ONLINE COAL FLOW MEASURING AND BALANCING (CONTROL) AND ONLINE COAL FINENESS MEASURING SYSTEM FOR COMBUSTION OPTIMISATION IN A THERMAL BOILER

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ABSTRACT: *The paper describes the beneficial application of online coal flow measurement and control and online coal fineness measurement for optimization of the combustion process inside coal-fired boilers. The system automatically balances the coal flow from pipe to pipe and monitors continuously the flow behavior. In combination with the online measurement of particle fineness the combustion efficiency, unburnt carbon and fouling are continuously optimized. The coal flow measuring system is designed to work continuously in closed-loop. It can be easily integrated into an existing monitoring & control environment. A systematic series of test measurements was done to validate the reliability of the system. The controller adjusts the valves automatically so as to maintain constant air-fuel rations at the burner levels. Additionally, the mill and the classifier are adjusted according to the readings of the coal flow and the size spectrum.*

1.0 INTRODUCTION

The pulverized-fuel balance, air fuel ratio and particle size spectrum are key parameters for the optimization of the combustion process for many large scale - fossil and biomass fired - boilers. These parameters directly influence factors such as ignition delay, combustion efficiency, LoI, emission levels as well as slagging and fouling. A reliable and continuous measuring system to provide these parameters is the basis for any modern boiler optimization system.

Typical large scale boilers use ball or mps mills to pulverize high grade coals with high efficiency. Equally splitting the coal dust into commonly 4 to 8 different pipes and hence into the burners is frequently an instationary process much dependent on coal properties and process properties such as machine wear. Despite the high importance for the combustion process mostly static splitter or riffler devices are applied for the coal balancing. Orificing valves, if existent at all, are predominately applied on static load information and the hydraulic interactions is only barley be taken into account.

Beside the coal mass flow, the particle fineness has a significant impact on the combustion process inside a boiler. It influences ignition delay, combustion efficiency and LoI, the NOx and CO emission levels as well as the slagging and fouling tendencies. By influencing the devolatilisation rate and the composition of volatiles at the burner the ignition and flame properties are determined and these in turn affect e.g. the NOx levels. Also, small, medium and large particles have different flow characteristics and vary in their furnace residence times. Since the heat balance and combustion time of a coal particle depends on its size, some particles may still be heated beyond their ash melting point or even undergoing reaction at their surface when entering the convection pass heating surfaces. In any case, the furnace exit gas temperature (FEGT) plays an important role when it comes to slagging and fouling. The carbon-in-ash level or loss of ignition (LoI) is yet another important property that is strongly affected by the size spectrum of the burning coal particles. Contributing to the problem, the particle-size spectrum is not a constant but may undergo rapid changes. Not only does it vary with the type of coal and composition (including water content) but also with the mill set-up and operating conditions and its wear and tear.

Despite the significant role that this property plays, there has yet not been a robust and reliable measuring system that works both, *online* and *inline*. The method employed to date is to collect samples and then measure the particle size distribution in the laboratory. Thereby the collection of samples may even bias the result. Due to the cumbersome and costly method, the frequency of sampling and sieving is limited. Worse, the time lag between sampling and analysis makes it impossible to use the data for feedback control. Optimisation, if at all possible, will always be limited to static settings.

The solution introduced in this paper is based on online measuring techniques giving instantaneous and continuously information about the in-pipe flow situation. In combination with a closed loop controller the system is capable to optimise the key-factors of the combustion process.

2.0 COAL FLOW MEASUREMENT AND CONTROL

Online coal flow measurements in combination with variable orificing valves allow the simultaneous measurement and closed-loop control of the coal flow and hence to improve the combustion process at burner level significantly. A robust, micro-wave based system is installed to continuously measure the coal mass flow and velocity in all the pipes of a utility boiler and thus quantifies the imbalance of the coal flow from pipe to pipe. The system offers several advantages:

- Robust, monitored sensors
- Continuous data with high sample rates (high dynamic response)
- Low wear and tear of sensor since only the ceramic sensor tip is in contact with the flow
- No effect of particle size, coal type, moisture and ash content on signal quality
- Easy application and low maintenance

The mass flow measurements at a permanent installation at pipes equipped with orificing valves are displayed in Figure 1.

