Analysis of Lignite Character in Inner Mongolia China

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Abstract. The character of indigenous lignite was measured by proximate analysis, ultimate analysis, coal ash analysis, coal true relative density, specific area et al. The results showed that the internal moisture content is 8-9%, volatile matter content is more than 45%, the oxygen content is above 20% while the sulphur content less than 0.5%. The main ash content is SiO₂ and Al₂O₃, ash fusion point is above 1200 degree centigrade. The calorific value is between 12-19MJ/kg. Macropore and mesopore is the pattern in the lignite.

1. Introduction
The lignite coal regions of Inner Mongolia account for 75% of the total lignite quantity in China [1]. The lignite was formed in the Jurassic era, often be considered as a low rank coal with characteristics between coal and peat, had low calorific value and high moisture content. Its low heating value limits its wide utilization. Now the lignite mainly used in electric power stations near coal mines[2]. The character of the lignite influence the gravity separation performance, combustion, thermal dissolution and so on[3-5].

The purpose of this work is to investigate the chemical composition, physical property and structural characteristics of the lignite. The character of the lignite is the main internal cause that affects combustion and pyrolysis performance.

2. Experimental
Lignite was supplied from Yiminhe(Y),Pingzhuang(P) and Zhalainuoer(Z) coal mine in Inner Mongolia in China. The sample was dried, ground and sieved to make the particle size is less than 75 μm with a 5EPC1×100 pulverizer. The Proximate analysis of the lignite was performed by a 5E-CHN2000 instrument, and ultimate analysis was carried out with a 5E-MAG6700 element analyzer and 5E-IRS3000 sulfur analyzer. A 5E-KCIV calorimeter was utilized to determine the calorific values. Ash fusion point and ash content were analysis by Carbolite ash fusion point determination meter and EDAX Inc XRF. True relative density was analysed by AccuPyc 1330 fully automatic. True density analyzer and the specific surface area was performed by ASAP2020 Specific surface area and aperture tester. IRTracer-100 FTIR was used to determination the functional groups of lignite. The crystalline structure of lignite was tested by XRD-7000.

3. Results and Discussion

3.1. Chemical composition of the lignite
Moisture content data are summarized in table 1. Proximate analyses data, ultimate analyses data and calorific value are briefly summarized in table 2. P and Z data have been provided in our previous research[6]. Ash content and ash fusion point was shown in table 3 and table 4.

As seen in the table, the total moisture content is from 17 to 30 percent, while the internal moisture content is closed to 8-9 percent. High total moisture content makes lignite difficult to be transported[7].

| sample | external water/% | internal water/% | total water/% |
|--------|------------------|------------------|--------------|
| Z      | 21.58            | 8.15             | 29.73        |
| P      | 8.21             | 9.46             | 17.67        |
| Y      | 11.01            | 9.20             | 20.21        |

Table 1. Water content of received basis samples.

| sample | M_ad/% | V_d/% | FC_d/% | A_d/% | Q_net,ar/MJ kg^-1 |
|--------|--------|-------|--------|-------|------------------|
| Z      | 4.90   | 39.92 | 48.29  | 11.78 | 16.84 |
| P      | 6.28   | 32.73 | 45.39  | 21.89 | 18.94 |
| Y      | 8.88   | 37.06 | 47.82  | 15.12 | 17.30 |

Table 2. Proximate analysis and ultimate analysis of the samples.

| sample | C_d/% | H_d/% | O_d/% | N_d/% | S_d/% |
|--------|-------|-------|-------|-------|-------|
| Z      | 63.07 | 3.88  | 20.52 | 0.60  | 0.14  |
| P      | 55.67 | 3.54  | 17.77 | 0.66  | 0.48  |
| Y      | 60.26 | 3.40  | 20.54 | 0.59  | 0.09  |

ad – air dry basis, d – dry basis, M – moisture, VM – volatile matter, FC – fixed carbon, A – ash, Qnet,ar – net calorific value

It can be seen from table 2 that the lignite can be characterized by its low calorific value. High ash content and high moisture make the lignite difficult to be used as power coal, while the sulphur content less than 0.5%. The calorific value of the lignite is in proportion to the fixed carbon content.

