INCREASE OF BOILER EFFICIENCY
BY SELECTIVE ON LOAD BOILER CLEANING
–
AN INNOVATIVE APPROACH USING DIRECT MEASUREMENT AND DYNAMIC SOFTWARE ALGORITHMS

D. Bartels, K. Pham, M. Schumacher, M. Frach, C. Mueller

Clyde Bergemann GmbH
Schillwiese 20
46485 Wesel
Germany
smayer@cbw.de

Abstract: Slagging and fouling of heating and reaction surfaces limits the steam generator efficiency. Characteristics and behaviour of deposits are subject to numerous influencing factors, such as fuel and process parameters, which make it necessary to link boiler cleaning and boiler process data and derive demand-driven cleaning criteria. This integration of process know-how enables boiler cleaning technology to increase steam generator availability and efficiency.

Key words: boiler cleaning, sensor system, intelligence, demand-driven

1. INTRODUCTION

Ash-related operational challenges caused by slagging and fouling are currently the main reason for reduced boiler efficiency and unscheduled shutdowns. As deposit formation is influenced by numerous and continuously varying process parameters, these parameters need to be considered during boiler cleaning to avoid inappropriate cleaning actions. To utilise boiler cleaning to guarantee steady boiler operation, it needs to be controlled by the following aspects:

- WHERE exactly is cleaning required?
- HOW intensive does the cleaning need to be?
- WHEN is the best point in time to execute cleaning?

The use of these aspects guarantees that boiler cleaning is executed demand-driven and no longer subject to manual or time-triggered control. Accomplished with plant specific process data, boiler cleaning can be flexibly adjusted to fuel and boiler specific conditions.

This kind of intelligent boiler cleaning has been applied to a coal-fired 350 MW tower-type boiler. This reference shows how an existing boiler cleaning system can be upgraded to a demand-driven operation by means of direct measurements combined with dynamic software algorithms.

2. INTELLIGENT BOILER CLEANING

During combustion, organic- and inorganic constituents of the coal are exposed to high temperatures. While the organic components are chemically converted during the combustion process the inorganic constituents, the ash forming matter, are released into the process. Here they cause ash deposition, namely slagging in the furnace and fouling in the convective zone.

Deposit formation is subject to numerous, continuously varying factors, such as the chemical composition of the fuel and the quantity and distribution of ash forming matter in the fuel. Furthermore, process parameters such as varying loads create load-dependent deposit characteristics and also different mill combinations effect slagging and fouling. Slagging on furnace walls strongly depends on the local flue gas temperature and related heat fluxes. Deposit formation at heating and reaction surfaces are also influenced by the actual flue gas temperature but even more by the flow characteristics of the ash particles. Due to this diversity of influencing factors and their interdependence, it is very unlikely that one global, once fixed and forever valid cleaning strategy is able to meet the described challenges. An intelligent, demand-driven boiler cleaning concept is needed, which is based on process know-how complemented by software and diagnostic systems.

2.1. State of boiler diagnostics and its limitations towards boiler cleaning applications

There are several computer-based online systems available to monitor single plant components or even complete processes, facilitating process analysis and optimisation [1]. They all collect data, calculate efficiencies and allow determining other performance parameters. Such performance parameters enable to limit the large number of available process parameters to a manageable quantity of values allowing an efficient operation of the process.

All currently available boiler diagnostic systems are only of limited use for boiler cleaning. One reason is that the calculation routines applied in such systems determine the overall heat absorption in the furnace but do not allow a selective analysis of the furnace with regard to the local heat transfer and degree of ash deposition or the best point in time for local furnace cleaning. In addition, due to missing real-time behaviour of such systems, the time delay between deposit accumulation and detection is up to two hours. Consequently, cleaning is carried out too late possibly resulting in severe deposits which are difficult to clean. The same situation is valid for the superheater and economiser zone. The overall fouling situation can be calculated but in most cases the calculations are not done in real-time due to a slow iterative calculation of the conductance of the heat exchanger surfaces. Furthermore, at many plants with boiler diagnostic systems, boiler cleaning is time-triggered. The diagnostic system acts as a timer only and the cleaning operations are preset based on "typical" operating conditions. There are also plants, where boiler cleaning in the convective pass is triggered by cleanliness factors. However, since there is no information available about where exactly the deposit is located, all sootblowers of the concerned heating surface have to be activated. Due to heterogeneous deposit distribution in the superheater region, such a global sootblower activation may lead to an over cleaning of less deposited areas, resulting in unnecessary steam consumption and increased risk of erosion. Areas with severe deposits instead stay insufficiently cleaned promoting continuous fouling and lowering the steam generator efficiency.

