Study on the Inference Factors of Huangling Coking Coal Pyrolysis

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Abstract. In order to reasonably and efficiently utilize Huangling coking coal resource, coal particle, heating rate, holding time, pyrolysis temperature and others factors were discussed for the influence of those factor on Huangling coking coal pyrolysis products. Several kinds of coal blending for coking experiments were carried out with different kinds of coal such as Huangling coking coal, Xida coal with high ash low sulfur, Xinghuo fat coal with high sulfur, Zhongxingyi coking coal with high sulfur, Hucun lean coal, mixed meager and lean coal. The results shown that the optimal coal particle size distribution was 0.5~1.5mm, the optimal heating rate was 8°C/min, the optimal holding time was 15min, the optimal pyrolysis temperature was 800°C for Huangling coking coal pyrolysis, the tar yield increased from 4.7% to 11.2%. The maximum tar yield of coal blending for coking under the best single factor experiment condition was 10.65% when the proporation of Huangling coking coal was 52%.

1. Introduction
With the rapid development of Chinese economy, the demand for oil and gas resources has increased. The existing oil and gas resource reserves has been difficult to meet the demands of the economic development because China is a rich coal, poor oil, little gas state. To ensure the energy self-sufficiency rate must be to realize the replacement of oil and gas by coal in the coal chemical industry the liquid fuel fields [1,2,3,4]. Tar produced by coal pyrolysis at low temperature is an important raw material for the preparation of liquid fuels, so it is of great significance to study the optimal pyrolysis conditions and increase the conversion rate of coal tar in the coal chemical industry [5,6,7,8]. Since the 18th century, Britain and Germany started to try to build the coal pyrolysis factory for producing lighting lamp oil and civil solid smokeless fuel, coal pyrolysis technology has matured with 200 years developing, coal pyrolysis was taken as a technical way of high efficiency utilization of coal and realized the integrated production of heat, electricity, steam, chemical and oil [9,10,11]. The deference of tar yield of pyrolysis caused by deferent pyrolysis conditions because the types and properties of coal were complex and different kinds of coal were suitable for itself pyrolysis conditions [12,12,13,14]. Huangling coking coal was directly token as fuel and burned can’t play the maximum economic benefits, and result in energy waste. It can be helpful for more reasonable, high efficient utilization of Huangling coking coal resources to determine the best conditions of coal pyrolysis through the study on coal pyrolysis experiment of coking coal in Shaanxi Shanmei Huangling Mining Co.,Ltd.
2. Experiment

Huangling coking coal was taken as research object, several factors effecting the yield of liquid products (tar) of Huangling coking coal pyrolysis were investigated such as coal particle size, pyrolysis temperature, heating rate and holding time, etc. Did experiment of coal blending for coking with Huangling coking coal, Xida coal with high ash low sulfur, Xinghuo coal with high sulfur, Zhongxingyi coking coal with high sulfur, Hucun coal, mixed lean coal to study the effect of the proportion of Huangling coking coal on tar yield and find the optimal proportion of Huangling coking coal.

2.1. Analysis of coal quantity

The experiments of analysis of coal quantity included proximate analysis, elemental analysis, technological characteristics analysis, coal petrogy characteristics analysis. Their results shown in table 1 and 2.

Table 1 Experimental results of coal quality analysis

| Type               | Proximate analysis (%) | Elemental analysis (%) |
|--------------------|------------------------|------------------------|
|                    | Mad | Vad  | Aad  | FCad | C    | H    | O    | N    | S    |
| Hunangling coal    | 3.45| 30.55| 18.65| 47.35| 77.82| 4.85 | 15.33| 3.48 | 0.31 |
| Xingda coal        | 1.49| 25.87| 12.50| 60.15| 76.44| 4.62 | 15.80| 2.83 | 0.31 |
| Xinghuo coal       | 2.57| 24.86| 14.02| 58.56| 75.15| 4.24 | 16.71| 2.48 | 1.06 |
| Zhongxingyi coal   | 1.60| 20.18| 11.15| 67.08| 78.18| 4.09 | 13.32| 2.86 | 1.56 |
| Hucun coal         | 2.09| 15.72| 12.15| 70.05| 83.39| 4.09 | 9.09 | 2.74 | 0.69 |
| Mixed meager lean coal | 1.03| 15.96| 12.22| 70.80| 82.18| 3.93 | 10.91| 2.81 | 0.18 |

