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Title:

A NOVEL COAL FEEDER FOR PRODUCTION OF LOW SULFUR FUEL

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ABSTRACT

A dual-screw feeder was designed and tested for desulfurization of coal. The key parts of this reactor are two screw tubes which independently feed coal and calcined lime, the inner tube acting as a coal pyrolizer and the outer tube acting as a desulfurizer with hot calcined lime pellets or other renewable sorbent pellets. The objective of this project is to study the feasibility of this advanced concept of desulfurization using the coal feeder.

In this quarter, the following tasks have been performed: 1) Analytical measurements of the organic sulfur content in the feed coal and the product char, 2) Setting up the combustor which is physically attached to the feeder system and will be used to study the combustion characteristics of char and volatiles produced from the pyrolysis process. The following preliminary conclusions have been obtained: 1) A 73.1% of the organic sulfur in Ohio #8 coal was removed in the dual-screw feeder reactor at a temperature of 475°C with the residence time of 6 min. 2) The combustor works stably and the operating temperature of the combustor can be adjusted by controlling the char feed rate and the air flowrate.

INTRODUCTION

Coal is predominantly used as a fuel for the production of electricity. Air pollution arising from coal combustion is now a major concern as coal is second to the petroleum and nature gas in total energy consumption. Various methods of sulfur removal from coal have been developed during the last two decades. However, the cost, as well as the low sorbent utilization, of current desulfurization technologies is still a drawback to the increased use of high sulfur coals.

A novel dual-screw feeder reactor was designed, for this project, to remove the sulfur in coal before combustion while the sulfur-compounds are converted to gaseous forms of product, mainly H_2S, during a mild pyrolysis process and are still highly concentrated. Two basic concepts are involved in the development of this reactor: the mild pyrolysis of coal and the reaction of H_2S with calcium based sorbent. It combines the pyrolysis and the sulfur removal processes together.

Under mild reducing pyrolysis condition, the pyritic sulfur in coal is released mainly in the form of H_2S. The release mechanism of organic sulfur is not well investigated, however it is generally known that the organic sulfur is released in the form of H_2S and COS below 600°C. The formation of H_2S is the key point to the enhancement of sorbent utilization in this project. The reaction rate of H_2S is significantly higher than that of SO_2 with CaO at the same temperature. Furthermore, the smaller molar volume of CaS than that of $CaSO_4$ indicates that the formation of CaS could proceed more completely than that of $CaSO_4$. Therefore, the higher utilization of sorbent (CaO) is possible.

In the pyrolysis process, coal is converted into char, tar and noncondensable gas. Different pyrolysis conditions may result in different product distribution and different sulfur distribution. Generally, the gaseous compounds include CO, CO_2, H_2, hydrocarbon and nitrogen and sulfur containing species. Coal pyrolysis is a very complicated process. The result strongly depends on the experimental conditions including the type of reactor used, the range of temperature, the heating rate and the method of analysis of the products. Much attention has been paid to the study of coal pyrolysis process during the last decade. The experimental methods generally include fluidized bed, fixed bed and batch reactors. However, the concept of a dual-screw feeder reactor has not been attempted before, in which coal pyrolysis and sulfur removal take place simultaneously.

During the last 6 months, a coal combustor was designed and constructed to study the combustion characteristics of the pyrolyzed products in order to evaluate the effectiveness of the dual-screw feeder as a part of a complete combustion system. By measuring the emission SO_2 from the stack of combustor, we are able to find the degree of reduction of SO_2 emission using the dual-screw feeder.

EXPERIMENTAL SYSTEM

The experimental system of coal feeder consists of four units: 1) The screw feeder reactor, 2) Sampling unit, 3) The analysis unit, and 4) The combustor.

The screw feeder reactor consists mainly of two augers which are driven by two motors independently. The inner screw is used for coal pyrolysis, and the outer one is for sulfur removal with calcined limestone pellets or other renewable sorbent pellets. By adjusting the speed of the motors, the particle residence time can be easily controlled. The reaction system is well sealed. In consideration of the high corrosiveness of H_2S and other evolved gases, all parts of this reactor are made of stainless steel. Two quenching tanks are used to collect char and reacted sorbent pellets.

