J. Jpn. Soc. Microgravity Appl. Vol. 28 No. 2 2011 (S13–S16)

8th Japan-China-Korea Workshop on Microgravity Sciences
for Asian Microgravity Pre-Symposium

The Facility for Pulverized Coal Combustion under Microgravity

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Abstract

Designing and developing a facility that can be used for pulverized coal combustion experiment in microgravity are presented. It is used to research pulverized coal combustion characteristics in microgravity. The structure, the working principle and the experimental results of this facility are introduced. Especially, the facility can record the image of the whole process of coal combustion clearly, and it can measure the ignition temperature of pulverized coal accurately. The Further improvements of the facility are presented.

1 Introduction

China is the largest country of coal production and consumer in the world [1)-2)]. To study on the pulverized coal pyrolysis, gasification, ignition, volatile matter, coke combustion and burnout, and other features in microgravity, it can organize the various combustion facilities in the combustion process better [3)-7)]. It would not only save energy consumption, but also minimize combustion emissions and protect the environment.

To study oxy-fuel combustion technology-one of the possible, promising technologies for capturing CO_2 from power plants, Japanese scholars had carried out coal combustion experiments under microgravity in 1994[8)-9)], Scientists of Tsinghua University conducted ignition experiments of single coal particle under microgravity using the 3.5s drop tower of Chinese Academy of Sciences National Microgravity Laboratory in 2007[10)]. However, due to limitations of space conditions, the experiments require facility having high temperature (up to 1223K), good airproof chamber, low power, small size, and light weight. The facility used on ground is difficult to work in space. The study on space microgravity combustion usually focuses on the single particle combustion of coal combustion experiments, the facilities could not be used under high temperature to study pulverized coal ignition temperature, burn out, emissions and so on. The goal of this study is to achieve space pulverized coal combustion experimental facility.

2 The facility

2.1 Operational principle

To study the ignition temperature of pulverized coal, it needs to control the furnace temperature and to increase gradually, putting pulverized coal into the furnace chamber at different temperatures, and then observing whether pulverized coal can be ignited so as to determine the ignition temperature of pulverized coal.

The space coal combustion experimental apparatus is mainly through the detection of coal gases in the combustion to attain the volatile changes in precipitation of char combustion and the burnout characteristics, combining with high-speed camera to monitor the combustion process of pulverized coal. The flame structure and flame temperature distribution can be recorded by CCD image.

To control the system of feeding powder (powder with different storage tanks), it can change the number of particles of different coal density and particle size, to study the impact of the ignition, combustion and pollutant emission characteristics of pulverized coal.

2.2 The structure of the facility

The facility is mainly composed of the furnace unit (FU), the inlet and outlet of gas and powder feeder unit (IOGPFU), the gas analysis unit (GAU), the observation unit (OU) and the control unit (CU), as shown in **Fig. 1**. FU provides the necessary environment for pulverized coal combustion; IOGPFU controls the coal power and gas into the furnace; GAU is used to measure composition and concentration of the exhaust gas; OU is used for the observation of coal ignition process; CU controls the furnace temperature, the inlet and outlet gas, the powder, the exhausting gas and the image recorder.

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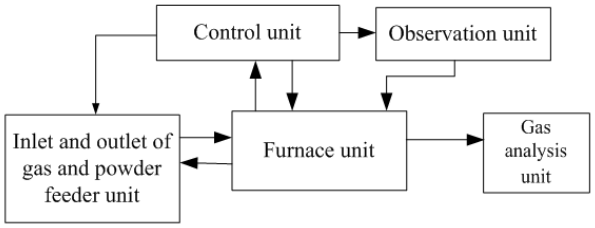