Table 2 Experimental results of coal quality analysis

| Type               | Technological characteristics analysis | Coal petrogy characteristics analysis |
|--------------------|----------------------------------------|--------------------------------------|
|                    | calorific value (J/g) | Caking index (%) | Plastometer indices (Y/mm) | Vitrinite (%) | Inertinite (%) | Exinite (%) | Mineral (%) |
| Hunangling coal    | 27402                   | 32.60             | 9                         | 60.37        | 3.23           | 32.28       | 4.12        |
| Xingda coal        | 30914                   | 60.87             | 21                        | 67.24        | 3.78           | 18.77       | 10.21       |
| Xinghuo coal       | 29756                   | 50.39             | 20                        | 71.48        | 0.00           | 26.95       | 1.57        |
| Zhongxingyi coal   | 32326                   | 61.18             | 17                        | 71.05        | 0.00           | 28.31       | 1.01        |
| Hucun coal         | 32517                   | 40.92             | 13                        | 76.54        | 0.85           | 19.56       | 3.05        |
| Mixed meager lean coal | 31998                 | 47.97             | 14                        | 86.21        | 0.67           | 11.01       | 2.11        |

2.2. Single factor experiment

Single factor experiment of coal particle size included 5 kinds of particle size fraction such as -0.15mm,0.15mm~0.5mm,0.5mm~1.0mm,1.0mm~1.5mm,1.5mm~2.5mm, heating rate were set as 6 °C/min,8 °C/min,10 °C/min,12 °C/min,15 °C/min; holding time were set as 10min,15min,20min,25min,30min; pyrolysis temperature were set as 700 °C, 750 °C, 780 °C, 800 °C,840 °C,860 °C.

2.3. Coal blending for coking experiment

There were 5 kinds of experimental schemes for exploring the impact of mixture ratio of coal on coal blending for coking productions in experiment, concrete experimental schemes were shown in table 3.
Table 3 Scheme of coal blending coking

| Scheme number | Huangling coal (%) | Xida coal (%) | Xinhuo Coal (%) | Zhongxinyi Coal (%) | Hucun coal (%) | Mixed lean coal (%) |
|---------------|--------------------|--------------|-----------------|---------------------|---------------|---------------------|
| Scheme 1 (%)  | 42                 | 10           | 6               | 9                   | 18            | 15                  |
| Scheme 2 (%)  | 47                 | 10           | 6               | 9                   | 15            | 13                  |
| Scheme 3 (%)  | 52                 | 8            | 6               | 9                   | 13            | 12                  |
| Scheme 4 (%)  | 57                 | 8            | 6               | 8                   | 10            | 11                  |
| Scheme 5 (%)  | 62                 | 8            | 6               | 6                   | 10            | 8                   |

3. Results and Discussion

3.1. Analysis of the influence of coal particle size on pyrolysis of Huangling coking coal

![Figure 1](image1.png)

Figure 1. The relationship between pyrolysis products and particle size.

We can see from figure 1: tar yield increases first and then decreases and increase again at the particle size >1.5 with the increase of coal particle size. When the coal particle size was 0.5~1.5mm, the tar yield of Huangling coking coal pyrolysis reached the maximum, its value was 8.15%. The fixed carbon content of coke of Huangling coking coal pyrolysis products increased rapidly to higher values and remained stable and then slowly increased with the increase of coal particle size. When the particle size of coal was less than 0.15mm, the fixed carbon content of coke was the lowest, which was 60.09%, the others coke fixed carbon content were nearly to 80% and the difference was great. According to the tar yield and fixed carbon content from the figure 1, the optimal particle size distribution was determined to be 0.5~1.5mm.

