INVESTIGATION ON PYROLYSIS OF ADUUNCHULUUN COAL

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Abstract

The generated products of heating of coal in airless condition are hard residue, condensed liquid, and gas. The condensed liquid product or tar is one of the most important product of pyrolysis. Therefore, a detailed investigation of the pyrolysis of brown coal and its tar studies provides basic theoretical knowledge for further thermal processing and application of coal. Have been determined the main technical characteristics and elemental composition of the analytical sample of Aduunchuluun coal. The pyrolysis experiments were performed at various heating temperatures (550-600°C) and determined the yields of pyrolysis products. The optimal heating temperature of pyrolysis of Aduunchuluun coal was chosen 500°C in which the yield of tar was higher (32%).

Introduction

Coal is an organic sedimentary rock that is formed from the accumulation and preservation of plant materials, usually in a swampy environment [1]. Coal is one of the most important energy sources, especially for power generation and the global coal demand is projected to grow further in the next years [2]. Apart from coal as primary energy fuel, different products such as metallurgical coke, coal tar, and synthetic gases can be derived and manufactured from coal, which represent an important feedstock for chemical industry. Converting coal into oil and gas allows coal to be utilised as an alternative fuel, which will affect the national safety and the economic sustainable development. Among the operating factors for coal pyrolysis, the temperature, pressure, and type of catalysts are used to play important roles on the product composition. Typical pyrolysis products of raw coal are generated primarily through the decomposition of aliphatic side chains, oxygen functional groups, and low-molecular-weight compounds [3]. Compared to oil and natural gas, coal resources are more evenly distributed worldwide and often readily accessible, e.g., by surface mining [2]. Mongolia is among the 10 coal rich countries in the world with the 175 billion tons of geologically estimated coal resources including high quality bituminous coking coals, subbituminous coals and lignite brown coals. More than 70% of this coal resources belongs to the brown coals [4].

Methods And Materials

The analytical coal samples of Aduunchuluun deposit were prepared for analysis according to ASTM D 2797. The main technical characteristics such as proximate and ultimate analysis were performed according to Mongolian National Standards **MNS 656-79 (moisture content), MNS 652-79 (ash yield), MNS 654-79 (volatile matter yield), MNS 669-87 (gross calorific value),** and **MNS 895-79 (sulfur content)**.

For the determination of mineral content in Aduunchuluun coal has been obtained completely burned ashes, slowly and continuously at range of 500-600°C in furnace. The content of mineral elements in coal samples and their oxides have been determined by using of X-ray fluorescence spectrometry.

The method of pyrolysis: The small-scale pyrolysis experiments were performed in a laboratory quarts retort (tube). The retort was placed in a horizontal electric tube furnace with a maximum heating temperature of 950°C

IR spectroscopy: The infrared spectroscopy (IR) spectra of the samples were obtained on a Bruker, Alpha II IR spectrometers. All the spectra were measured in the frequency range of 4000 to 400 cm-1, and 32 scans were taken per sample.

GC/MS spectrometry analysis:

Used apparatus: Agilent 7890A Agilent 5975C GCMS system and capillary column J&W DB-5,30mx, 0.25mm I.D. 0.25µm (122-5032), Carrier gas: He, Mass range: 50-550, -Starting temperature of furnace: 100°C, Heating temperature and time: 220°C and 46 min, respectively.

Results

The results of proximate and ultimate analysis of coal samples of Aduunchuluun deposit are shown in Table 1.

TABLE 1. Proximate and ultimate analyses of Aduunchuluun coal.

Sample	Proximate analysis, %				Ultimate analysis, %			
	W^a	A^d	V^{daf}	Q^{daf}, kcal/kg	C^{daf}	H^{daf}	St	,(N+O)^{daf}
coal	20.16	13.54	48.00	6362.60	66.75	4.93	2.22	27.65

TABLE 2. The content of different type of sulphur in the coal sample of Aduunchuluun coal.

Type of sample	Sulfate sulfur, S^a_{SO4}, %	Pyrite sulfur, S^a_s, %	Organic sulfur, S^a_{org}, %	Total sulfur, S^a_{total}, %
Coal	0.155	0.72	1.325	2.22

TABLE 3. Chemical composition of coal ash from the Aduunchuluun deposit, wt %.

Na_2O	MgO	Al_2O_3	SiO_2	SO_3	K_2O	CaO	Mn_2O_3	Fe_2O_3	TiO_2	SrO
0.71	10.98	5.04	7.39	39.45	0.21	28.87	0.53	6.15	0.37	0.30

TABLE 4. The content of the radioactive element.

No	Sample	Isotop content, Bk/kg				Elemental content			Ra-equivalent, Bk/kg
		Ra-226	Th-232	K-40	^{137}Cs	U, g/ton	Th, g/ton	K, %	
1.	Coal	9284	3	<29	<1.1	760.4	0.6	<0.1	9278
2.	Ash	59	<1.3	<29	<1.1	4.8	<0.3	<0.1	52

TABLE 5. The yields of pyrolysis products vs different heating temperatures.

