MITIGATING RECOVERY BOILER DAMAGE AND INCREASING SOOTBLOWING EFFICIENCY WITH CLINKER DETECTION SYSTEM

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ABSTRACT

The recovery boiler at the International Paper Saillat, France, mill has had a history of floor damage due to large clinkers falling from the upper furnace and landing on the floor tubes. The damage is of concern, as it results in unplanned tube replacements during outages. To better understand this damage and the root causes, a Clinker Detection System was installed.

The detection system was made up of an array of industrial sensors placed under the boiler floor. The system was calibrated by dropping known weights onto the floor. A finite element analysis was also done under various clinker-impact scenarios.

As a result of this instrumentation, a number of large clinker impacts were identified and the source of the clinkers determined by associating impacts with the operation of the sootblowers, thereby determining the effectiveness of each sootblower. By combining the results of the Clinker Detection System and the finite element analysis, an estimate could also be made regarding plastic deformation (damage) of the floor tubes. Another beneficial feature of this system is to track a chill and blow's ability to shed deposits in real-time.

KEYWORDS

Sootblower Effectiveness, Chill and Blow, Thermal Shedding, Deposit, Clinker Detection System

INTRODUCTION

To keep a recovery boiler operating efficiently and for extended periods of time (upwards of 12 months between water washes), operators are in a constant struggle to manage fireside deposits caused by the combustion of black liquor. As these deposits become larger, they reduce the heat transfer efficiency of the boiler causing the flue gas temperature to increase. The increase in flue gas temperature leaving the superheater can promote plugging downstream in the generating bank. In addition, the larger the deposit becomes the greater the risk of clinkers impacting and damaging the boiler floor, which increases the safety exposure of a smelt/water explosion in the boiler. As the operators work to meet the mill's production demand, they are armed with two primary tools to manage the development of deposits: sootblowing and thermal shedding (chill-and-blow) events. Understanding when and how to use these tools is not always straightforward, as the operators must balance the positive and negative effects of each based on often-subjective and inconclusive data. Furthermore, sootblowing is restricted to the physical placement of the sootblowers, and the

effectiveness of thermal-shedding events is often limited to the superheater section (as presented by Tran in Removal of Recovery boiler fireside deposits by thermal shedding [1]).

In an effort to develop a system to detect boiler-floor damage from falling deposits (clinkers) inside an International Paper mill in Saillat, France, Integrated Test & Measurement conceptualized a solution that captures not only the size but also the location of the falling deposits. In addition to measuring **floor-tube damage**, the monitoring system — branded as the Clinker Detection System (CDS) — would also prove valuable in understanding: superheater **Sootblower Effectiveness** (identifying locations in the superheater where fouling frequently occurs by correlating the clinker impacts with the operation of the sootblowers) and real-time feedback to **Thermal Shedding Events** (measuring the rate of deposit removal during a thermal shedding event).

The system described in this paper is the subject of a U.S. Patent Application [2].

SYSTEM DESCRIPTION

To understand the principle of the system, we evaluate the life cycle of deposits, which develop on the boiler tubes before being displaced, usually by a sootblower. Once displaced, the deposit may be carried over into the generating bank ash hopper or economizer precipitators by the flue gas. If the deposit is large enough in size and upstream from the generating bank, it will slide down the nose arch or fall directly from the superheater and impact the boiler floor, which may lead to damaged floor tubes. Understanding where these deposits develop and to what extent they ultimately impact the floor is of value to the efficient operation of the boiler and further proves the need for a novel solution.

The detection system is a proprietary technology developed by ITM to measure both the size and frequency of deposits (clinkers) that impact a boiler floor. The system utilizes an industrial controller to monitor sensors and record potentially damaging clinker-impact events. The system also correlates sootblower operation with these impacts to provide valuable feedback about sootblower effectiveness. In addition, the system determines the number of impacts and amount of material shed, which can then be used to optimize sootblower scheduling during normal boiler operation and chill-and-blow events.

