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## Experimental Analysis of Low-rank Fuel Drying Characteristics

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# Experimental Analysis of Low-rank Fuel Drying Characteristics

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**Abstract.** Drying technology of low rank coal, which is the leading technology of low rank coal thermal chemical processing, plays an important role for the efficient use of low rank coal. It has made clear the influence factors of low rank coal drying process and effect of related factors by studying low rank coal occurrence form of moisture and the drying mechanism. In the paper, it has carried on the experimental study in drying characteristic under the condition of fluidized drying in the tube furnace with YuZhou Long-flame coal as the research object, and obtained the correlation curve of the particle size, fluidization velocity, drying temperature, drying rate and the influence factors. At last, according to the experiment and the system economy, the drying process parameters are optimized: the drying temperature is 210 °C, the fluidization air velocity is 1.6 m/s, the drying time is 5 minutes.

## 1. Introduction

Hebei Kailuan Yuzhou mining company is located in the north of the Yu county, Hebei Province. At present, the annual production capacity of long-flame coal is 1.5 million tons, and the mining area is rich in long-flame coal resources, with recoverable reserves of 148.05 million tons. However, the high water content of raw coal has a negative impact on coal utilization [1]. Therefore, it is necessary to solve the current low rank coal problem.

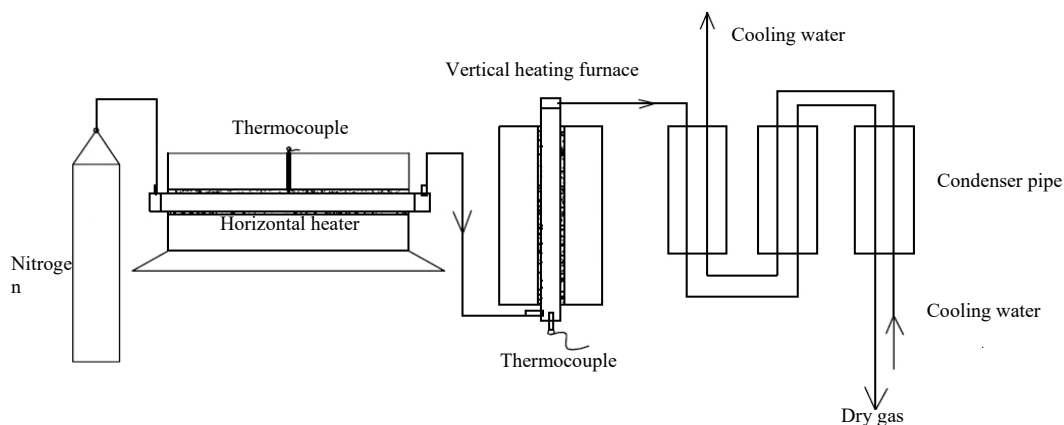
In order to improve the efficiency of low-rank coal drying process, many countries have accelerated the research on lignite drying characteristics and made great progress. Vorre et al.[2-3] studied the influence of temperature, particle size and nitrogen flow velocity on the drying rate, and fitted the monomolecular drying kinetic equation related to temperature, particle size and airflow velocity for lignite during the constant speed drying process. Li et al.[4] studied the drying kinetics and water reabsorption characteristics of low-rank coal in Indonesia by using thermogravimetric analyzer and thermostatic drying oven. The activation energy of Indonesia low rank coal was obtained by kinetic analysis. Wang lei et al.[5] studied the hot-air drying characteristics of fly ash in a fixed bed. According to the experimental results, the equation for calculating the equilibrium moisture is obtained, which is a function of air temperature and relative humidity. Zhang et al.[6] carried out the hot air drying experiment of lignite fixed bed. The results showed that particle size, hot air temperature and hot air velocity had important effects on the drying rate of particles. Looi[7] studied the drying characteristics of 10 ~ 14 mm lignite particles in the high pressure of the superheated steam in a fixed bed dryer on particle size distribution, and the experimental results showed that the lignite drying rate was mainly affected by particle surface and the external influence on the thermal efficiency of the circulating, and



steam pressure influence on the drying rate was not big, but the balance of the lignite increased with pressure and water; Diamond[8] studied the drying characteristics of Northern Ireland lignite in a fluidized bed drying laboratory size, and concluded that the different drying forces at different stages of fluidized drying of lignite resulted in obvious differences in drying rates and characteristics. Wang haifeng[9] et al. studied the drying characteristics of Tongliao lignite with different temperatures and particle sizes by using a fluidized bed dryer. The results showed that reducing the initial moisture content of the coal into the furnace could effectively shorten the drying time and improve the drying efficiency.

