviations are represented by the red and pink vertical lines, respectively.

**Methodology for Benefit Estimation**

For the precalciner the calculation of benefits is conducted according to the following scheme:

- Use historical data to calculate average and standard deviations of the critical magnitudes
- Assess as to which extent kiln feeding could be made more accurate
- Use models generated from the sensitivity analysis. This allows calculating the effect of this change on the precalciner temperature variability
- Calculate the effect on the fuel consumption of a change in precalciner temperature setpoint
- Estimate financial benefits
- Realize further savings by reducing the excess oxygen setpoint

Fig. 7 shows the starting conditions in the precalciner. Note the large variability of the feed as root cause for the variability of the temperature.

The variability of the temperature decreases after improving the accuracy of the kiln feeder (see Fig. 8). The improvement can be accurately and systematically quantified using ABB's methodology based on process model identification.
Fig. 9 depicts the final status after having selected a new setpoint for the precalciner temperature. Note how fuel consumption could be reduced. The financial value of this chain of improvements is estimated to be a five-digits US dollar number per year.

However, if the feed rate cannot be increased due to bottlenecks in the systems outside the precalciner, the reachable benefits would be based only on fuel consumption reductions, in this case of about 2%. The final precalciner status would be as depicted in Fig. 10.

The benefits of these recommendations have been calculated using the following simple formula and data (see Fig. 11 and Fig. 12).

2.3 Path to Operational Excellence

Recommendation 1

Kiln feed feeder as major source of disturbance for precalciner operation, whereas deviations of up to 5% are commonly observed. The feeder has a negative bias, which produces high PC temperatures.

Estimations with our models suggest that correcting this feeder will lead to either 1% production increase or alternatively, if that is not possible, to an equivalent reduction of coal consumption, we recommend:

- Retune underlying PID loop
**Recommendation 2**

Precalculator temperature sensor produces erratic results. From the data it is also seen that precalculator temperature is better assessed via Cyclone 5 sensor, and we therefore recommend:

- Change PCT sensor location
- Consider installation of two more sensors for more robust results
- Use the median as temperature indicator, as opposed to average

**Recommendation 3**

Preheater O2 is at a relatively high level of 4%. This means relatively high specific energy consumption, in this case of about 780-800kcal/kg.

It is further noted that no CO measurement exists. This is considered a disadvantage as, in order to increase the efficiency, it will be necessary to reduce the excess oxygen level. In a "scarce oxygen" situation it is important to have a CO measurement for better assessment of the combustion conditions. Our recommendations are:

- Reduce oxygen setpoint from 4% to 3%, and achieve it via reduction of fan rate
- Consider CO online analyzers in the preheater outlet and/or the precalciners for better monitoring of the combustion conditions

In addition to audits and assessments in specific process areas, it is also important to take a plant-wide view. In the next Chapter the usage of an information management system and an energy management system are described.
3. Plant-wide Topics

3.1 Information management system

It is evident for making long-term analysis of plant performance that the plant records process data. Such a system is an important item of plant optimization initiatives as it facilitates tracking their success. Such a plant information management system is for example ABB's Knowledge Manager (see Fig. 13):

3.2 Energy Management System

Electrical power cost account for a substantial share of the total cement production cost. Moreover, in presence of constraints given by the power grid and/or variable electrical power prices, power management becomes a matter that needs serious attention from management. This is even more the case when the cement plant has captive power generation, as it increases the degree of freedom to respond to the variability of the external conditions.

In such conditions the plant manager must take decisions on a daily basis, such as which parts of the plant may be disconnected from the grid and in which order. Optimally these decisions are based on:

- the plant conditions (e.g. which equipment is online or on maintenance, which mills are more or less efficient)
- the cement market condition (need for a particular cement type, and existence of it in storage)
- power market (power prices, grid constraints, possibility to buy and sell power).
In order to make optimal decisions all aspects of the problem need to be considered.

A modern cement plant needs a plant-wide energy management system due to the following reasons:

- Liberalized power market
- Plant captive generation
- Power grid constraints

As an example, a plant needs 20MW in normal operation, while having captive power of 14MW. At the same time, there are time-dependent constraints on the amount of power that can be drawn from the grid: at peak hours maximum 1 MW can be taken from the grid, which means that the cement plant needs to reduce consumption by 5MW during those parts of the day. It follows that the cement plant needs a dynamic and flexible strategy in place to deal with the power constraints at all times.

It is clear from it that some consumers can be used to reduce power consumption by about 5MW at peak times. For instance, the crushers, the conveyor belt ("cross country") and the cement mills are large consumers that can be stopped basically at any time without compromising plant integrity.

However, for several reasons stopping some of the equipments (e.g. cement mills) should be avoided if possible. Further, it is also clear that depending on the plant conditions, it may not be necessary to disconnect all these large consumers. It follows that the cement plant needs a system that allows for consistent decision making, based on the real conditions in the plant and in the market on the particular date.
The functionality of such a system is tailored to meet the needs of the cement industry.

We recommend the installation of an Energy Management system in two phases:

First phase

- Monitoring of main consumers (see table)
- Short-term (15 minutes to several hours) forecast of power consumption over these consumers

Second phase

- Increase granularity of energy monitoring system
- Create closed loop strategy for optimal decision making at peak times or at times of grid restrictions

ABB has created a leading energy management system. Below we name a subset of the functionality that ABB's system offers:

- Monitoring of equipment efficiency
- Establishment of targets and monitoring of actual energy efficiency to improve real-time decision making
- Prediction of accurate energy demand schedules
- Allocation of energy consumption to off-peak hours and energy production to peak hours
- Utilization of several optional energy sources
- Use of most cost effective sources and fuel types combination
- Cost accounting for company’s internal energy distribution
4. Figures

Fig. 1: Cement FingerPrint process
Fig. 2: Cement FingerPrint project plan
Fig. 3: Critical PID Controllers in a cement plant

Fig. 4: Cement FingerPrint value proposition
Fig. 5: Precalciner process diagram
Fig. 6: Precalculator historical data

Fig. 7: Precalculator starting conditions
Fig. 8: Precalciner conditions after improvement of kiln feeder accuracy

Fig. 9: Final status in the precalciner
Fig. 10: Final status of precalciner if the feed rate cannot be increased.

Benefit = 24 × NumberDays × \(\text{ProductMargin} \times \Delta\text{Feed/ClinkerFactor} + \text{FuelCost} \times \Delta\text{Fuel}\)

Fig. 11: Benefit formula
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<th>Name</th>
<th>Unit</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
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<td>NumberDays</td>
<td>1/year</td>
<td>330</td>
<td>Number of Operating Days Per Year</td>
</tr>
<tr>
<td>2</td>
<td>ProductMargin</td>
<td>USD/ton</td>
<td>20</td>
<td>“Ebit margin” per ton of cement</td>
</tr>
<tr>
<td>3</td>
<td>∆Feed</td>
<td>Ton/hr</td>
<td>2 / 0</td>
<td>Production Increase</td>
</tr>
<tr>
<td>4</td>
<td>ClinkerFactor</td>
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<td>1.6</td>
<td>Feed to produce 1 unit of clinker</td>
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<tr>
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<td>FuelCost</td>
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<td>40</td>
<td>Cost per ton of fuel</td>
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<td>Reduction in Fuel Consumption</td>
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<td>7</td>
<td>Benefit</td>
<td>USD/year</td>
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<td>Financial Impact</td>
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</table>

Fig. 12: Table - Benefit calculation
Fig. 13: Knowledge Manager