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Bed Material Agglomeration During Fluidized Bed Combustion

Technical Progress Report for the Period
January 1, 1993 - March 31, 1993

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Abstract

A survey of agglomeration and deposit formation in industrial fluidized bed boilers is in progress. Preliminary results indicate that at least five boilers were experiencing some form of bed material agglomeration. In these instances it was observed that large particles were forming within the bed which were larger than the feed. Four operators could confirm that the larger bed particles had formed due to bed particles sticking together or agglomerating. Deposit formation was reported at nine sites with these deposits being found most commonly at coal feed locations and in cyclones. Other deposit locations included side walls and return loops. Examples of these agglomerates and deposits have been received from five of the surveyed facilities.

Also during this quarter, a bulk sample of Illinois No. 6 coal was obtained from the Fossil Energy Program at Ames Laboratory here at Iowa State University and prepared for combustion tests. This sample was first ground to a top-size of 3/8" using a jaw crusher then a size fraction of 3/8" x 8 (U.S. mesh) was then obtained by sieving using a Gilson Test-Master. This size fraction was selected for the preliminary laboratory-scale experiments designed to simulate the dense bed conditions that exist in the bottom of CFB combustors. To ensure uniformity of fuel composition among combustion runs, the sized coal was riffled using a cone and long row method and stored in bags for each experiment.

During this quarter additional modifications were made to the combustor. These modifications were made to achieve better control of fluidization regimes and to aid in monitoring the hydrodynamic and chemical conditions within the reactor. A pressure transducer has now been connected to pressure taps on the combustor and wired into the computer data acquisition system. This transducer will monitor pressure fluctuation within the bed providing a mechanism to determine the kinetics of agglomerate growth. To improve the resolution of frequency measurements, an electronic filter has been constructed to reduce high-frequency measurement noise. The combustor was also modified so the fluidization air can be mixed with nitrogen. By changing the proportion of nitrogen to air, either oxidizing or reducing conditions can be simulated while maintaining similar fluidization velocities. Using this technique, fluidization regimes can also be set independently of the amount of excess oxygen. Additional modifications to the combustor include changing the ball valve controlling the primary air flow to a globe needle valve, which permits better control of primary air to the combustor, and completion of a system to remove tars from sampled exhaust gases.

Bed Material Agglomeration During Fluidized Bed Combustion

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Objective

The purpose of this project is to determine the physical and chemical reactions which lead to the undesired agglomeration of bed material during fluidized bed combustion and to relate these reactions to specific causes.

Progress

Industrial Survey

The survey of agglomeration and deposit formation in industrial fluidized bed boilers is in progress. To date, twenty-seven fluidized bed operators have been contacted. We have received thirteen responses to our survey and we are awaiting responses from eleven others. Three facilities were unwilling to participate in the survey. A summary of these results is given in Table 1.

Table 1. Preliminary results of agglomeration and deposition survey of thirteen industrial fluidized bed boiler operators.

	<u>YES</u>	<u>NO</u>
<u>Bed agglomerates</u>		
Large particles in bed (No. of facilities)	6	7
<u>If large particles in bed</u>		
Bed particles larger than feed	5	1
Bed particles sticking together	4	2
<u>Deposit formation</u>		
Observed Deposits	9	4
<u>Deposit locations</u>		
Coal feed locations	6	3
Side walls	3	6
cyclone	5	4
return loop	3	6
<u>Suspect problems are due to:</u>		
Temperature	0	13
Alkali	0	13
Low-rank fuel	1	12

Preliminary results indicate that at least five boilers were experiencing some form of bed material agglomeration. In these instances it was observed that large particles were forming in the bed which were larger than the feed. Four operators could confirm that the larger bed particles had formed due to bed particles sticking together or agglomerating. Deposit formation was reported at nine sites with these deposits being found most commonly at coal feed locations and in cyclones. Other deposit locations included side walls and return loops.

Samples of agglomerates and deposits have been received from five of the surveyed facilities. These will be examined using several analytical techniques. The bulk chemistry of layers within the deposit will be determined using either x-ray fluorescence (XRF) or inductively coupled plasma - atomic emission spectroscopy (ICP-AES). Thin sections of the samples will be made for polarized-light microscopy. Using optical microscopy we will apply petrographic techniques to interpret mineralogic reactions and to make photographic "maps" for electron microprobe analyses and scanning electron microscopy (SEM). Electron microprobe analyses will give us the chemical composition of individual particles and localized areas within particles or layers. These analyses will be supplemented by x-ray diffraction (XRD) analyses to determine the bulk mineralogy of individual layers within the deposits. Our SEM is equipped with a Kevex energy-dispersive microanalyzer which has a "thin window" for the semi-quantitative determination of oxygen. Using these techniques we should be able to interpret the mineralogic reactions occurring during deposit formation and reconstruct the "history" of the deposit.

Sample Preparation for Combustion Tests in a Laboratory-Scale FBC.