Fig. 1 Scheme of the facility

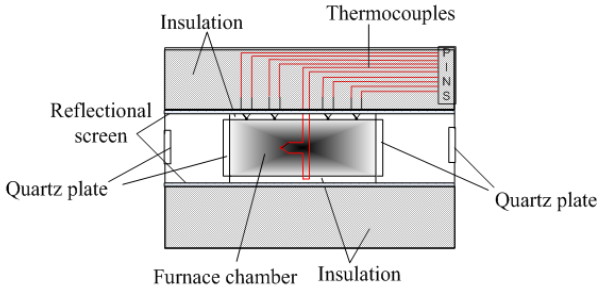


Fig. 2 Furnace unit

2.3 The furnace unit

The furnace unit is mainly composed of the furnace chamber, the heating element, the thermocouples, the thermal insulation, the reflectional screen and the shell. The furnace chamber is a cylinder, and its material is stainless steel tube with size of ϕ30mm × 80 mm. The heating element is consists of solenoid-typed resistance wire. Five K-type thermocouples distributed along the axial of furnace chamber, the middle one of which is installed inner of the furnace chamber, and used to measure the inner temperature of the furnace directly, which is the most closest to the actual temperature of pulverized coal. The others are installed against the lateral of furnace chamber nearby the heating resistance wire, as shown in **Fig. 2**. The insulation layer and the reflectional screen are in outside of the furnace chamber. Shell is used to fix and protect the furnace chamber and insulation materials. Two pieces of quartz glasses are installed in each side of the furnace chamber. By this way, the phenomena of pulverized coal combustion in the furnace chamber can be observed from both sides of the furnace.

2.4 The IOGPFU

The IOGPFU and the GAU are shown in **Fig. 3**. It is composed of the gas tank, valve 1, valve 2, valve 3, and the coal storage tanks. Valve 1 and valve 2 are used for controlling the amount of the powder insufflating the furnace chamber. Valve 3 is used to control emissions, and reduce the pressure of the furnace chamber. Gas sensors are installed in the GAU for detecting the components and consistence of the emission gas. Pumping system is used to exhaust residual gas from the furnace chamber and the GAU, so as to provide a clean environment before the next experiment.

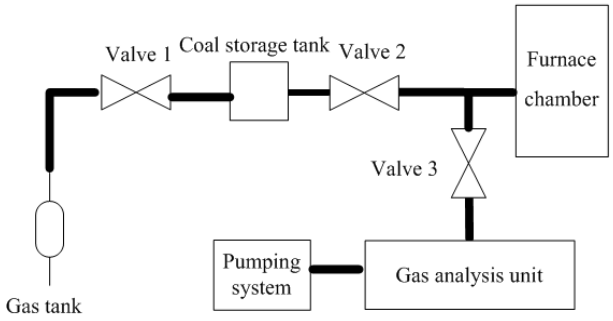


Fig. 3 IOGPFU and GAU

2.5 Observation unit

Observation unit is a high-speed CCD with frame rate of 210 frames / sec, a resolution of 648 × 488, pixel size of 7.4um × 7.4um. Using the high-speed sampling function of the observation equipment, it can record the process of burning coal in detail, and provide a detailed image data for scientific research.

2.6 Control unit

Control unit is a control system based on 8051 CPU, it can control the whole experiment on the process of with powder feeding control, exhaust control, temperature control, data acquisition and storage, data transmission and the other functions. Control system is consisted of the signals amplifier circuit, the analog switche, the A/D converter, the CPU, the data register, the program memory, the RS422 communication interface, the furnace power control and solenoid valve control circuit, etc.

3 Primary experimental results

3.1 The Process of an experiment

According to the ratio calculated, pulverized coal and gas which combustion experiments required will be stored separately in gas tank and coal storage tanks. Gas tank pressure is 4 atm. Initially, the valve 1, valve 2 and valve 3 are all close. When experiment begins, the valve 3 opened, pumping system runs and drains the exhaust gas of furnace chamber, the GAU as well. After 3-4 seconds, pumping system stops and valve 3 is closed. When the furnace temperature reaches a setpoint value, the valve 1 and the valve 2 are opened simultaneously, pulverized coal and gas are blown into the furnace chamber. The phenomena can be observed through the transparent window of the furnace. CCD camera, which can record the whole process of coal combustion, is started before pulverized coal is insufflated into the furnace chamber. After a period of time (usually 1-2 seconds), the valve 1 and the valve 2 are closed. When the temperature is higher, the valve 3 is open to release

the pressure caused by raising of furnace temperature, meanwhile the exhaust gas will be sucked into the GAU where gas components and consistence can be analyzed.

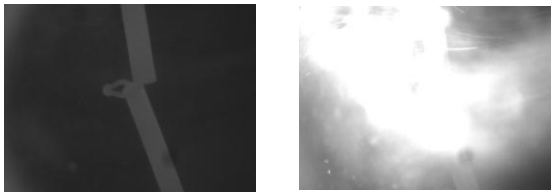
3.2 Record the process of an experiment

The experiment is conducted by the facility. The conditions of the experiment are in the air atmosphere, the coal particle size is 106-150um.