Temperatures, °C	Time, min	Hard residue, %	Tar, %	Pyrolysis water, %	Gas,%
200	80	81.74	-	16.16	2.10
300	80	78.41	0.73	18.05	2.81
400	80	65.09	1.87	23.20	10.84
500	80	64.25	1.91	21.74	12.10
600	80	52.31	2.73	22.50	22.46
700	80	52.52	2.01	21.65	23.82

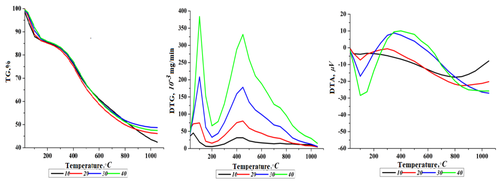

FIGURE 1. The thermogravimetric analysis of the Aduunchuluun coal.

TABLE 6. The yields of pyrolysis tar of Aduunchuluun coal.

Boiling temperature range , °C	Yield fraction, %	Refractive index	Color	Description
boiling starts at 180°C	11.82	1.511	yellow	light fractions
180-330°C	26.59	1.533	brown	middle fractions
More than 330°C	56.13	-	Black-brown	heavy fractions
loss	5.46	-	-	-

TABLE 7. The results of the GC / MS analysis of neutral oil in coal tar.

Aliphatic groups		
Identified compounds		content, %
Alkanes C_9 –C_{28}		10.741
Cycloalkanes C_9 – C_{17}		5.749
Alkenes C_9-C_{14}		11.791
Aromatic groups		
1 cyclo aromatics	Benzene, their derivatives	51.89
2 cyclo aromatics	Naphthalene, their derivatives	33.463
heteroatom aromatic compounds		9.613
Polar groups		
Alcohols		12.57
Others		2.5

Discussion

Shown from Table 1, the content of volatile matter, the ratio of H/C=0.88, carbon and oxygen content indicate that coal from Aduunchuluun deposit is a low rank B2 (ISO 11760) brown coal.

Organic sulfur with a higher content than other types of sulfur, which has a negative effect on energy fuel and enrichment, and may positively affect catalysis for the liquefaction process.

The tar product of Aduunchuluun coal consists of mainly aliphatic, aromatic, and aromatic-aliphatic, phenols and esters compounds with functional groups in their molecules.

Conclusions

The results of pyrolysis experiment of Aduunchuluun coal show that 52.3% of coal organic masses remained as a hard residue after pyrolysis. The yield of all liquid and gas products is 47.7 % at the optimal heating temperature of 600°C, which is showing that there was an intensive thermal decomposition of the coal organic mass with higher degree of conversion.

The determined chemical composition of pyrolysis tar in group organic compounds by chemical analysis shows that the tar consists mostly neutral oils with highest content of 76.78%, asphalteines 5%, and free carbons 16.65% and organic bases, organic acids, and phenolic compounds were less than 1.57%.

Totally 101 compounds in coal tar were determined using GS/MS analytical method. Among them, there are 39 types of aliphatic hydrocarbons that accounts for 28.28% of the coal tar, and 48 types of aromatics hydrocarbon compounds, which accounts for 94.96% such as benzene, naphthalene, and their derivatives.

Future Directions

The thermal decomposition of the coal can generate a lot of tar, decomposition water, and gases, and it is considered suitable for deep processing of this type of coal.

The solid product (hard residue) after the pyrolysis Aduunchuluun coal is one of the main products and can be used as smokeless fuel and activated carbon after briquetting and activation.

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References

1. James G. Speight. The Chemistry and Technology of Coal. Third edition. CRC Press. p.1-8
2. IEA, Medium-term Coal Market Report 2013. International Energy Agency, Paris, France (2013).
3. Hong B., X. Wang, Z. Zhou and G. Yu, A comparison of the gas-product-release characteristics from coal pyrolysis and hydrogasification. Energy Technol., 1(8), p449-456 (2013).
4. Purevsuren B., Davaajav Ya., Erdenechimeg R. (2010) Investigation on largest coal deposits in Mongolia. *Monograph,* Toonotprint., p.212.
5. Purevsuren B. (2007) Coal is the main source of energy. *In Abstracts of papers*, Second Korean and Mongolian Energy Conference, Yonsei University, Seoul, 13.
6. Monkhoobor D., Batchimeg G (2009). "Molecular structure and spectroscopy" Ulaanbaatar.
7. Gerbish Sh., Dalkhsuren B., Norov H. (1988) Study of coal mineral composition by gamma activation method. ICCT, MAS. Organic matter research. Ulaanbaatar
8. Zoljargal J. MAK CTL Project in Mongolia, World Clean Coal Conference, Mongolia (2014) Conference Proceedings in UB.

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