This global calculation method of the deposit situation is not suited to adjust cleaning parameters flexibly to fuel and process specific requirements. In addition, there is no direct assessment of the cleaning success possible, since local variations of heat transfer within a heating exchanger are not detectable.

2.2 Boiler diagnostics based on direct local measurement and dynamic software algorithms

The above mentioned disadvantages with regard to real-time monitoring of process behaviour and local deposit growth as well as the possibility to react on fuel and process specific changes, require the combined use of novel dynamic software algorithms and directly measured process characteristics in the steam generator. The consideration of plant specific process data enables the boiler cleaning system to perform cleaning actions in a way that efficiency and availability of the steam generator is sustained or even increased.

The selective detection and evaluation of slagging in the furnace has been published earlier [2,3] and is not part of this paper.

Several measurement techniques have been tested before for detecting heterogeneously distributed deposits within the superheater region. However, first the sensor-based weight measurement by means of multi-dimensional strain gauges proved to be a suitable method. The sensors are placed at the hanger rods in the boiler penthouse, whereas the specific location depends on the boiler design and the position of the cleaning devices.

Deposit build-up on heat exchanger elements leads to a weight increase which is measured by the sensors as an electric signal. Figure 1 shows a typical development of superheater weight and thereby deposit weight and the influence of cleaning actions on the weight. Target of this measurement is to determine local deposit accumulation via weight differences.

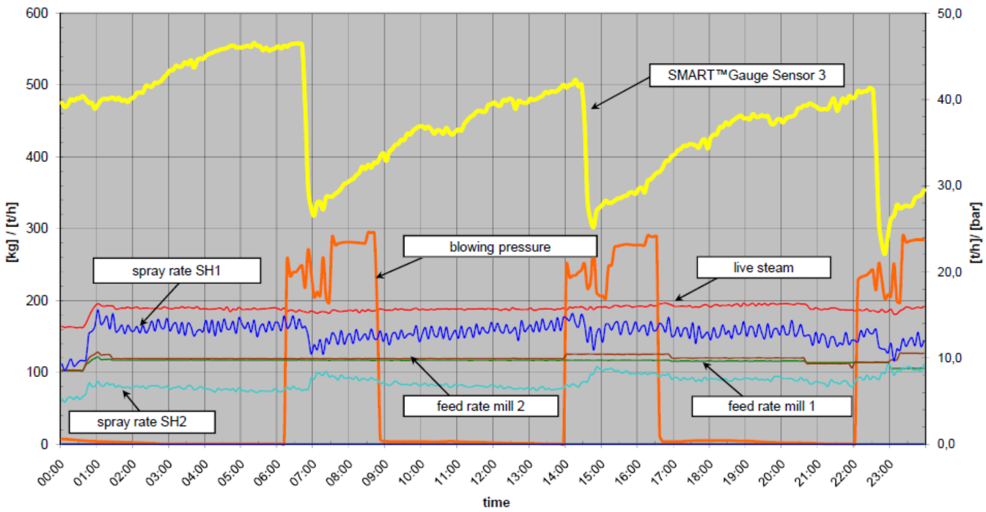

Figure 1: Signal response of weight measurement at a superheater.

Heat exchanger bundles are usually mounted at a multitude of sub-carriers fixed to the boiler framework via hanger rods (Figure 2). Vertically and horizontally mounted heat exchanger bundles require different processing of the measured weight signal. Since vertical heat exchanger bundles have individual hanger rods, the results of the direct measurements can be applied directly to locally identify the deposits. Together with plant specific process data, this information will be used to define best in class cleaning parameters in terms of timing, cleaning intensity and local selection of required cleaning devices.

