STUDIES OF FLY ASH AND ASH DEPOSITS FROM AN AFBC SYSTEM

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INTRODUCTION

The combustion of coal in a fluidized bed combustor with a limestone bed is one method of controlling sulfur oxides emission. Atmospheric Fluidized Bed Combustion (AFBC) results in two different kinds of solid residues, bed ash and fly ash. The formation of both bed ash and fly ash during the combustion of coal is a very complex environmentally dependent reaction. Significant parameters include the combustion conditions and the characteristics of the limestone used. If a high chlorine coal is used in an AFBC system, the addition of limestone may help reduce hydrogen chloride emission. On the other hand, due to the large amount of ash produced by a power plant, the use of these materials in an environmentally acceptable manner should be considered. The analysis of how the composition of the limestone changes during combustion can provide fundamental data, not only to evaluate the way the limestone functioned during combustion, but also to possibly determine how to use the residue.

During the last decade several studies have been conducted to characterize AFBC residues. Most of these activities focus on the physical properties of fly ash, such as particle size distribution, specific density, the morphological properties, and chemical properties which include the analysis of trace elements, organic compounds and chemical compositions. Knowledge of the distribution of elements such as sulfur and chlorine in fly ash is necessary, not only to understand the principle and efficiency of sulfation of limestone, but also to evaluate the role of the limestone in the capture of sulfur oxides.

EXPERIMENTAL

Experiments were conducted with the 12-inch (0.3 m) laboratory AFBC system at Western Kentucky University using operating conditions similar to those at the 160-MW system at the TVA Shawnee Steam Plant located near Paducah, KY. Two kinds of coal were used in this study, one is a low-chlorine (0.012% Cl and 3.0% S) western Kentucky # 9 coal (95011), the other is high-chlorine (0.28% Cl and 2.4% S) Illinois # 6 coal (95031). The limestone was from Kentucky Stone in Princeton, KY. Six moveable heat exchanger tubes are located within the bed area of the AFBC system. Typical operation involves setting the correct coal/limestone feeds and air flows and then using the moveable tubes to adjust the bed temperature to the desired setting. The combustor's operating parameters (air flow, coal/limestone feed, temperature) were adjusted according to the experimental requirements during combustion.

A TGA-501 thermogravimetric analyzer from the LECO Corporation in St. Joseph, MI was used for determination of the moisture and ash contents of the fly ashes. Carbon, hydrogen and nitrogen contents in the fly ashes were determined using a LECO CHN-1000 system. The sulfur contents were determined with a LECO SC-432 sulfur analyzer. Chloride contents were measured by bomb decomposition followed by determination of chloride with an ion selective electrode.

RESULTS AND DISCUSSION

Several parameters and their effects on the absorption of sulfur dioxide and HCl by the bed ash and fly ash were investigated. The parameters to be discussed in this paper include the bed temperature, the calcium-to-sulfur ratio in the combustion mixture, and the type of coal used.

The Effect of Bed Temperature on the Absorption of SO_2 and HCl. The sulfur contents of fly ash and bed ash reflect the different trends in ash composition that occur with changes in bed temperature. Figure 1 illustrates that the sulfur content in the fly ash increases as the bed temperature is increased. In contrast, Figure 2 shows that the sulfur content of the bed ash decreases with an increase in the bed temperature. At the lower temperature of 1116 K most of the sulfur dioxide produced during combustion is absorbed by the calcined limestone in the bed ash. The optimal sulfur retention is obtained around 1120K, where the sulfur retention reaches around 96%. With an increase in temperature, several factors may contribute to the reduction in the amount of SO_2 captured by the calcined limestone. At higher temperatures (>1120K) the active internal surface of the limestone particles is decreased, which may be due to the effect of sintering of limestone particles. At higher temperatures the equilibrium involving the formation of $CaSO_4$ from CaO, O_2, and SO_2 is shifted away from the formation of the sulfate salt and toward the free SO_2. As a result, more SO_2 is available to react with particles of lime in the fly ash and the sulfur concentration increases in the fly ash at the higher operating temperatures.

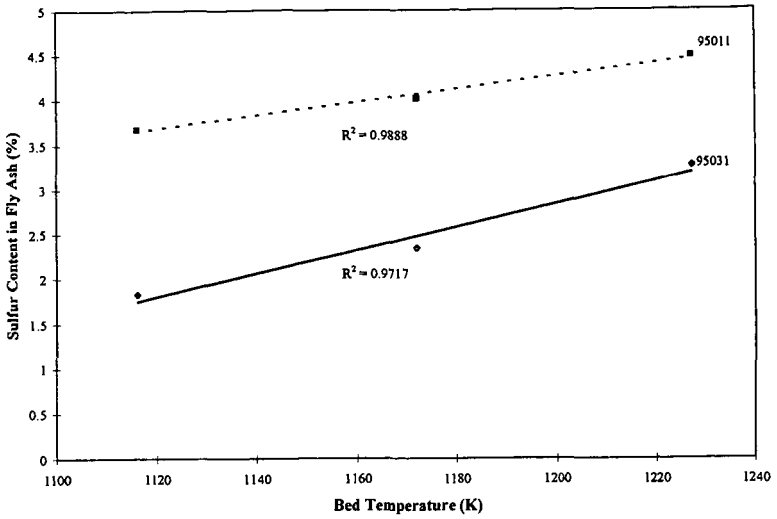

Figure 1. The effect of bed temperature on the concentration of sulfur in the fly ash of the AFBC system.