To characterize the clinkers impacting the boiler floor, multiple accelerometers were affixed to the floor's supporting structure. This data was collected and processed alongside the sootblower operating parameters using an industrial controller allowing for the association of the clinker with the operating sootblower in real time. The results provide operators with actionable insight into their boiler's operation.

An overview of this system, highlighting the four major actors (Clinker Location, Active Sootblower, Falling Clinker, and Boiler Floor) in the system, is illustrated in Fig. 1.
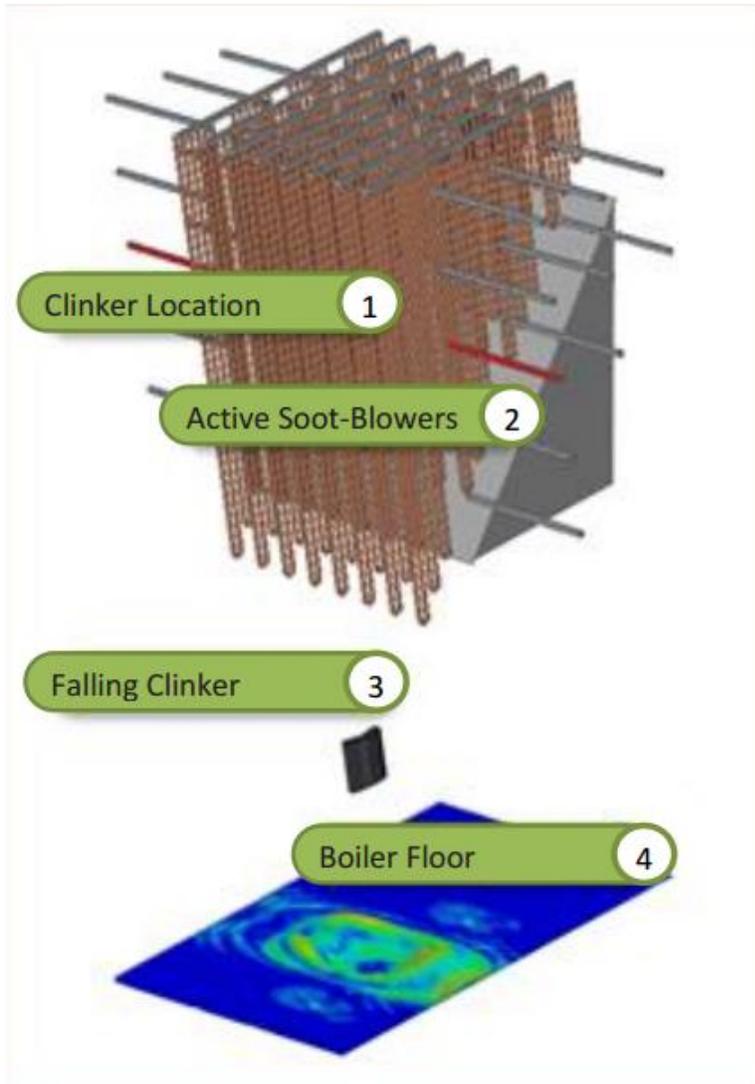
Fig. 1 - System Overview

FLOOR TUBE DAMAGE

As stated previously, the original objective was to develop a system that would provide real-time actionable insight to boiler operators as to where and when clinkers were damaging the floor tubes (see Fig. 2 below) so that steps could be taken to mitigate the risk of water entering the boiler system from the damaged floor tubes. Furthermore, as discussed in a later section, it would also prove beneficial to understand where the clinkers were forming in the first place so the operators can take preventative measures to halt the formation of deposits.