## 2. Experimental equipment

In order to be as close as possible to the real industrial device, hot nitrogen was used to dry the coal samples in the fluidized state in the fluidized pipeline in the experiment, and the horizontal furnace and the vertical furnace were used to heat the nitrogen to ensure that it reached the experimental temperature and kept constant. The thermocouple is used for monitoring the temperature to ensure the experimental temperature. The gas temperature of the dried coal sample is high. In order not to cause damage to the on-line gas analyzer, the dry gas is cooled by the condensing device before entering the on-line gas analyzer. The cooled gas was fed into an online gas analyzer to determine its composition, which provided a basis for the experiment. Fig. 1 is the diagram of the experimental device.



**Figure 1.** Diagram of experimental device

## 3. Determination of design parameters

### 3.1. Determination of Fluidized Wind Speed

In order to determine the critical fluidized wind speed and calculate the theoretical value of the critical fluidized wind speed was calculated, the experimental method is used to determine the fluidized air velocity required.

$$U_{mf} = 0.294 (d_p^{0.584} / V_g^{0.056}) [(P_p - P_g) / P_g]^{0.528} \quad (1)$$

In the formula:

$U_{mf}$  — Critical fluidization velocity

$d_p = \phi \sum X_i d_i$

$V_g$  — Kinematic viscosity of gas

$P_p$  — Bed material density

$P_g$  — Smoke density

Dry gas parameters in the formula is selected the physical parameters when the temperature is 240 °C, and according to the experiment plan,  $d_p$  takes 13 mm,  $P_p$  is 1400 kg/m<sup>3</sup>, then the critical fluidization velocity is calculated 1.8 m/s from the type. According to the critical fluidized wind speed, the coal

sample fluidized wind speed was measured experimentally, and the fluidized wind speed was finally determined to be 1.6m/s and 1.8m/s after the experiment. The drying characteristics were measured under the two fluidized wind speeds.

### 3.2. Determination of Drying Temperature

The precipitation temperature of the volatile matter temperature is 270 °C or so by thermogravimetric curve, but if directly using gas with 270 °C to dry, it needs to consider the following questions:

1) If the dry gas contains oxygen, it can see from experiments that when the temperature reaches 240 °C, part of coal samples can burn. So if directly using 270 °C drying, it can cause larger coal loss.

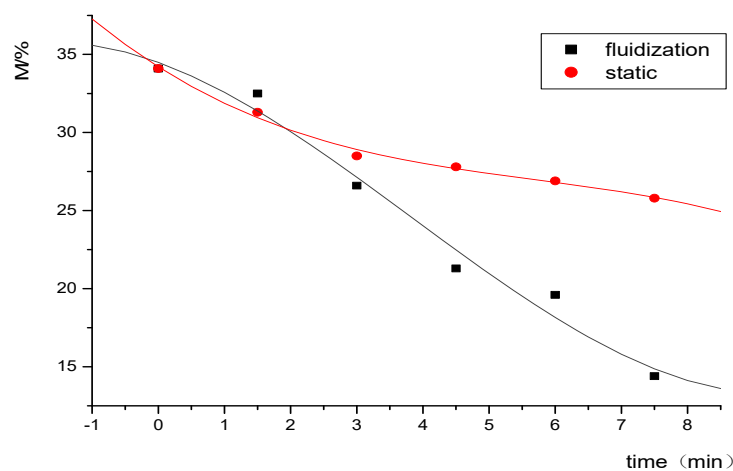
2) It takes some time to overall warming of the coal samples, so some volatile matter separate out when the dry gas temperature at 270 °C. But coal needs staying in the dryer for a certain amount of time to enter the pyrolysis furnace, this process cannot keep no overtemperature of coal temperature. The temperature continues to rise, resulting in a large number of volatile matter to separate out.