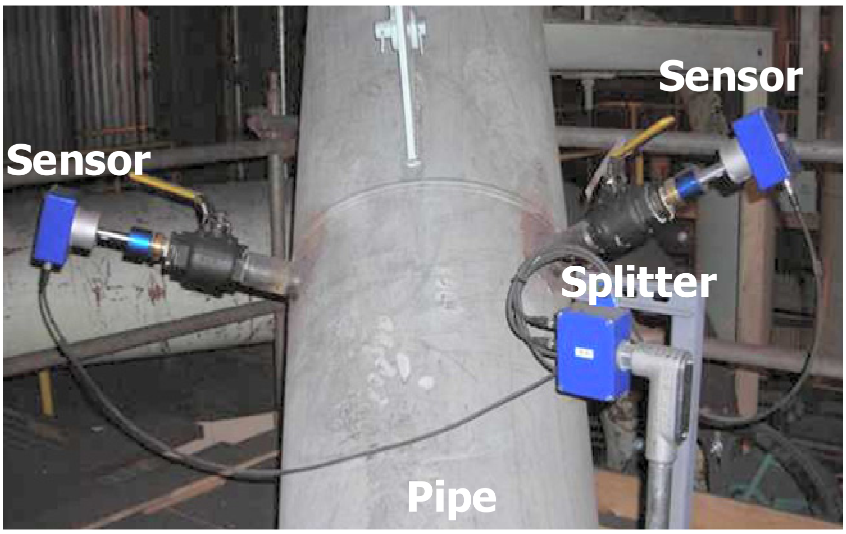

Figure 1 Configuration of microwave sensors at a pipe

All data are collected in a data acquisition unit and processed to determine the coal flow in each pipe in real-time. All flow signals are permanently monitored to identify failures in a very early stage. Figure 2 shows the excellent linear signal at operation at various loads.

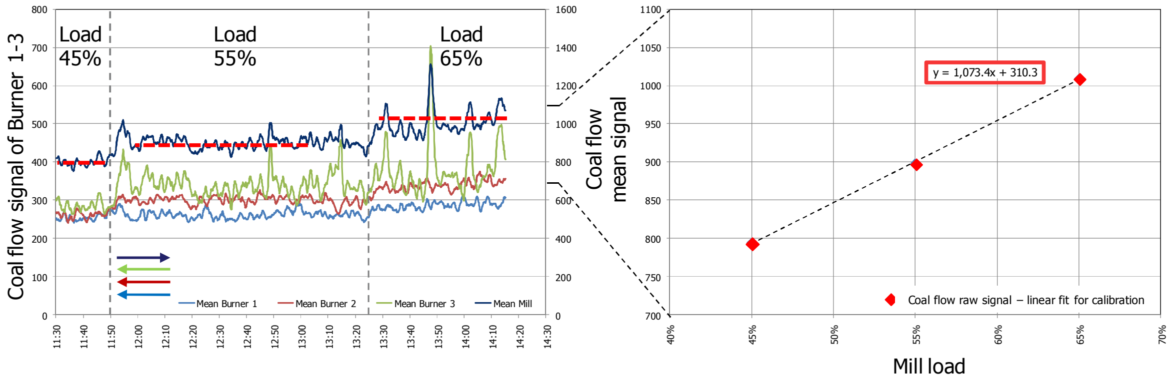

Figure 2 Mass flow signals at different loads

The information is used in a control unit (closed-loop) to derive set-point adjustments for automatic variable orifice valves that are specifically designed for optimal coal and air flow control. The control software is based on advanced, model-based control strategies. The applied approach uses explicit and implicit knowledge of the process behavior and considers the interactions between the involved process variables. Thereby constraints with complex interactions must be taken care of.

For the control of the valves the control unit either allows independent operation from the DCS system or transfers data and set-points to the DCS. Thereby, two control options are available: either direct control by the control unit, and independent of the plant DCS or through an interface that transfers the calculated set-points to the DCS where the DCS takes over valve actuation. The modular system design allows easy adaptation to the mill and pipe arrangement at customer site.

The non-linear behavior of valves is a commonly monitored problem with coal flow controls and is one of the strongest arguments for a closed-loop, constantly monitored control system. Additionally the signal quality and validity as well as the response characteristics of the control loop need to be closely monitored. For this purpose a “smart-sensor” is an integral part of the control concept.

Different valve designs can be utilized as adjustable orificing valves. An innovative, adjustable orificing valve share the advantage of simple design in combination with a low installation effort at the expenditure of a less predictable control characteristic increased pipe wear. They have an improved control characteristic and a low wear at the cost of a more complex design, see Figure 3.