Fig. 2 - Deposits impacting the boiler floor can have serious consequences on the floor tubes

To combat the damage to the floor tubes, the mill took two approaches. They enhanced the support of the floor tubes by modifying the supporting structure, and they installed a detection system for monitoring the clinker impacts. To understand how the clinker impacts affected the floor tubes, a dynamic mechanical finite element analysis (FEA) model was developed to simulate the response between the boiler floor and impacting clinker. Once developed, the model was refined and validated using data obtained from the accelerometers, installed as part of the monitoring system, during calibration tests.
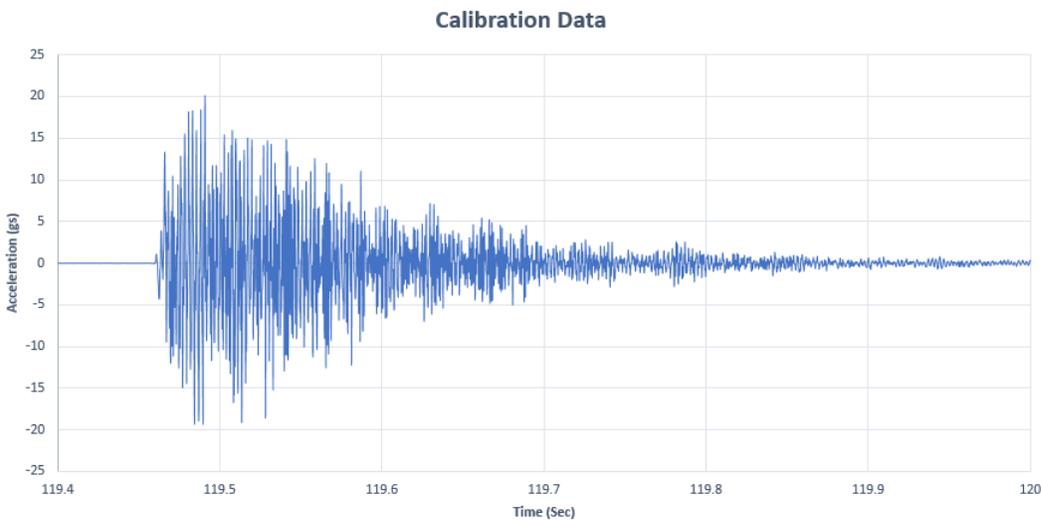
Fig. 3 - Calibration Data

During the calibration, eighteen (18) salt bags, 9-12kg and 9-25kg, were dropped from nine (9) access holes located just below the nose arch, 30 meters above the boiler floor. To understand where the clinkers were impacting the floor, the floor was divided into six (6) zones (A1, A2, B1, B2, C1, and C2 – where A is located along the front of the furnace and row C is located under the nose arch). The calibration was completed just as the boiler was starting up, so the floor tubes were fully exposed. Each of the bags were dropped one at a time through one of the access holes, and the zone at which the bag impacted the floor was documented. The output from a vibration sensor during one of the calibration drops is presented in Fig. 3 above. The zone, drop height, and bag weight were then used to calibrate the monitoring system output and validate the FEA model. The calculated deposit weights are based on the kinetic energy produced during a 30-meter fall (e.g. kgs @ 30 meters).