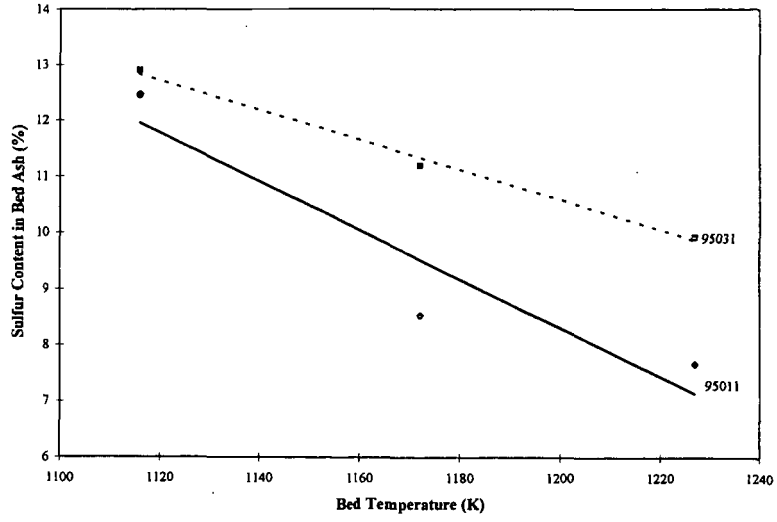

Figure 2. The effect of temperature on the concentration of sulfur in the bed ash of the AFBC system.

The effect of bed temperature on the chloride content in fly ash and bed ash are shown in Figures 3 and 4. It is obvious that the chloride content in the source coal is a decisive factor in the distribution of chloride in ash. The low chlorine coal (95011) released less hydrogen chloride during combustion and there are almost no temperature effects on the absorption of HCl in both the fly ash and bed ash from the combustion of this coal. For the high chlorine coal (95031), both Figures 3 and 4 show that chloride retention is more favorable at low temperatures.[1,2]

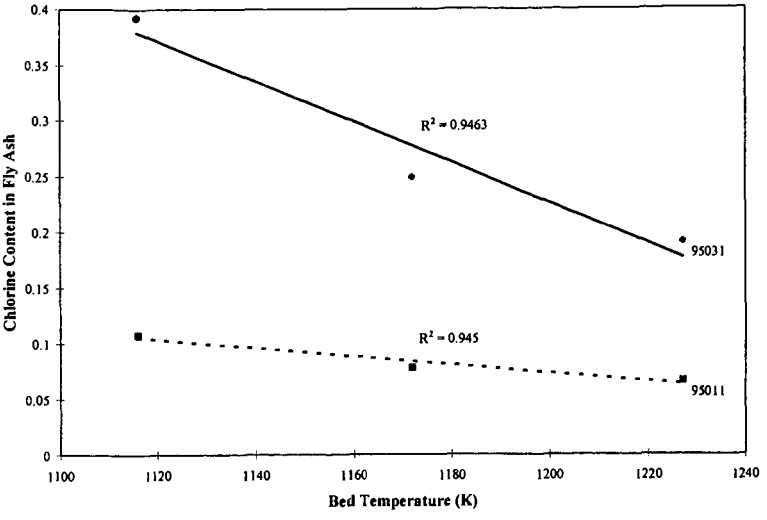

Figure 3. The effect of bed temperature on the chloride content in the fly ash from the AFBC system.

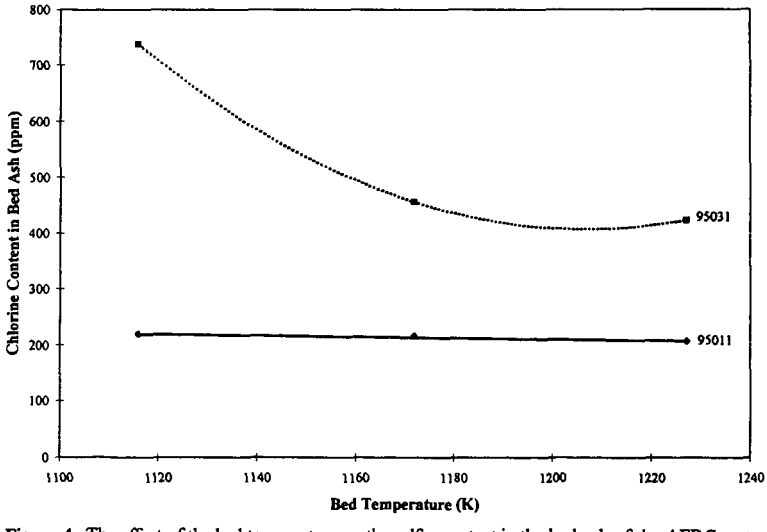

Figure 4. The effect of the bed temperature on the sulfur content in the bed ash of the AFBC system.

