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Title:

A NOVEL COAL FEEDER FOR PRODUCTION OF LOW SULFUR FUEL

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ABSTRACT

In this project, a dual-screw feeder was designed for desulfurization of coal. The key parts of this reactor are two screw tubes which are used to feed coal and calcined lime particles separately, the inner tube acting as a coal pyrolyzer 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 an advanced concept of desulfurization in this coal feeder.

In this quarter, the following tasks have been performed: 1) Change of the single-end driving mechanism of the screw shaft to a double-end driving mechanism, 2) Study of the total sulfur balance on the reactor system, 3) Analytical measurements of the organic sulfur content in the original coal, and 4) Design of a combustor which will be physically attached to the feeder system and will be used to study the combustion characteristics of char and volatiles produced in the pyrolysis process. Some preliminary conclusions have been obtained: 1) Double-end driving mechanism of the inner screw feeder is useful to result in a uniform stress on the shaft and to raise the reaction temperature. 2) The total sulfur balance shows that the sulfur removal efficiency of CaO in this reactor is very high. 3) The organic sulfur of Ohio #8 coal is about 1.72% which is 45.4% of the total sulfur content.

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. 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 utility 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. The experimental methods generally include fluidized bed, fixed bed and batch reactors. No information is available on a dual-screw feeder reactor in which coal pyrolysis and sulfur removal take place simultaneously.

EXPERIMENTAL SYSTEM

The experimental system consists of three units. 1) The screw feeder reactor, 2) Sampling unit and 3) The analysis unit.

The screw feeder reactor consists mainly of two augers which are driven by two motors separately. 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 considering 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 products and reacted sorbent pellets.

Three sections of band type electrical heaters with three separate temperature controllers were installed on the surface of outer tube to provide uniform temperature distribution along the feeder tube. Several thermocouples are employed 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 entrains the gas collection unit. To determine the gas composition, a Perkin Elmer Gas Chromatography (GC) is used. Two GC columns were installed in this unit. One 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 the carrier gas. All standard curves were 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 and the mass balance is made.

The relation between residence time and screw rotation speed was determined by using the metal balls.

The sulfur content in char and coal is analyzed by using a LECO sulfur analyzer.

The Ohio #8 coal (4-35 mesh) was used in the experiments. The total sulfur content in coal sample is 3.15%(wt).

RESULTS AND DISCUSSION

1) Redesign of the Drive Mechanism of Inner Screw

When coal particles are heated to a certain temperature (for Ohio #8 coal, it is about 450°C), they swell and become plastic and sticky. The molten coal particles tend to stick on the surface of both inner screw and inner tube. As a result, a large stress torque is produced. Due to increased friction between the inner screw and the tube wall during a longer operating time and an elevated temperature above 600°C, the inner screw was broken at the end of one experimental run. After careful consideration, it was decided to change the drive mechanism of the inner screw. Previously, the inner screw shaft was driven at one end, and the rotational torque was large. After reconstruction, the inner screw shaft is driven at both ends to evenly distribute the load and thus to reduce the rotation torque.

The experimental results showed that the reconstruction of the reactor was successful. The reaction temperature now can be raised to 600°C. This improvement is important for desulfurization in the coal pyrolysis process for an extended period of operation.

2) Sulfur Balance On Reactor

Table 1 shows the sulfur balance on the reactor. It is seen that the sulfur concentration of gas which results from pyrolysis process in inner tube and flows through the outer tube where it reacts with CaO pellets becomes undetectable by GC. It indicates that the sulfur-containing gas could be thoroughly cleaned with CaO pellets in the dual-screw feeder reactor.

3) 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 1.43% (45.4% of total sulfur). The analysis of char which is from different pyrolysis conditions is in process.

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 expected that when the temperature is raised above 600°C, more than 95% of organic sulfur would be removed.

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.

(b) Continued analysis of organic sulfur in char to study the kinetics of organic sulfur removal.

(c) Constructing the combustor to study the combustion characteristics of char.

Table 1. Sulfur Balance on Reactor

T=475°C t=6min.	Input(g)		Product				
	Coal	CaO	Char	Gas	Tar	CaO	Total
	300	300	216.0	50.1	25.1	305.1	596.3
S%	3.15	0	2.89	0	2.25	0.74	
S(g)	9.45	0	6.24	0	0.65	2.26	9.10

T=400°C t=5min.	Input(g)		Product				
	Coal	CaO	Char	Gas	Tar	CaO	Total
	600	400	555.5	13.9	21.6	405.2	996.2
S%	3.15	0	3.01	0	7.22	0.175	
S(g)	18.90	0	16.72	0	1.56	0.727	19.01

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