Once validated, the model proved to be a vital tool in predicting how the new supporting structure design would affect the floor tubes by the clinker impacts, as shown in Fig. 4 below.
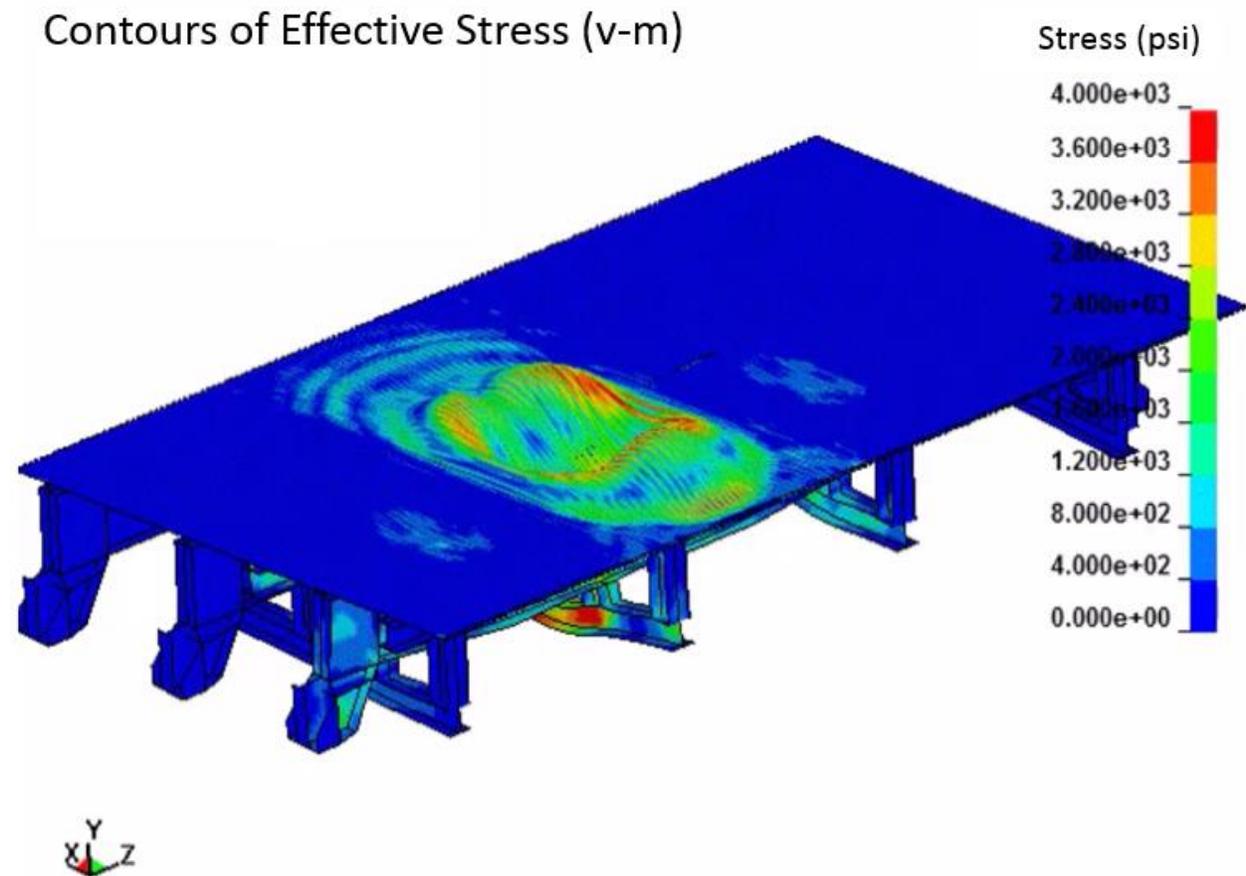
Fig. 4 - FEA Results

By using the non-linear curve in Fig. 5, we can approximate the degree of deformation (damage) based on the response of the vibration sensors.