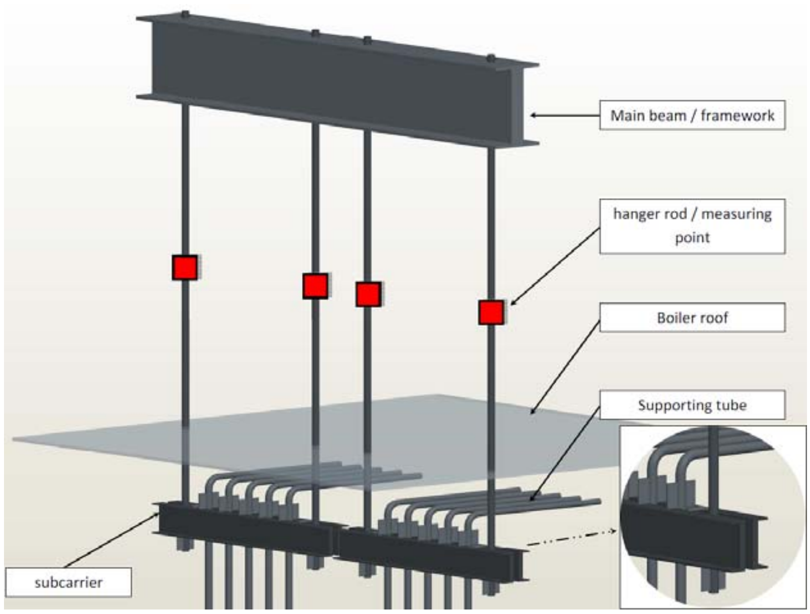

Figure 2: Suspension of heat exchanger bundles with mounted weight sensors.

In tower-type boilers, all heat exchanger bundles are suspended at the same hanger rods. The direct measurements give information about weight differences across all heat exchanger bundles over the height of the convective zone. To get to know where exactly within this zone the relevant deposits are located, in addition a thermodynamic model (TDM) is applied based on a boiler model presenting the given boiler design and characteristics. The TDM uses process data of the water-/steam-cycle and of the flue gas stream and its accuracy strongly depends on the quality of these data. While processing the data the TDM assesses important process characteristics such as the Cleanliness Factor (CF). The Cleanliness Factor is the ratio of the conductance of a heat exchanger at a given point in time and at clean conditions and it is used to initiate demand-driven boiler cleaning. Combining the results of the weight measurement and the thermodynamic calculation, two independent information about the deposit situation are available. An intelligent combination of both information together with plant specific process data makes it possible to locally determine the deposit within a heat exchanger zone. Furthermore, it allows a selective evaluation of a non-uniform deposit distribution over the heat exchanger cross-section. Hence, the convective zone is divided into several defined zones and the deposit situation can be determined for each of these. This provides the base to clean each of these zones demand-driven with optimal cleaning parameters depending on the current fouling situation.

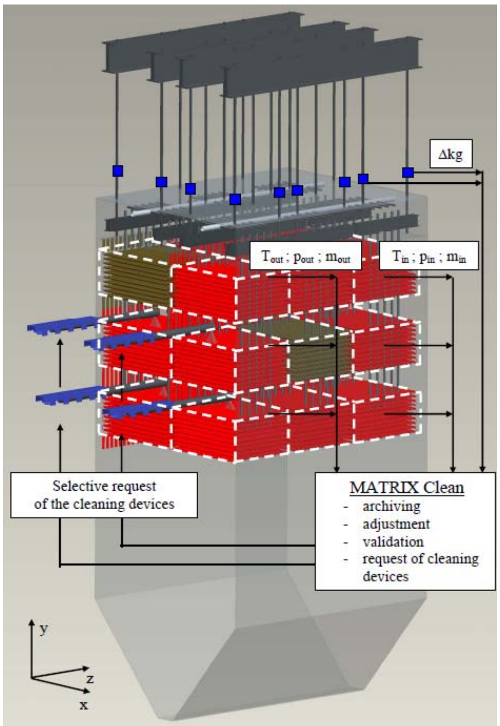

Figure 3: Split of the superheater area in zones for selective deposit analysis.

Figure 3 shows schematically the split of the superheater area in different zones. This segmentation does also allow operating cleaning devices selectively, meaning only devices located near the detected deposits are activated. Since the continuous direct measurement feeds back the cleaning results immediately, cleaning parameters can be automatically adjusted. The combination of demand-driven cleaning operation and dynamic parameter adjustment makes it possible to reduce the number of cleaning cycles while improving cleaning results and increasing steam generator efficiency.