Consider the two points, the temperature can't be higher than 270 °C. The drying temperature in the determination of calorific value should not exceed 240 °C, because part of the coal sample can burn at 240 °C or so. But the size of the pulverized coal used in the determination of calorific value is 0.2 mm, which is larger, the airflow temperature affects the coal particle surface temperature and internal temperature. Heat transfer from the surface to the internal needs a period of time, so the lowest drying temperature is selected 150 °C, and can be appropriate to raise its temperature on the basis of 210 °C. The coal quality may improve when volatile matter separate out accompanied by removing oxygen functional groups in the drying process, so the highest drying temperature is determined 240 °C. To sum up, the experiment drying temperature is selected the range of 150 °C ~ 240 °C, and measures once every 30 °C, meaning to measure drying characteristics at 150 °C, 180 °C, 210 °C and 240 °C.

## 4. Experiment on drying characteristics

### 4.1. Drying Effect Comparison of Static Drying and Fluidized Drying

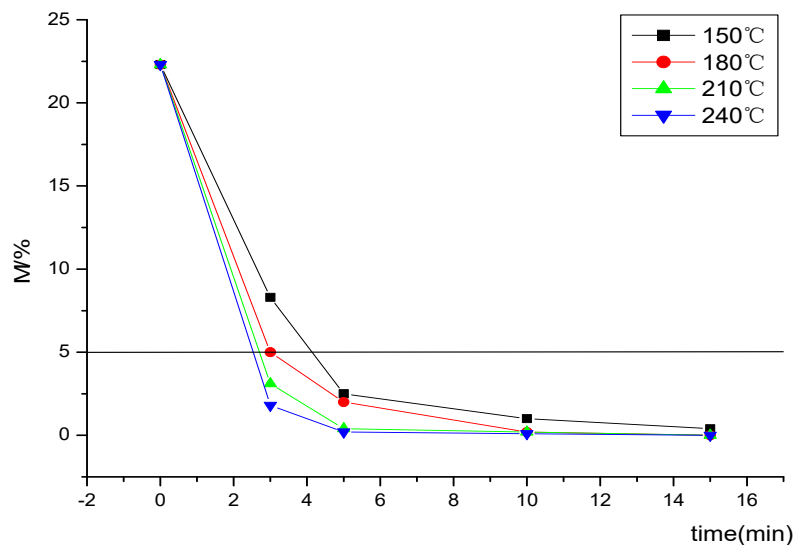
Fig. 2 showed the drying effect comparison between the static drying and fluidized drying, it could clearly seen through experiment contrast that the fluidized drying effect was better than static drying. The moisture content after static dry is still over 25% under the condition of the same moisture content of the coal and the same time of 7.5 min, but the moisture content after fluidized drying has fallen to less than 15%. It can be seen that fluidized drying should be adopted as far as possible in the coal drying process.



**Figure 2.** Comparison of drying effects between static drying and fluidized drying

#### 4.2. Influence of Drying Temperature on Drying Characteristics

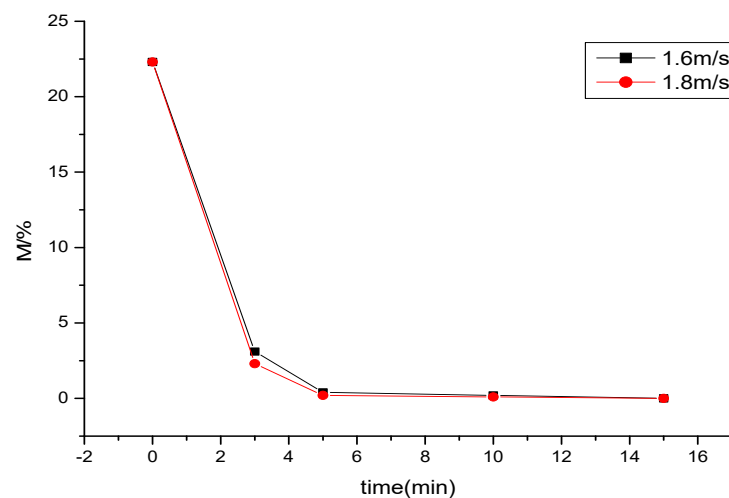
Fig. 3 showed the changes of coal's moisture content under the different temperature of dry gas. It could see that the drying rate obviously increased with drying temperature increasing. When the drying time is 3 min, it didn't reach the expected 5% moisture content of coal only when the drying temperature is 150 °C. But the coal sample at other drying temperatures after 3 min, moisture content is below 5%, and it stepped into a drying speed down stage as the drying time continuing. It still had significant moisture removal at the temperature of 150 °C and 180 °C after 5 min, but it had no obvious change at 210 °C and 240 °C, so it had no practical significance to dry too long time under the two temperature.