Floor Deformation from Clinkers

$$y = 0.625e^{0.0211x}$$

Plastic Deformation (mm) — vertical axis

Clinker Weight (kg @ 30 meters) — horizontal axis
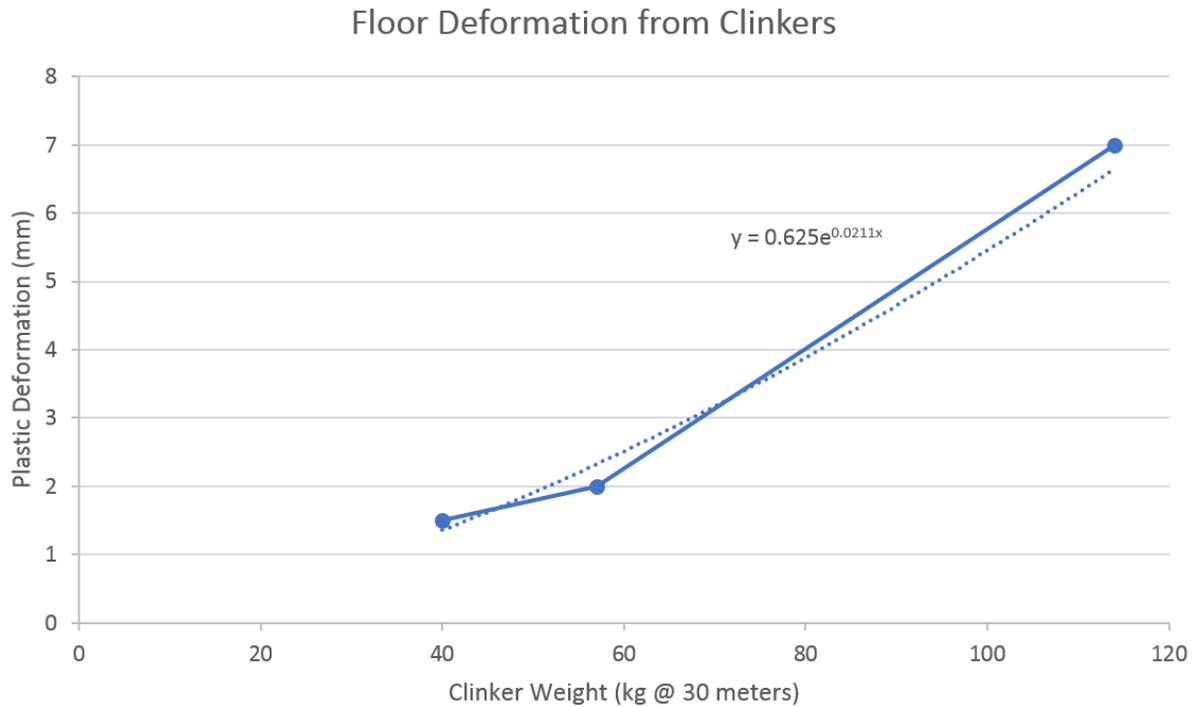
Fig. 5 - Relationship between Clinker and floor-tube deformation

SOOTBLOWER EFFECTIVENESS

A major benefit of the system is the ability to determine where the deposits are forming based on the relationship between the clinker impacts and the operating sootblowers. By correlating clinker impacts with sootblower operations, we can gauge an individual sootblower's effectiveness in removing deposits. This provides the operators with actionable intelligence to manage sootblower frequency to help prevent against the formation of deposits that would become clinkers. Additionally, this is a fundamental principle to support the results we have found in the thermal-shedding event, which is discussed in detail in the following section. The sootblower control system at the Saillat Mill runs one sootblower per side at a time, therefore, when a clinker impacted the right-hand side of the boiler floor, we associate that clinker with the sootblower that was running on the right-hand side of the boiler at the time the deposit detached from the boiler tube. The detection software algorithms take into account how long it takes deposits to travel from the time of detaching to impact, and that time lag is factored in to predict where the deposits are forming. For example, there is little lag between the detach time and the impact time for the wall tubes above the furnace. For deposits that come from sections of the superheater that are farther up the nose arch, we must allow more time for the deposit to detach from the tube, slide down the nose arch and impact the boiler floor. An illustration of the boiler layout showing the relative positions of the superheater, nose arch and sootblowers is presented below in Fig. 6.
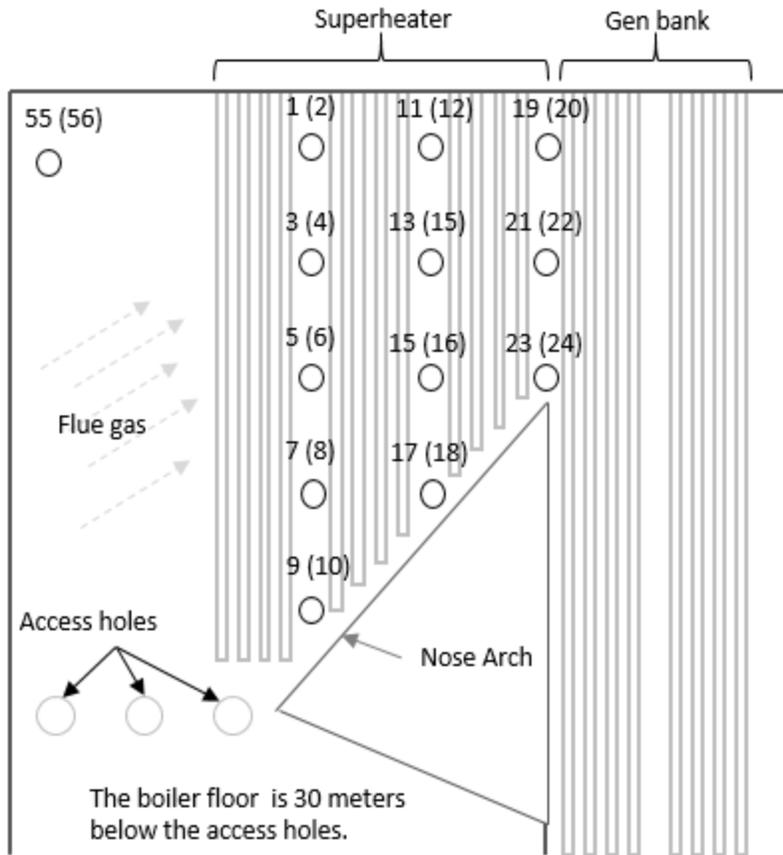
Fig. 6 - International Paper Saillat, France Boiler Superheater with Sootblower Locations