Before ignition, the first step is to heat the furnace chamber to a setpoint temperature (1016K). The second step is to insufflate pulverized coal by the gas, and then record the process of the combustion in the furnace chamber. **Figure 5**(a) shows the case before pulverized coal is blown into the furnace chamber, in this moment the furnace chamber temperature is into the pulverized coal ignition temperature field. **Figure 5** (b) shows the image that coal is fired, at the moment the coal is blown into the furnace chamber, as there are sufficient air flow, combustion of volatile is burned firstly, **Fig. 5** (c) shows burning is in process and **Fig. 5** (d) shows burning near finish, it shows the flame image obviously. Thermocouples record the temperature in real-time. The whole pulverized coal combustion process can be clearly observed and recorded by this facility.

3.3 The measurement of the ignition

Coal ignition was always described as the fuel and oxidizer achieving a continuous reaction process, often used coal flashing to identify ignition. The ignition of coal particle is very important for understanding how to switch existing burners from operation on air to operation on O2/CO2 atmosphere. It is unclear whether the ignition delay under oxy-fuel conditions is the same for single coal particle with coal particles, the ignition behavior of pulverized coal and the role of CO2 under oxy-fuel combustion conditions remain unclear. In order to get



(a) Before powder is blown (b) Pulverized coal is burning

(c) Burning is in process (d) Burning near finish

Fig. 5 The images of ignition point

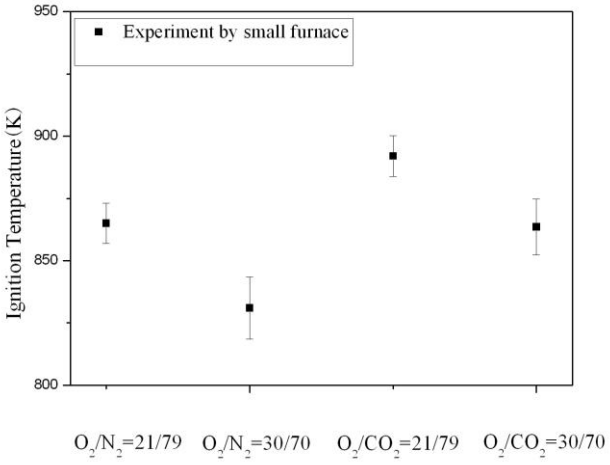


Fig. 6 Pulverized coal ignition temperature

accurate pulverized coal ignition temperature in O2/N2 and O_2/CO_2 atmosphere, a typical bituminous coal ignition characteristic was studied using the facility.

It uses the Datong bituminous coal with the particle diameter ranges from 106 to 150um to measure its ignition in the experiments. We found that when atmosphere changing from O_2/N_2 to O_2/CO_2 with the oxygen concentration is both 0.21, ignition temperature increases about 21K. The results also show that an increased oxygen concentration for coal-O_2/CO_2 combustion, if correctly selected, can produce ignition delay time and ignition temperature similar to those obtained under O_2/N_2 atmosphere. The experiment results we did have the similar trend compared to the results that other scholars have done[10]. Coal ignition and combustion is a complicated process and some fundamental insights are still unveiled. At 1-g, the process might be greatly influenced by the nature convection and the buoyancy effect. So the 1-g ignition temperatures of coal particles maybe higher than the u-g ones[11].

4 Conclusion

The facility could achieve a better accurate measurement of coal ignition temperature, because the temperature sensor is directly installed in the coal burning furnace chamber, it can measure the ignition temperature of coal directly and more accurately than the experiments which uses the dropper which only measures furnace wall operating temperature[8)-9)]. The facility can achieve the injection of pulverized coal, so that the coal can be rapidly heated. Compared to thermal gravimetric analysis, the facility can simulate the actual operation of the power plant more accurately. The results of ignition of pulverized coal show that the measurement is more accurate after lots of testing. As results, the facility provides a powerful tool for studying the characteristics of pulverized coal

combustion.

For the limitation of the conditions, the facility needs to improve as following: 1.we can not accurately obtain the concentration of pulverized coal into the furnace chamber, while it's an important factor of affecting the ignition temperature of pulverized coal. To obtain the relationship among the time of valve opened, gas pressure and the amounts of coal input, the problem will be solved by measurement and calculation.

Acknowledgement

We thank pro. Zhai Guangjie for presenting the scheme of the furnace, and designing the structure of the furnace; Pro. Jiang Yuanda for providing the conditions of experiments; Cai Shijie for helping us to do the experiments.

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(Received 17 Sept. 2010; Accepted 5 Jul. 2011)