Three sections of band-type electrical heaters with three separate temperature controllers are installed on the wall of outer tube to provide a uniform temperature distribution along the feeder tube. Several thermocouples are attached to the outer wall of the reactor to measure the surface temperature.

After pyrolysis, the volatiles flow out of the reactor and flow through the condensers. The condensable substances ("tar", it is actually a mixture of tar and water) are condensed there and the cooled gas enters the gas collection unit. To determine the gas composition, a Perkin Elmer Gas Chromatography (GC) is used with two GC columns. One column is for H_2S, and the other for hydrocarbon, carbon oxides, hydrogen and nitrogen. The GC operating temperature was experimentally selected at 70°C. Helium is used as a carrier gas. All standard curves are determined prior to experiments. A sample bag is used to collect the cooled gas. At the end of experiment, the weight and the volume of the collected noncondensable gas are measured. The amount of char and tar are determined gravimetrically so that a proper mass balance is made. The relation between residence time and screw rotation speed was determined by using the metal balls traveling through the feeder. The sulfur content in char and coal is analyzed by using a LECO sulfur analyzer and the organic sulfur component is measured according to the ASTM method.

Ohio #8 coal of size 4-35 mesh is used for the present experiments. The total sulfur content in coal sample is 3.15 wt% and the organic sulfur is 1.72 wt%, which accounts for 45.4% of the total sulfur content.

In study of the combustion characteristics of the pyrolyzed products, the char and the volatiles produced from the pyrolysis process are introduced into the combustor which is 10 feet in height(See Fig. 1). The stack is well insulated in order to maintain the required combustion temperature. A rotating disk is installed in the combustor to achieve a uniform temperature as well as easy removal of flyash. The air flow rate is controlled by an air blower below the combustion tube. The rotating disk is located at the bottom one fourth of the length of the combustion tube. When combustion is initiated, the tube starts resonating with its characteristic sonic resonance frequency. This type of combustor has been proved to be useful for a small scale combustion for a high combustion efficiency owing to its fluidizing effect of sonic resonance. Three thermocouples are installed along the stack to measure the axial temperature distribution. A small amount of stack gas is continually fed into the condensers, through a filter and then goes into the SO_2 analyzer for continuous monitoring of the SO_2 mission level.

RESULTS AND DISCUSSION

1) Organic Sulfur Analysis

Under mild pyrolysis condition, the released sulfur from coal is mostly organic sulfur. The ASTM standard method is used to analyze the organic sulfur content in both coal and char. The organic sulfur in Ohio #8 coal has been determined as 1.72% (45.4% of total sulfur). Table 1 shows the results of the organic sulfur measurement in chars obtained from the pyrolysis process in the dual-screw feeder.

From previous experimental results, it is known that at a temperature of 475°C and a residence time of 6 min., 33.2% of total sulfur or 73.1% of organic sulfur releases from coal. It is shown from the result in Table 2 that at that condition, 73.4% of organic sulfur is removed. This is a strong evidence that under the experimental conditions, mostly organic sulfur is released. Also, it is seen that as the reaction temperature and residence time increase, the organic sulfur removal efficiency is raised. It is expected that when the temperature is raised and/or the residence time is increased, more than 95% of organic sulfur could be removed using this process.

2) The Combustor

Preliminary experiments on the combustor have shown that the temperature in the combustor can go up to about 1700°F. At this level of temperature, almost all the sulfur element can be convert to SO_2 quickly. The char from dual-screw feeder is continuously fed into the combustor by another auger which is installed between the quench box of the dual-screw feeder and the combustor. By adjusting the feed rate of char and the air flowrate, one can control the combustion temperature. The pyrolyzed gas which is cleaned with calcined lime pellets in the outer tube of the feeder is also fed into the combustor to utilize all the available fuel from the original coal as well as to make a proper sulfur balance.

When the pyrolysis condition in the screw feeder is changed, the SO_2 content in the combustor stack will be changing. By measuring the SO_2 concentration in the stack gas, we will be able to evaluate the degree of desulfurization by use of the screw-feeder and the optimal operating condition of the system.