THERMAL SHEDDING EVENT

Thermal shedding is achieved by removing the fuel from the furnace and rapidly cooling the deposits while maintaining the operation of the sootblowers. The change in dimensional size between the tube and the deposit weakens the bond between them. The deposits that don't immediately fall are swept away by the sootblower and impact the boiler floor. By monitoring the deposits as they impact the floor, the detection system can qualify the duration of the cleaning event by identifying when the shedding ceases. Thus, potentially reducing the amount of time the boiler is down.

Figure 7 below shows that a great majority of the clinker drops were caused by the column of sootblowers located between the secondary and tertiary superheater sections (e.g. IK 1-10) and the sootblowers near the roof and front wall. (e.g. IK55 and 56). The location of the sootblowers is illustrated in Fig. 6 above. As H. Tran pointed out [1], more shedding occurs with deposits closest to the furnace as they undergo more thermal shock. Also, the majority of leading edge deposits will be present on the first two superheater sections, and these large deposits are more likely to be the ones captured by the monitoring system.

The primary goal for the system installed at the Saillat Mill was to determine clinker impacts that could cause damage to the floor tubes, therefore, smaller impacts were disregarded. This may cause misleading results during the chill and blow for the deposits that fall from the sections above the nose arch. In these sections, deposits, which are in a brittle state from the thermal shock, may impact the nose arch and break up into smaller deposits before sliding down the arch and impacting the boiler floor. At times during severe shedding, these small slides of deposits may resemble more of a flow than a discrete set of clinkers sliding down the arch, making it difficult for the system to quantify the absolute volume of

material being shed. The number of deposits that are shed without the aid of a sootblower is increased during a chill and blow, making it harder to determine the original location of the deposit based on sootblower operation.

To what degree the response of the monitoring system is influenced by the bed (e.g. density and thickness) is largely unknown at the time, however, we do know that the bed will influence the results. This influence may be of greater concern during a shedding event when a large volume of deposits build on the bed in a short period of time.