3.2. Analysis of the influence of holding time on pyrolysis of Huangling coking coal

We can see from figure 2: tar yield firstly increased to maximum, then decreased to the lowest point, and then increased slightly until reaching a steady trend during the holding time was increased from 10min to 30min. When the holding time was 15 min, the tar yield of Huangling coking coal pyrolysis reached the maximum. Its value was 5.9%. The fixed carbon content of coke of Huangling coking coal pyrolysis products decreased first to lower values and increased slowly. When the holding time was 30 min, the fixed carbon content of coke was the highest, the others coke fixed carbon content were nearly
and little difference. According to the tar yield and fixed carbon content from the figure 2, the optimal holding time was determined to be 15 min.

![Figure 2](image)

**Figure 2.** The relationship between pyrolysis products and holding time.

### 3.3. Analysis of the influence of heating rate on pyrolysis of Huangling coking coal

![Figure 3](image)

**Figure 3.** The relationship between pyrolysis products and heating rate.

We can see from figure 3: tar yield increases first then rapidly down, and then stabilized with the increase of heating rate. When heating rate was greater than 10°C/min, the tar yield was generally low, and the tar yield was greatly different from the tar yield of pyrolysis at a small heating rate. When heating rate was 8°C/min, the tar yield was highest, its value was 11.2%. The fixed carbon content of coke of Huangling coking coal pyrolysis products increased first, then decrease, and then increase again. On the whole, the trend of fixed carbon in coke was relatively stable, floating at 80% up and down. According to the tar yield and fixed carbon content from the figure 3, the optimal heating rate was determined to be 8min°C/min.
3.4. Analysis of the influence of pyrolysis temperature on pyrolysis of Huangling coking coal

![Figure 4](image)

**Figure 4.** The relationship between pyrolysis products and pyrolysis temperature.

We can see from figure 4: At first, tar yield increased slowly, then increased rapidly to the highest point after 750°C, and then decreased until it became stable. When the pyrolysis temperature was 800°C, the tar yield of Huangling coking coal after pyrolysis can reach the maximum, the value is 11.2%. The fixed carbon in coke fluctuates near 80% when the temperature is lower than 800°C, and the carbon content of coke was more than 80% when the pyrolysis temperature was higher than 800°C, and it was a slow increasing trend. According to the tar yield and fixed carbon content from the figure 4, the optimal pyrolysis was determined to be 800°C.

3.5. Analysis of the influence of coal blending proportion on pyrolysis of Huangling coking coal

![Figure 5](image)

**Figure 5.** The relationship between pyrolysis products and the proportion of Huangling coal

We can see from figure 5: The tar yield increased first to the highest point and then decreased with the increase of the proportion of Huangling coking coal from 42% to 62%. When the Huangling coking coal
proportion was 52%, the tar yield of Huangling coking coal after pyrolysis reached the maximum, its value was 10.65%. The fixed carbon content in coke fluctuates decreased first and then increased to its maximum value, then decreased slowly. When the Huangling coking coal proportion was 52%, the maximum fixed carbon in coke, 81.04%. We can see the coal blending scheme 3 (Huangling coking coal ratio is 52%) was the most reasonable in the five kinds of coal blending schemes from the research on the influence of coal blending proportion on coal blending coking.

4. Conclusion
(1) The effects of particle size, holding time, heating rate, pyrolysis temperature on the products of Huangling coking coal pyrolysis were studied by the method of single factor experiment. The results shown that optimal particle size was 0.5~1.5mm, optimal holding time was 15min, optimal heating rate was 8°C/min, optimum pyrolysis temperature was 800°C.

(2) On the basis of the single factor experiment, Coal blending for coking experiment was used to optimize the coal blend proportion of Huangling coking coal. In the case of coke with qualified quality, and the optimal coal blending scheme was scheme ③, which was as follows: Hangling coking coal was 52%, Xida coal was 8%, Xinghuo coal was 6%, Zhongxinyi coal was 9%, Hucun coal was 10%, mixed meager lean coal was 12%.

(3) The tar yield of pyrolysis products can reach 11.2% from 4.7% under the optimal single factor conditions. Among all the influencing factors, heating rate had the greatest influence on the tar yield of pyrolysis products, followed by the coal particle size and pyrolysis temperature, the holding time had some influence on the tar yield of pyrolysis products, but not as significant as the other three factors.

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