Table 3. Ash fusion point of the sample.

| Ash sample | DT | ST | FT |
|------------|----|----|----|
| Z          | 1092| 1202| 1302|
| P          | 1138| 1418| >1500|
| Y          | 1132| 1198| 1248|

Table 4. Ash content.

|                 | Al2O3 | SiO2 | SO3 | K2O | CaO | TiO2 | MnO | Fe2O3 | MgO |
|-----------------|-------|------|-----|-----|-----|------|-----|-------|-----|
| Z               | 10.65 | 52.39| 9.39| 0.30| 21.38| 0.73 | 0.61| 4.13  | 0.42|
| P               | 17.11 | 72.04| 1.38| 2.57| 3.11 | 1.19 | 0.04| 2.37  | 0.19|
| Y               | 6.18  | 62.73| 4.92| 0.15| 18.88| 0.40 | 0.10| 2.45  | 4.19|

Table 3 and table 4 showed that SiO2 is the major ingredient of the ash. The previous research indicated that the ash fusion point values decrease with the increase of SiO2 Mass percentage when the SiO2 Mass percentage value between 45% to 60%, SiO2 plays a role of flux[8,9]. There was no certain
regulations of the SiO₂ Mass percentage value and ash fusion point values when the SiO₂ mass percentage above 60%, while the ash fusion point value was high when the SiO₂ Mass percentage value exceed 70%, that is consistent with the experimental results.

Al₂O₃ content has an effect on ash fusion point value. Al₂O₃ has a solid crystal structure and the fusion point is 2025 ℃. The ash fusion point value goes up regularly with the Al₂O₃ content increased when its content higher 15%.

3.2. Physical characteristics of lignite
True relative density of the lignite was summered in table 5, The specific surface area and aperture were shown in table 6. The adsorption isotherm of lignite was shown in figure 1.

| sample | True relative density (g/cm³) |
|--------|-------------------------------|
| Z      | 1.4082                        |
| P      | 1.4706                        |
| Y      | 1.5280                        |

It is evident from Table 5, the true relative density value is higher than the existing test results, the reason is mechanical crushing make the pore be broke. The true relative density value is related to the porosity, the high true relative density value corresponding to the low porosity.

| sample | BET/m²·g⁻¹ | BJH/nm |
|--------|------------|--------|
| Z      | 2.78       | 40.84  |
| P      | 5.97       | 18.21  |
| Y      | 3.05       | 52.73  |

Figure1. Adsorption-desorption isotherms of the sample.
Dr. Zhao[10] mentioned adsorption isotherms were divided into five types according to the pore distribution, generally the isotherm of coal type belongs to II type. It can be seen from Figure 1 that the line type belonged to III type. That means the major hole pattern in the lignite is mesopore and macropore, the results are agree with table 6.

3.3. Structural characteristics of lignite

FTIR characterizes the surface functional groups of coal. The thermal decomposition products is relationship with the functional groups of coal, the coal pyrolysis is the functional-groups decomposition. X-ray diffraction is an important method to determine crystal structure at present. Organic matter in coal is a substance between crystal and amorphous. The result can represent the arrangement of carbon atoms in coal.

Infrared spectra of lignite was showed in Figure 2. Transmission occurs at the frequency of 3695 cm$^{-1}$ and 3620 cm$^{-1}$ belongs to hydroxy free stretching vibration. There is a wide transmission peak from 3500 cm$^{-1}$ to 3100 cm$^{-1}$, It can be assigned to hydroxyl especially phenolic hydroxyl group. There is a number of hydrogen bond reciprocity because of the associated with the phenolic hydroxyl group, which make the high oxygen-containing groups number. The weak acromion peak at 2900 cm$^{-1}$ and 2870 cm$^{-1}$ is attribute to the stretching vibration of -CH in the alkyl chain, which indicating that aliphatic structure exists in lignite. Peak about 1610 cm$^{-1}$ is the contribution of the C=C bond on the aromatic ring. It is concluded that there are aldehyde and ketone groups in the lignite.

The XRD curve was shown in Figure 3. It can be seen from figure 3, the peak of the curve is wider and irregular, the carbon atoms are randomly arranged in organic molecule of the lignite with low degree of the crystalline and low condensation of aromatic rings.
d002 represents the distance between the aromatic layers, the high value the big of the layer. That means the loose construction of the lignite, the value of d002 was shown in table 7.

![Figure 3. XRD curves of the sample.](image)

Table 7. Structural parameters of microcrystals of the sample.

| sample | diffraction angle/° | d_{002}/nm |
|--------|----------------------|------------|
| Z      | 26.59                | 0.33492    |
| P      | 26.59                | 0.33491    |
| Y      | 26.71                | 0.33341    |

4. Conclusion
The chemical composition and physical properties of lignite were studied to provide theory gist for study combustion and pyrolysis behaviour. Our results showed the following conclusions.

The moisture content is above 30% of the lignite, with high volatile that the value is above 45%. The lignite has the high oxygen content and the low sulphur content. SiO$_2$ is the main component of the ash, the other is Al$_2$O$_3$, which make the ash fusion point value above 1200°C

Particle size of the lignite differ widely, the major hole pattern in the lignite is mesopore and macropore, that make the lignite has the loose construction.

There are more oxygen-containing functional groups in the lignite. Lignite has the low degree of aromatization and carbon atoms in organic molecules are disorder.

The directions of our future study will focus on emission rules of combustion pollutants related with the character of the lignite.

5. References
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