**Figure 3.** Drying curves at different drying temperatures

#### 4.3. Influence of Fluidized Wind Speed on Drying Characteristics

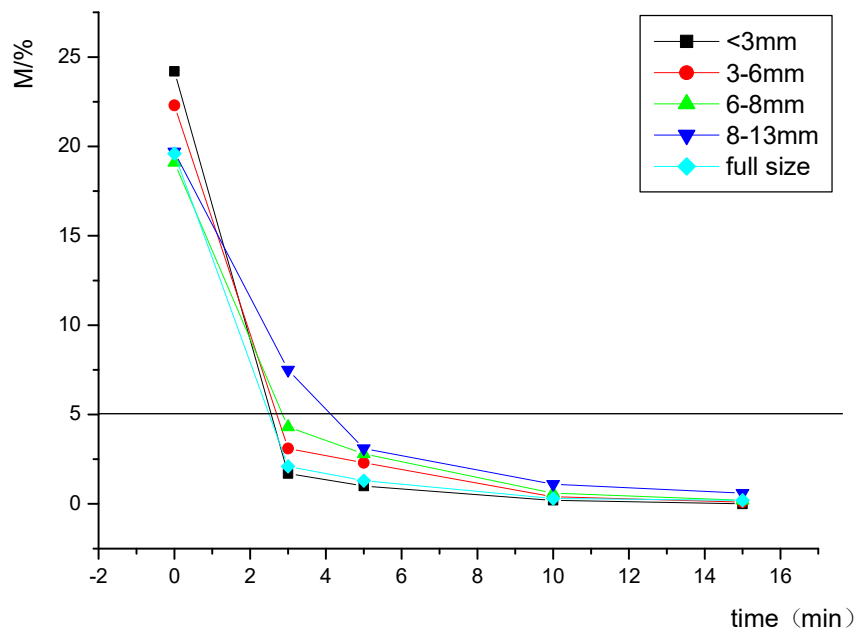
FIG. 4 showed the drying curves under different fluidized wind speeds with other same conditions. Different fluidization wind speeds had little effect on the drying effect with moisture content less than 1% when drying for 3 minutes except that the temperature rose rapidly during the experiment. However, the energy consumption under the high wind speed is higher than that under the low wind speed. Therefore, thinking in terms of the experimental results and energy consumption, the fluidized wind speed was used relatively small fluidized wind speed, and the fluidized wind speed of 1.6m/s is suitable.



**Figure 4.** Drying curves under different fluidized wind speeds

#### 4.4. Influence of Particle Size on Drying Characteristics

Fig. 5 showed moisture content changes of different size of coal samples under the same temperature of dry gas. The experimental data showed that the moisture content of different size was slightly different, which the moisture content of particle size  $< 3$  mm diameter is higher than other size. And under the condition of  $210^{\circ}\text{C}$  and 3 min, moisture content of size  $8 \sim 13$  mm of coal samples had not reached the expected 5%, but the moisture content of other drying temperature after 3 min is below 5%. All coal samples with different particle sizes reached up to standard when the drying time increasing to 5 min. After drying for 10 min, the moisture content of all particle sizes had no changes. The drying process of coal samples with full particle size is basically between those with  $< 3$  mm and those with  $3 \sim 6$  mm, and the results are consistent with particle size distribution.



**Figure 5.** Drying curves of different particle sizes

#### 5. Conclusion

Paper made the drying experiment plan, and studied the influence of sample size, fluidized velocity and temperature on drying characteristics of Yuzhou long-flame coal. The conclusions were as follows: 1) the effect of fluidized drying is better than that of static drying, 2) the drying rate increased significantly with the increase of drying temperature and the decrease of the particle size, 3) the fluidized air velocity had little effect on the drying effect. To apply industrial device, Only considering the moisture removal and no the effects of oxygen containing functional groups removal on pyrolysis, the paper suggested in terms of the experimental conclusion and economy that the drying temperature was  $210^{\circ}\text{C}$ , fluidization wind speed was  $1.6\text{ m/s}$ , and the drying time was 5 min. If considering the effects of oxygen containing functional groups removal on pyrolysis, drying temperature could appropriate the ascent to  $240^{\circ}\text{C} \sim 270^{\circ}\text{C}$ .

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