3. Results

The described sensor-based optimisation system has been applied to a 350 MW hard coal-fired power plant La Robla and is in operation since more than one year. The plant is located in the municipality La Robla in the Spanish province of León. The tower-type boiler is equipped with an arch fired system of 24 burners, has 6 coal mills and produces 1,150 tons of steam at 180 bar and 537° C. The coal burnt is supplied by a local mine.

Table 1: Coal analysis

C [%]	70,95
H [%]	2,9
N [%]	1,45
O [%]	1,53
S [%]	2,4
Ash [%]	20,77
Moisture [%]	11,67
Hu [cal/g]	6606,86

The existing boiler cleaning system comprises 84 steam-operated wall blowers in the furnace and 42 long retractable sootblowers in the superheater and economiser area. While improving the boiler diagnostics with a sensor-based optimisation system this existing boiler cleaning system remained unchanged. Uncontrollable deposits and erosion of heat exchanger surfaces did very often lead to emergency shutdowns and high maintenance costs. The applied boiler diagnostic system did not determine the deposit situation in such a way that it could have been used for improved control of the boiler cleaning system and cleaning has been carried out time-triggered.

In the beginning of the project the prime goal was defined to optimise the existing boiler cleaning equipment to improve steam generator efficiency and availability. The secondary goal was to reduce costs for boiler cleaning.

To get the core problem of unpredictable deposit formation in the furnace and the convective pass under control, the boiler was equipped with different diagnostic tools. A total of 20 heat flux sensors was placed in the membrane wall of the furnace to detect critical deposit formation before it can put the boiler performance at risk.

An evaluation unit uses special algorithms to define the current slagging condition and characteristics out of the signals measured by the heat flux sensors. Combining such signals with relevant process data a software module generates the optimal cleaning strategy for the furnace.

In the superheater and economiser area, 16 weight measuring sensors have been placed at the hanger rods on the boiler roof. Figure 4 shows the positioning of the weight sensors over the cross-section. The rectangular cross-section of the boiler is split in half. Each sensor detects in its zone smallest changes in weight.

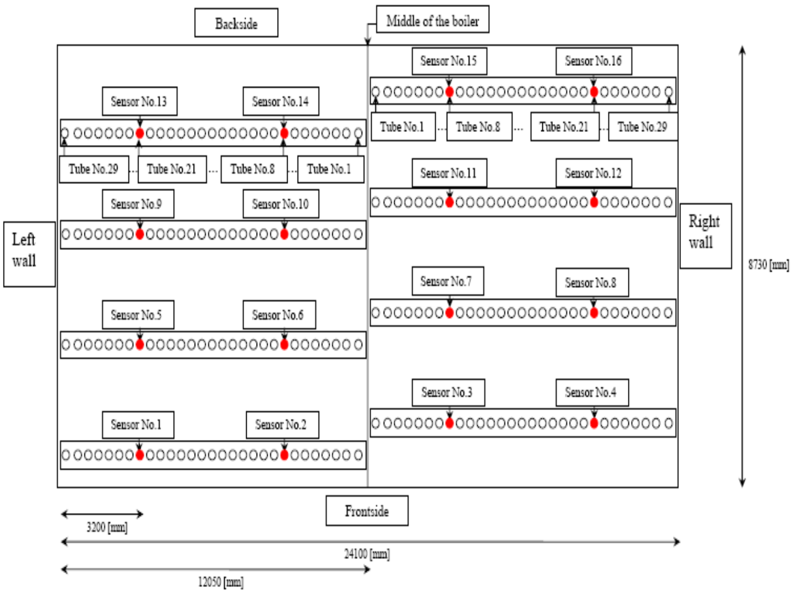

Figure 4: Positioning of the weight sensors over the cross-section.