For the initial combustion tests, Illinois No. 6 coal was obtained from the Fossil Energy Program at Ames Laboratory here at Iowa State University. This coal was selected because of its similarity to the fuel used in earlier combustion experiments. This particular coal came from a 2 ton run-of-mine sample collected from the River King Underground Mine No. 1 of the Peabody Coal Company, Freeburg, Illinois. The bulk sample was collected at the mine and stored under argon during shipping. It was then riffled using a cone and long row method into 55 gallon barrels and stored under argon. From this bulk sample we received a representative barrel or approximately 200 lbs of coal.

To prepare the coal for combustion tests, it was ground to a top-size of 3/8" using a jaw crusher. A size fraction of 3/8" x 8 (U.S. mesh) was then obtained by sieving using a Gilson Test-Master. This size fraction was selected for laboratory-scale experiments designed to simulate the dense bed conditions within a circulating fluidized bed combustor. To ensure uniformity of fuel composition between combustion runs, the sized coal was riffled using a cone and long row method and stored in bags for each experiment. Table 2 shows the proximate, ultimate, and sulfur forms analyses of the sized sample to be used in the initial combustion tests.

For the preliminary combustion tests, the bed of the combustor will consist of locally available river sand. Approximately 750 lbs of sand was collected from a quarry near Ames, Iowa. The sample was air dried then sized to 30 x 40 US mesh using a Gilson Test-Master sieving apparatus. A new sand bed will be used for each combustion test.

Table 2. Proximate, ultimate, and sulfur forms analyses of Illinois No. 6 coal after sample preparation for combustion tests.

		<u>As received</u>	<u>Dry</u>
Proximate:	Moisture (%)	4.2	0.0
	Ash (%)	25.2	26.3
	Volatile (%)	33.5	35.0
	Fixed Carbon (%)	<u>37.1</u>	<u>38.7</u>
	Total	100.0	100.0
Ultimate:	Moisture (%)	4.2	0.0
	Carbon (%)	54.03	56.40
	Hydrogen (%)	3.81	3.49
	Nitrogen (%)	0.99	1.03
	Total Sulfur (%)	5.02	5.24
	Ash (%)	25.2	26.3
	Oxygen (diff.) (%)	<u>6.75</u>	<u>7.54</u>
	Total	100.0	100.0
Sulfur forms:	Sulfate Sulfur (%)	0.10	0.10
	Pyritic Sulfur (%)	3.04	3.17
	Organic Sulfur (%)	1.88	1.97

Combustor Modifications

During this quarter additional modifications were made to the combustor. These modifications were made to achieve better control of fluidization regimes and to aid in monitoring the hydrodynamic and chemical conditions within the reactor. As reported last quarter, a pressure transducer was received from Davis Instruments. This transducer has now been connected to pressure taps on the combustor and wired into the computer data acquisition system. The transducer was tested by recording combustor bed pressure at one second intervals during combustor operation. The data files from these tests consisted of 4096 readings. To improve the resolution of frequency measurements, a fourth order low-pass filter for the pressure transducer output was constructed to reduce high frequency measurement noise. A schematic of this filter is shown in Figure 1. The filter was designed for a sample frequency of 0.16 Hz. This corresponds to a cutoff frequency of 0.08 Hz on a bode plot of the transducer output signal.

Figure 1. Schematic of the fourth order low-pass filter constructed to reduce high frequency noise in the pressure transducer output.

The combustor was also modified so the fluidization air can be mixed with nitrogen. By changing the proportion of nitrogen to air, either oxidizing or reducing conditions can be simulated while maintaining similar fluidization velocities. Using this technique, fluidization regimes can also be set independently of the amount of excess oxygen.

Additional modifications to the combustor include changing the ball valve controlling the primary air flow to a globe needle valve and completion of a system to reduce the amount of tars in the exhaust gases. The new valve permits better control of primary air to the combustor. The need to reduce tars in the exhaust gas samples is because many of the planned experiments are to be performed at substoichiometric conditions. These conditions lead to tar formation in the exhaust gases which could damage the exhaust gas analyzers. The tar removal system consists of two stages. The first is a secondary air line placed directly above the combustor bed. This will promote the combustion of unburned particles in the freeboard and reduce the formation of tars. The second stage is a cold trap upstream of the gas analyzers. The cold trap consists of a large glass tube packed with polyglass fiber fill all immersed in an ice bath. This should condense any remaining tars on the fiber fill before the exhaust gases reach the gas analyzers.

Replacement of the liquefied petroleum gas (LPG) bottles in the laboratory by a natural gas (NG) pipe line was completed this quarter. This was done primarily for safety reasons to eliminate the greater explosive hazard of LP gas. The NG pipe line has a line pressure of 10 psig which is necessary for combustor startups. In addition, a gas burner has been designed with installation to be completed soon. This burner is anticipated to increase the mean time between failure (MTBF) of the flame arrestor. This flame arrestor is a stainless steel screen attached to the combustor's distributor.

Future Work

Work for the next quarter includes completion of combustor modifications to monitor pressure fluctuations and the installation of the electronic filter. We will begin preliminary combustion experiments based on a test matrix in which the amount of theoretical air will be varied. For the initial set of experiments we intend to use Illinois No. 6 coal. Analyses of the agglomerate and deposit samples received from the industrial fluidized bed combustors will begin.

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