Despite these uncertainties, this methodology provides considerable insight into when deposits are removed, especially when compared to other chill-and-blow events. Ultimately, these advances help operators to optimize chill and blow parameters (time, amount of cooling, sootblowers used, etc.).
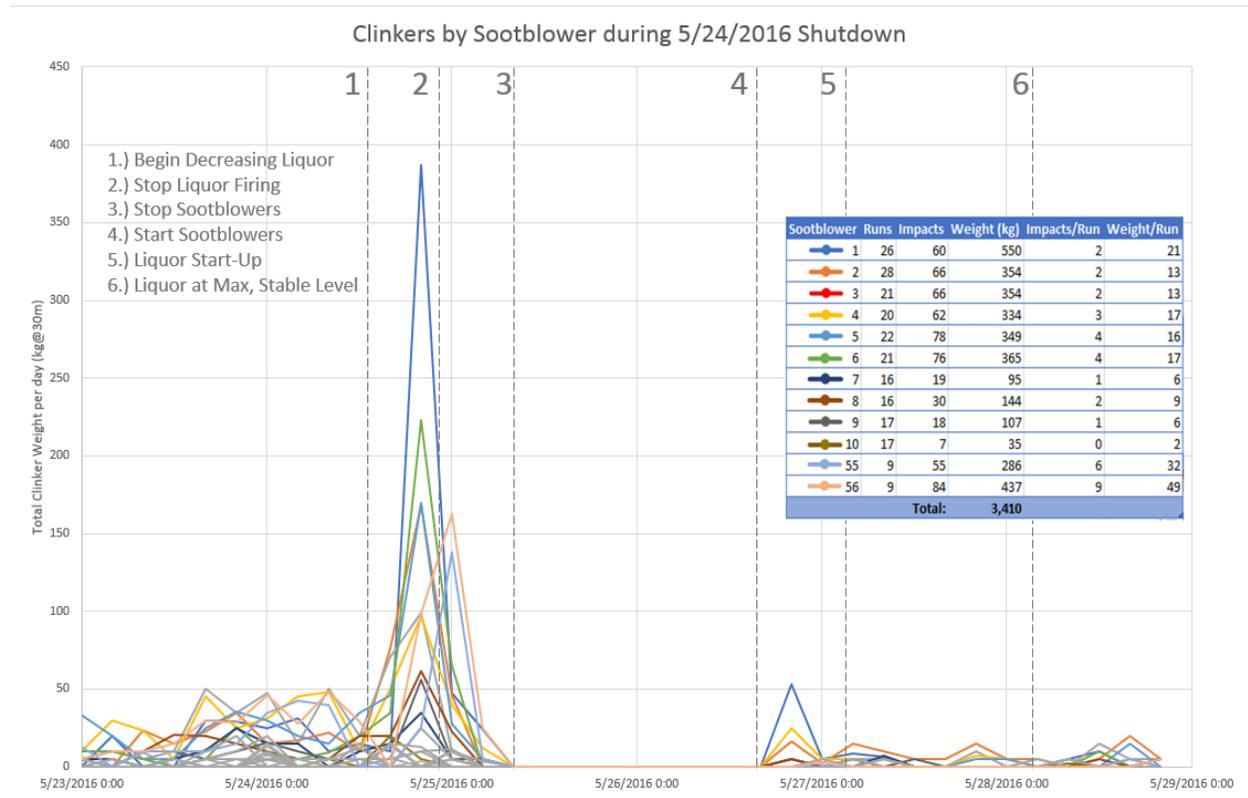
Fig. 7 - Thermal-Shedding Event (Chill and Blow)

CONCLUSIONS

The initial scope of the detection system was to quantify the relationship between falling deposits (clinkers) and boiler floor tube damage, what was ultimately delivered is a solution that provides conclusive insight enabling boiler operators and intelligent sootblower control systems to mitigate boiler damage and increase sootblowing efficiency.

Specifically, the detection system is an effective tool for identifying the magnitude and location of clinker impacts that can cause floor-tube damage and failure. Furthermore, the system can identify locations in the superheater where fouling frequently occurs and can identify how effective sootblowers are at the removal of deposits in the superheater sections during normal boiler operations as well as during thermal-shedding events. Beyond that, the system can provide real-time feedback during thermal-shedding events.

Although the results are conclusive, as with any tool, there is room for improvement. We know that the furnace bed for example, influences our measurement results, but to what extent? We also know that the floor tubes are stiffer the closer they are to the walls, but to what degree does this affect our measurement? These are good questions, but they are questions of precision not practice. In practice, changing a sootblower's frequency of operation based on its effectiveness (number of clinkers per blow for a given sootblower) is a rational response.

While several enhancements are being made to the system to increase reliability and performance, the detection system is ready for commercialization.

REFERENCES

[1]   H. Tran, M. Martinez, D.W. Reeve, T. Cole, R.A. Damon, and D.T. Clay, "Removal of Recovery Boiler Fireside Deposits By Thermal Shedding", Pulp & Paper Canada 94:11 (1993).

[2]   U.S. Patent Application No. 14/340,661, Publication No. 2016/0025485 (filed Jul. 25, 2014) (Tim Carlier, applicant).