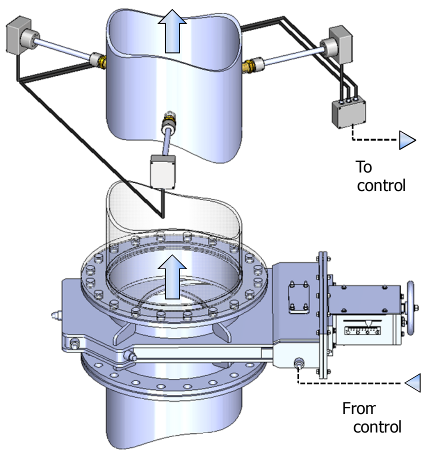

Figure 3: Closed-loop control set-up with adjustable orificing valve

3.0 COAL FINENESS AND RELATED MEASUREMENT DATA

A laser-based system measures the particle size distribution, coal and air velocity, mass flow, air/fuel ratio and temperature simultaneously within a measurement volume that is placed at the tip of an insertable probe. By traversing the lance through the pipe, a spatially resolved distribution along the cross section of the coal pipe can be measured. In contrast to laser diffraction methods this measurement technique also covers large particles up to 4 mm, while the lower range covers particle sizes down to 20 µm. This is sufficient for most pulverized coal combustion furnaces.

Since the system provides inline and online information of the flow inside the pipe it is far superior to standard sieving systems and procedures. Compared to the standard sampling technique the online system cuts down the required time to 20 %, not counting the time to analyse the probe. Additionally no mechanical interaction with particles and no impact of the operator influence the instantaneous measurement result.

Thus any corrective action can also be implemented immediately as opposed the sieving method wherein the results take a large time and hence any corrective action will take place only when the results are made available – in some cases the coal quality in the coal pipes could also have changed by that time defeating the purpose of the sieving exercise.

The advantages of the system can be summarised as follows:

- Portable system, easy to handle and operate
- Wide measuring range 20µm up to 4000 µm
- No mechanical interaction with particles
- Fast and reliable results during operation as compared to the conventional sieving method
- Immediate analysis and results with integrated evaluation
- Online reporting for improved performance management

Figure 4 shows an example of online measured coal fineness, coal and air flow.

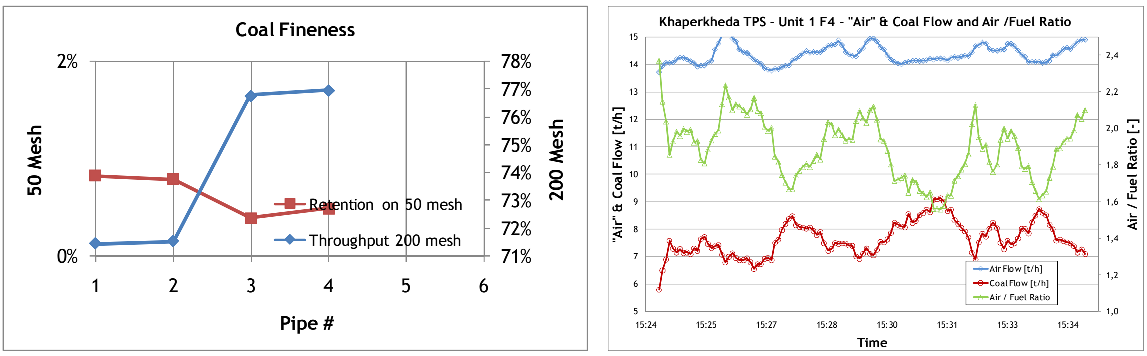

Figure 4 Online measurement of particle fineness, coal and air flow

The online fineness measurement enables entirely new fields of application: Its online capability makes it possible

- to optimise mill and separator parameters,
- to identify changes of particle fineness due to wear and tear or changes of configuration,
- to check the performance of any microwave-based dynamic coal flow technology, and
- to support preventive and predictive maintenance
- to utilise the information in coal mill loop control.

The system is an effective tool in establishing the optimum coal particle size (radius) required in achieving combustion optimization. Since boiler operating conditions and coal quality often vary significantly, an offline optimisation based on traditional sampling methods is not feasible. For example the online capability can be utilised to improve the mill and separator settings. During the measurements the mill parameters and the adjustments of the separators can systematically varied and the effects of these variations can be analysed online. This allows for a very efficient real-time optimisation of the separator adjustments in such a way, that an appropriate control strategy can be established, leading to an increase of separator efficiency and particle size homogeneity and a reduction of mass circulation rate through separator. By adjusting the proper coal fineness a reduction in unburnt carbon (LoI) is achieved.

The complete system is compatible to any coal-fired thermal plant. It can be adapted to different designs and configurations.

Figure 5 Improved boiler operation before (left) and after optimization

4.0 REFERENCES

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