The Effect of Ca/S Ratio and Coal Type. Figures 5 and 6 show the effect of Ca/S ratio on the sulfur and chlorine retention in ash. One can see from these figures that the Ca/S ratio has more influence on the sulfur retention for the high sulfur content coal (95011). With the increase of the Ca/S ratio, the sulfur content in fly ash increased. Also, it can be seen that there is little effect of Ca/S on the chloride content in fly ash. On the other hand, Figure 6 shows that the Ca/S ratio is more important for the capture of chloride compared to sulfur for high chlorine content coal (95031). It is assumed that the HCl is probably captured in the low bed temperature region when the flue gas is passing through the heat exchange tube region because the reaction between HCl and CaO is more favorable at the low temperature.[1,2]

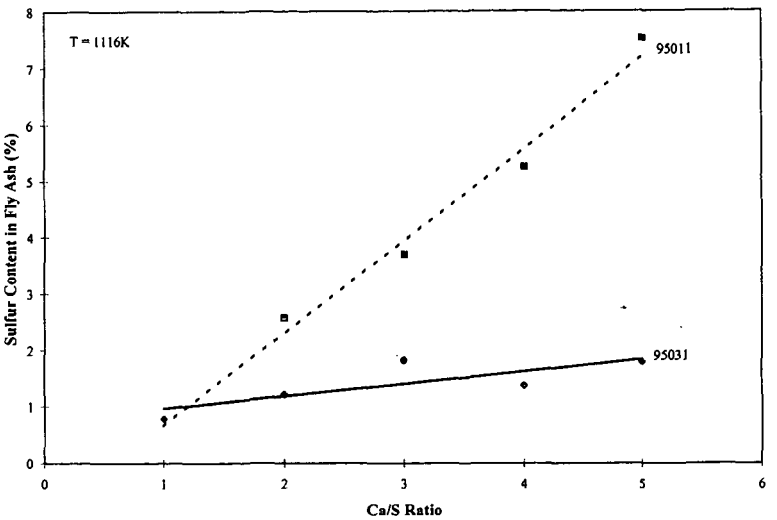

Figure 5. The effect of the Ca/S ratio on the sulfur content in the fly ash.

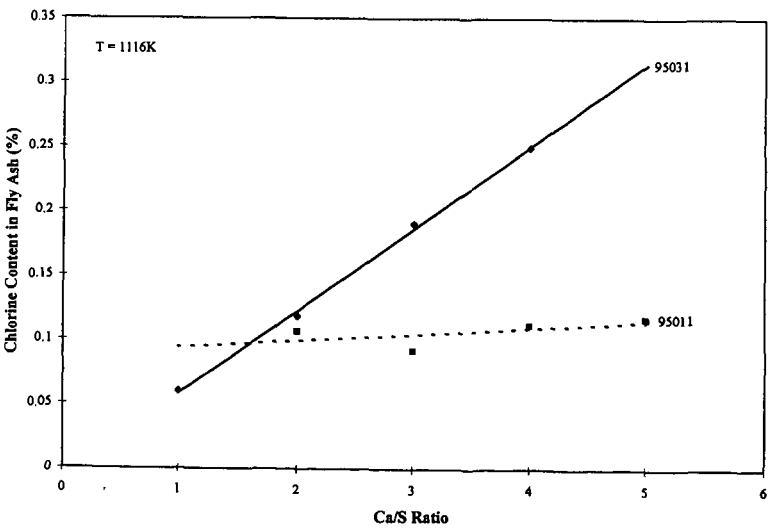

Figure 6. The effect of the Ca/S ratio on the chloride content in the fly ash.

CONCLUSIONS

Based on the data presented in this paper the following observations and statements can be made.

- The bed temperature in an AFBC system plays a key role in the retention of sulfur and chloride in ash. When the bed temperature is too high, less SO_2 is absorbed in the bed ash and more is absorbed in the fly ash.
- The chloride content of a coal is an important factor in the retention of chloride in the ash. Chloride retention in both the fly ash and bed ash is more favorable at low operating temperatures.
- When the sulfur or chlorine content in coal reaches a certain point, the Ca/S ratio in the combustion mixture will be an important factor in the absorption of SO_2 and HCl.

ACKNOWLEDGMENTS

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