PLANNED FUTURE WORK

The following works are planned for the next quarter:

(a) Continued experiments on dual-screw feeder to study the sulfur removal at higher temperature with long residence time.

(b) Experiments on the combustor to study the combustion characteristics of char and the SO_2 emission under various operating conditions.

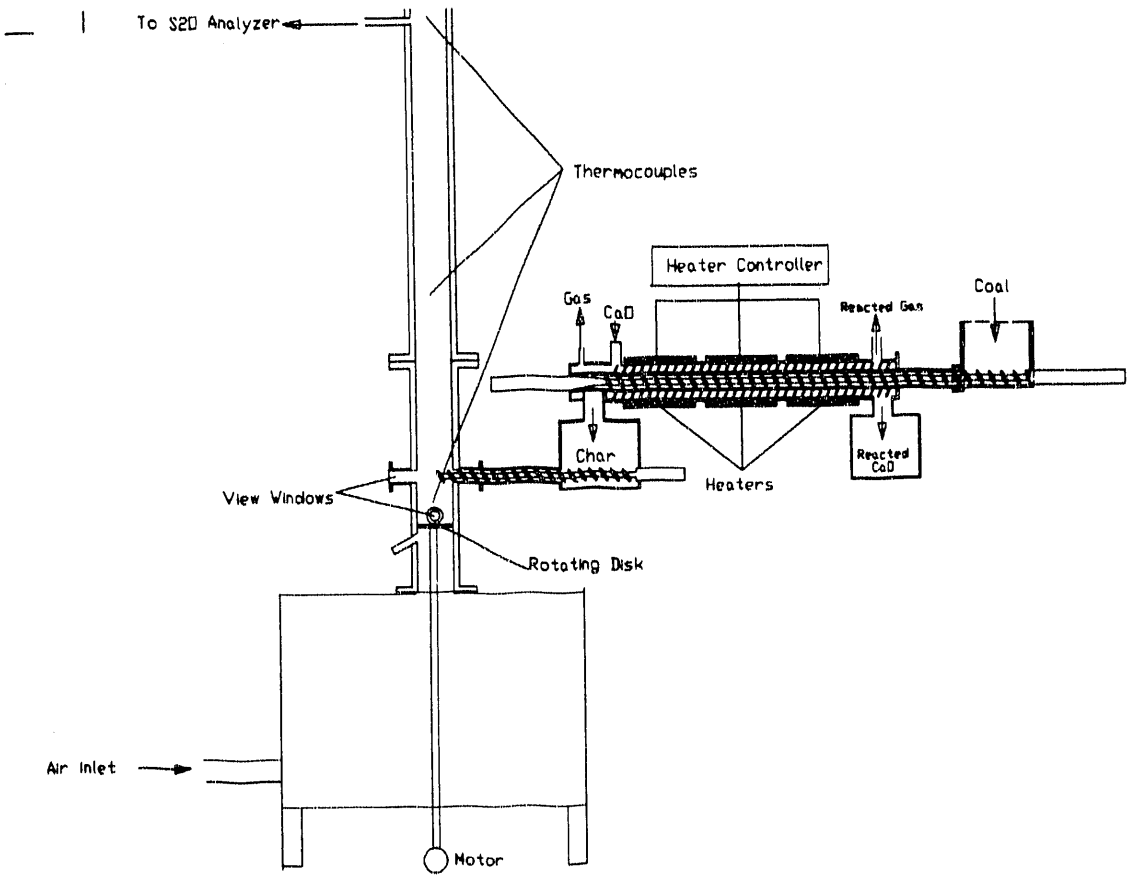

Figure 1 Coal Combustor System with the Dual–Coal Feeder

Table 1. The Organic Sulfur Content(wt%) In Char Produced Under Different Pyrolysis Condition

Residence Time (min)	Temperature (°C)			
	400	425	450	475
2				1.289
3		1.510		
4				
5	1.056		0.941	1.062
6				0.63

Table 2. The Organic Sulfur Removal efficiency(wt%)

Residence Time(min)	Temperature (°C)			
	400	425	450	475
2				36.8
3		18.2		
4				
5	42.7		52.8	54.2
6				73.4

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