

(19) The Use of Real Time Measurement and Artificial Intelligence to Improve Efficiency and Reduce Emissions at Coal-Fired Power Plants

This two-year effort will seek to develop a technique to measure coal properties in real time, and to process the data such that coal-fired electric utility operators can adjust their operation to avoid slagging and fouling.

Total project cost: \$750,000

Funding request: \$600,000

Project Lead: NYSERDA

Project Participants: Brayton Point Generating State; Energy Research Company; Lehigh University

Start Date: August 1, 2005

End Date: August 1, 2007

Presentations/Publications

None this quarter.

Patents

None.

Progress in Past Quarter and Current Status

Apparatus Modifications

Further evaluation of the data collected in the prior quarter revealed the need to improve the sensitivity of the LIBS system. The response of the system to changes in concentrations of elements in coal samples was low, resulting in relatively poor discrimination between different coals. For example, iron peaks in the LIBS spectra exhibited small changes in amplitude for relatively large changes in iron concentration. This lack of sensitivity was especially noticeable in the data collected with the photodetectors used to collect LIBS data on carbon, hydrogen, oxygen, sulfur, nitrogen, and potassium.

We performed a thorough reevaluation of the photodetector system and found that the low sensitivity of the system was partially due to uneven distribution of the light emitted from the LIBS spark among the different photodetectors. Light is fed to the different photodetectors from a branching fiber optic cable assembly whose forward end is pointed at the LIBS spark with each branch being connected to a photodiode with a filter to measure the emission from its assigned element. The uneven distribution of light in the fiber optic bundle was verified by passing a red HeNe laser beam through each branch of the fiber optic cable and measuring the area of the resulting spot of light exiting the cable at the other end. Spots from different branches did not closely overlap, implying that each branch was collecting light from different parts of LIBS plasmas in the sample chamber. We therefore introduced a lens system to correct this situation between the fiber optic cable collecting the light and the branching fiber optic cable connected to the photodetectors.

We verified that the design fixed the problem in two ways. First, we demonstrated that the light from the HeNe laser illuminated the same area at the exit of the fiber optic cable when the laser light was coupled to each of the branches of the bundle. Second, we collected data from LIBS sparks in air with both the photodetector system and a spectrometer system (Acton) capable of simultaneously measuring LIBS signals from H, N, and O. The light emissions from each LIBS spark for these elements were compared between the two collection systems. If the photodetector system was evenly distributing the light, then the photodetector signal from each element should correlate with the corresponding signals on the spectrometer. This is true because spectrometers are carefully engineered to distribute light evenly across their spectral range. We performed this comparison with LIBS data while using different temporal collection windows with respect to the laser pulse. Since the plasma changes size as it evolves over its

lifetime, using different temporal windows allowed us to test if light from plasmas of different sizes are distributed evenly by the improved photodetector system. We found that the emissions for different elements from the two detection systems correlated very well.

Further testing revealed that the vacuum chamber required improved seals to maintain an air-free environment in the chamber. Removal of the air is essential because LIBS signals from carbon, hydrogen, oxygen, and nitrogen in the air will interfere with accurate readings of these elements in the coal. A photograph of the improved system is shown below in Figure 4. The gas port fittings were upgraded with Swagelok vacuum fittings.

A comparison of LIBS spectra with air in the chamber and then in pure argon demonstrate the high degree to which nitrogen, oxygen, and hydrogen from the air are removed. An air spectrum is shown in Figure 6, with the characteristic hydrogen, nitrogen, and oxygen LIBS peaks identified in the figure. To purge the chamber, we used the following procedure:

1. Load sample into chamber and put door into place
2. Pump down chamber to -25" Hg for 1 minute.
3. Turn on purge gas and increase chamber pressure to -10" Hg
4. Reduce chamber to desired pressure for measurements, typically -20" Hg

Plans for Next Quarter:

In the next quarter we will continue optimize the apparatus to improve the sensitivity of the measurements. The work done to improve the sample chamber will continue with tests to ensure that it is air tight and will hold a vacuum of -20" Hg during the experiments. Following these tests we will collect LIBS spectra from coal samples to ascertain the level of improvement in sensitivity as a result of these improvements.

Subsequent to these tests we will look at further optimizations to improve the results via changing experimental parameters such as:

- Laser power density on the sample surface
- Laser wavelength (1064nm, 532nm, or 266nm)
- Spatial separation of the LIBS sparks on the sample coupons
- Temporal separation between the LIBS sparks to allow the ventilation system to clear away aerosols generated by the spark
- Vacuum pressure
- Temporal window after the laser spark to maximize the signal-to-noise for the different elements of interest

After the system has been optimized, we will collect data from a spectrum of coals and document the accuracy and precision of the system, as well as that of the neural network software to compute the ash fusion temperature, slagging factor, and heating value.