Superheater Fouling Monitor System
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Introduction

A novel use of strain gage technology is demonstrated at TVA’s Cumberland Fossil plant under an EPRI/TVA project. Strain gages are being used to sense slag deposits in the superheat sections by measuring weight increases as the deposits grow. In TVA’s Cumberland plant, a 1300MW wall fired plant burning Illinois Basin Coal, slag deposition on the upper furnace sections, particularly the pendants, has been a recurring problem. The deposits have on occasion gone undetected and grown in size large enough to detach and fall causing extensive damage to the lower slopes. These large “clinkers” have resulted in forced outages for repair, and costs into the millions of dollars for each outage. Previous measurement methods have had limited success in detecting deposits early enough to remove them before they cause damage. For example, three cameras have been installed in ports across the wall facing the superheat pendants to attempt visual detection of the deposits, but since some locations are not visible through the cameras, clinkers have formed causing outages. This novel approach for strain gage technology holds promise to assist in early detection of the deposits and consideration as a supplement to Intelligent Sootblowing (ISB) technology.

Superheater Fouling Monitor

Deposits are formed when the ash in the flue gas is at a temperature above its melting point. The laboratory term for the initial melting point is the initial deformation temperature. Typical values of initial deformation temperature for coal are in the range of 1975 °F to 2420 °F range. With typical gas temperatures of 2500°F in the furnace, the ash is in a semi-molten condition and when it comes in contact with boiler pendant surfaces that are at a relatively cooler temperature, a deposit is formed.

In the Clyde Bergemann Superheater Fouling Monitor system, strain gages are being used to sense slag deposits in the superheat sections by measuring weight increases as the deposits grow. Data from each gage is converted to weight using the stress strain relationship:

\[ S = E \epsilon \]

- \( S \) = Stress in pounds per square inch
- \( E \) = Modulus of elasticity (30x10^6 for steel)
- \( \epsilon \) = strain in micro inches per inch.

Using the diameter of the rod a cross sectional area can be calculated, and the stress is multiplied by the area of the rod. The weight measurement can be started at any time within the process and any subsequent readings indicate the change in weight from starting conditions. Thus it is not necessary to start from a totally unloaded rod. The special gages used also have a factor that must be applied to the calculation. Since the gages are actually made up of two gages reading in the direction of the strain and two gages reading 90 degrees from the strain a factor of 2.6 is used as a divisor. This is a factor of two for the two gages in line with the stress and a factor of .3 for each of the 90 degree gages for a total of 2.6.

At the TVA Cumberland plant the Secondary Superheater is supported by 18 stain gages on the suspension structure of the superheat pendants as shown in Figure 1. Figure 2 a photograph of the strain gages installed on the support rods above the penthouse. Figure 3 shows the pendant configuration inside the penthouse above the boiler. There are 73 pendants across the boiler. Eight pendants attach to a steel beam inside the penthouse (see Figure 4), and each beam is suspended from the two rods upon which the strain gages are attached.
FIGURE 1. STRAIN GAGE CONFIGURATION AND LOCATION

FIGURE 2. STRAIN GAGES ON THE SUPERHEAT SUPPORT RODS
FIGURE 3. PENDANTS INSIDE THE PENTHOUSE

FIGURE 4. SUPPORT BEAM SHOWING ROD THAT PENETRATES THE ROOF
The strain gage data collection and processing system configuration provided by Clyde Bergemann consists of a data amplifier receiving data from the strain gages. The gages are installed on the superheat support rods connected through an Ethernet cable to a personal computer in the control room, which contains the input processing and operator interface software. Graphical representations of the pendants with color coded status as to weight loading from the gages constitute the operator interface. Figures 5 and 6

FIGURE 5. DATA AMPLIFIER

FIGURE 6. OPERATOR DISPLAY IN CENTRAL CONTROL ROOM
Operational Results

Figures 7 and 8 show trends of the data from the strain gages. Figure 7 is a plot of the total weight from the nine gages on the north side of the furnace collected from June 23 to June 28, 2003. Figure 8 is the total weight of all nine gages on the south side from the same period.

FIGURE 7. TOTAL WEIGHT OF THE NINE GAGES ON THE NORTH SIDE

FIGURE 8. TOTAL WEIGHT FROM THE NINE GAGES ON THE SOUTH SIDE
The trend period was selected because the unit was off line on June 28 due to a tube leak in another section of the furnace. Upon inspection of the upper furnace a 10 x 20 feet slag deposit was discovered in the south side superheat pendants. Figure 8 shows the upward trend that indicates the deposit was growing in size over a two-day interval.

In another instance, the system was able to detect an increase in weight in August related to a large “clinker” that formed on the superheater. In Figure 9 the signal from two gages is plotted over the days before the “clinker” was removed. An attempt was made to remove the “clinker” on August 10 that was not successful, as is reflected in no change in the weight measured by the gages. On August 13 the “clinker” was removed and the weight measured by the gages dropped by a large amount. One gage indicated almost 2000 pounds of weight loss and the second lost about 1000. This illustrates the sensitivity of the system to lateral weight gain. The system provides not only an indication of the overall weight gain in the superheater section of the boiler, but also lateral indication of “clinker” build up.

![Figure 9. Gage Response to Slag Fall](image)

As shown in Figure 10, the gage data can reflect the operation of the sootblowers. Over the period trended, each operation of a blower is shown with the start and stop of the blower. Blower operation is plotted along with the total weight of half of the gages. Since the blowers at Cumberland operate from the left and right side of the unit and can only reach halfway across, a blower will only clean a given area on half of the convection pass. Figure 10 shows the weight on the south side of the boiler and the blowers associated with that side. Each blower operation is tabulated in Table 1. The average of four or five blower operations is calculated and sorted. Thus it can be seen that blower number 14 is much more effective in removing deposits from the south side of the superheater than any other blower. Blowers 2, 4, 18, and 6 are about equally effective. Blowers 10 and 16 are the least effective.

Blowers may be less effective for two primary reasons. First there may be some problem with steam supply such as improper steam pressure and flow to the blower. Or the blower may have an obstruction in the lance tube or nozzle. Second, the area that the blower is cleaning may not have any deposits to remove. The second reason is assumed in this analysis. However, when the gage system indicates that a blower is not effective, that blower should be checked to ensure proper operational parameters.
This information can be used as a control function for the blower system. The most effective blower would be chosen to blow more often, while the less effective blower would be used less often. This would save steam and prevent blowing when there are no deposits to remove; thus effecting reduced tube erosion.

**FIGURE 10. SOUTH SIDE WEIGHT AND BLOWER OPERATIONS**
Conclusions

Strain gage technology holds promise for optimizing early slag deposition detection in TVA’s Cumberland Plant. The data from this installation provides a potential measurement for closed loop control of soot blowers to maximize the effectiveness of the cleaning philosophy. Utilized in conjunction with a total boiler cleaning system the strain gage technology can be the key deciding factor on determining where to clean, with what sootblower to clean and to only utilize the sootblowers required. This will lead to potential sootblower steam/air savings and reduced tube erosion caused by over blowing. Controlling slag formation will reduce unplanned outages and provide increased boiler performance.

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