Since the horizontal heat exchanger bundles are suspended at the same hanger rods, the results of the direct weight measurements are complemented by a thermodynamic simulation of the process allowing determining local decrease of heat transfer due to deposit formation. An evaluation unit receives the weight data and the calculated deposit conditions and defines based on these the current cleanliness state of each zone. This information combined with process data allows defining the optimal cleaning strategy in terms of timing and cleaning intensity. Figure 5 shows a typical signal response of the weight sensors No. 5 and 9 as well as the calculated Cleanliness Factors (CF) of different heat exchanger surfaces. During 15:21 to 15:50, the cleaning effect of the sootblowers effecting superheater 2 (SH2) can be observed. The weight development of senor No. 5 indicates the need for cleaning in its zone. The thermodynamic calculation does also display a deposit accumulation at superheater 2 (CF_SH2). The cleaning action leads to a weight decrease by approx. 100 kg, which is followed by a rising CF-value at superheater 2 (SH2). Following this action the signals characterising reheater 2 (RH2) indicate a need for cleaning. Here as well one can see a weight reduction by 100 kg in the vicinity of sensors No. 5 and 9 and a significant rise of the CF-value of RH2 from approx. 78% to 91%.

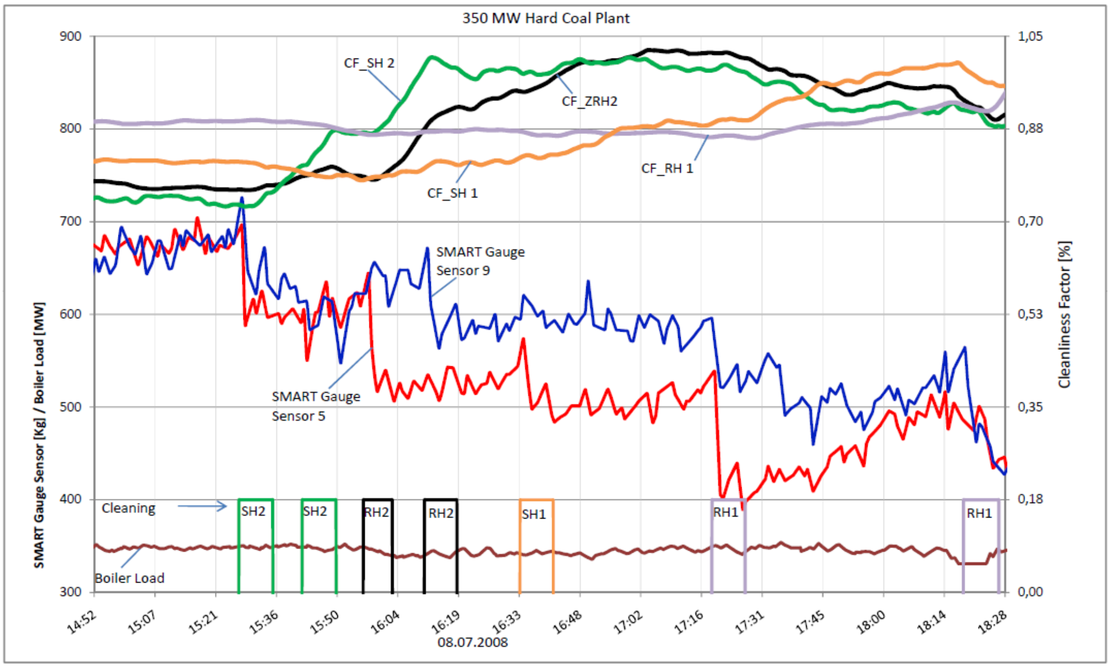

Figure 5: Typical signal response of weight development, Cleanliness Factors and boiler cleaning actions.

4. Conclusions

By operating the boiler cleaning system in a demand-driven mode, the average heat transfer in the furnace increased by 10%. Another achievement of this optimised control of the boiler cleaning is the stable boiler outlet temperature at full-load over a period of 2 month compared to a phase with manually operated boiler cleaning.

The new optimisation system does also provide a number of additional information to the operators for further optimisation of the boiler cleaning process. With the change from a time-triggered to a demand-driven control, the number of cleaning actions reduced by 35% with corresponding steam savings and reduced tube erosion.

REFERENCES

[1] Couch, G., Understanding slagging and fouling during pf combustion, IEA Coal Research, London, Report 72, 1994

[2] Leithner, R., Harnisch, K., Bewertungskriterien für Diagnosessysteme, VDI Berichte, Nr. 1641, 2001

[3] Tippkötter, T., Wessel, B., Bartels, F., Simon, S., Performance Increase of Steam Generators by Intelligent Sootblowing in the Furnace, published during Power Gen Europe 2003, 2003