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Evaluation on Pyrolysis and Mild Oxidation Characteristics of Tar-rich Coal

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ABSTRACT

The tar-rich coal is not only coal, but also a kind of coal-based oil and gas resources. If the pyrolysis technology and scale application are broken through, the abundant oil resource derived from tar-rich coal can be obtained. The underground in-situ pyrolysis technology of tar-rich coal has been proposed lately. Through this technology, the oil-gas resources with in tar-rich coal are preferentially extracted without environmental pollution and excessive semi-coke production. Here, the pyrolysis and mild oxidation characteristics of tar-rich coal were firstly evaluated using thermogravimetric analysis.

Keywords: tar-rich coal, oil-gas resource, underground in-situ pyrolysis, semi-coke, CO_2 reduction

NOMENCLATURES

Abbreviations	
DTG	Differential Thermogravimetric
TG	Thermogravimetric
ad	air-dried basis
d	dry basis
daf	dry ash-free basis
Symbols	
A	Ash
C	Carbon
FC	Fixed carbon
H	Hydrogen
M	Moisture
N	Nitrogen
O	Oxygen
V	Volatile matter

1. INTRODUCTION

The tar-rich coal is known as a coal with tar yield of 7-12% (7% < Tar_d <12%), which is not only coal, but also a kind of coal-based oil-gas resources. Coal can be classified into tar-containing coal (Tar_d <7%), tar-rich coal (7% < Tar_d <12%), and tar-high coal (Tar_d >12%) [1]. In five provinces of Northwest China, over 500 billion tons of tar-rich coal are verified, as shown in Fig. 1. If the tar-rich coal is appropriately exploited and utilized, numerous oil resource can be derived, which is extremely important for China without sufficient conventional oil resources.

Oil can be produced from traditional coal-to-liquids (CTL) technologies above the ground, such as direct coal liquefaction and indirect coal liquefaction [2-5]. However, the well-known CTL technology on ground brings about serious environmental pollution and excessive semi-coke production, such as particle matter emission, gaseous emission, and coking wastewater, which cannot satisfy the requirement of energy security and carbon neutrality nowadays.

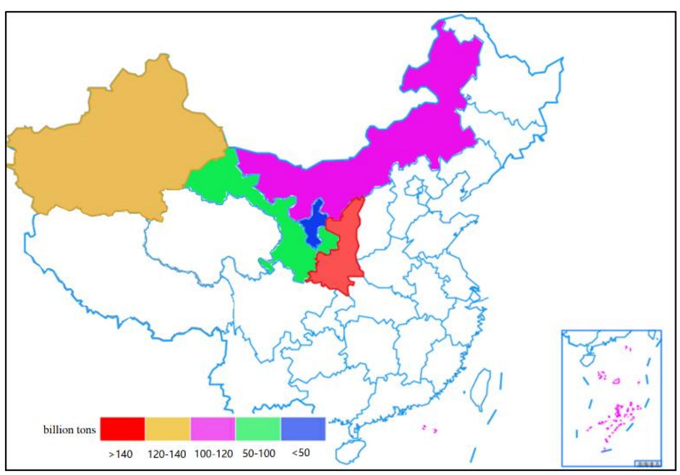

Fig. 1. The distribution of main tar-rich coal in China

Consequently, the underground in-situ pyrolysis technology of tar-rich coal has been proposed lately. Without exploitation, the tar-rich coal is heated and pyrolyzed underground through heat carrier medium, and then the oil-gas production is transported to ground followed by the subsequent separation and further processing. This new technology for tar-rich coal has advantages of environment-friendly, sustainability, and carbon reduction etc., while challenges are still encountered due to the extremely different conditions between ground and underground, such as high-pressure, ununiform of coal seam, wide scale, difficulty of effective heat transfer, and precise temperature control underground. The underground in-situ pyrolysis technology has been extensively used on exploitation of oil shale [6-9], while little work has been conducted on tar-rich coal. The properties of tar-rich coal differ greatly from those of oil shale, and thus specific study on tar-rich coal is necessary. Here, the pyrolysis characteristics and mild oxidation with limited oxygen of tar-rich coal were firstly evaluated using thermogravimetric analysis.

2. EXPERIMENTAL

2.1 Samples

Firstly, the tar-rich coal samples were exploited from North in Shaanxi Provence of China. Nine samples from the identical coal mine were analyzed to demonstrate the chemical properties of representative tar-rich coal. Figure 2 depicts the proximate and ultimate analyses of tar-rich coal samples. The V_{daf} content is between 31% and 39% with an average value of ~35%, with limited ash and moisture, which is known as a kind of superior low-rank coals. The production distribution of tar-rich coal at low temperature carbonization is shown in Fig. 3. The tar yield on air-dried basis ranges from 6.8% to 9.5% with an average of 8.1%. While the tar yield of dry basis is even higher and averages 9.4%. The in-situ pyrolysis of tar-rich coal leaves the majority of semi-coke underground.

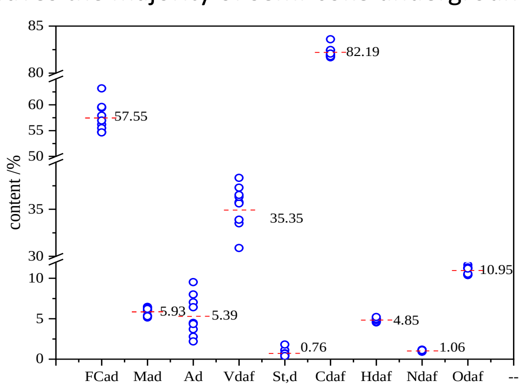

Fig. 2. Proximate and ultimate analyses of tar-rich coals

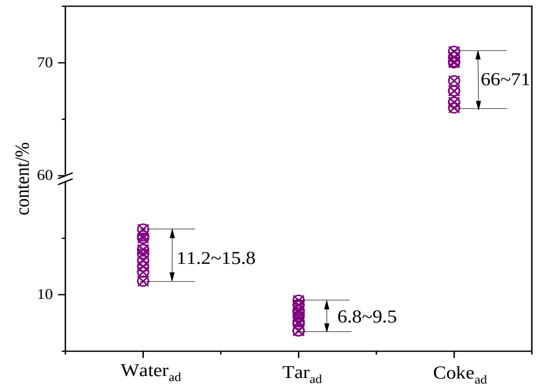

Fig. 3. The production distribution of tar-rich coal at low temperature carbonization

2.2 Experimental method

Thermogravimetric experiments were conducted using a Setaram simultaneous thermal analyzer (Labsys Evo) and Al_2O_3 crucible with a volume of 90 μm, which has been extensively employed in previous studies on solid fuels [10, 11]. The influences of pyrolysis atmosphere (N_2 and CO_2), limited oxygen (simulating the mild oxidation process), heating temperature, and heating rate were experimentally studied, respectively.

3. RESULTS AND DISCUSSION

During the in-situ pyrolysis of tar-rich coal, the control of temperature is of great significance. Hence, the effect of pyrolysis temperature in N_2 atmosphere was firstly investigated, as illustrated in Fig. 4 and Fig. 5. As depicted in Fig. 4, with the elevation of temperature, the dehydration sub-process is firstly proceeded at low temperature, followed by the discharge of volatile matter, including gaseous phase and oil component, which begins above 300 °C and reaches peak between 400~500 °C.

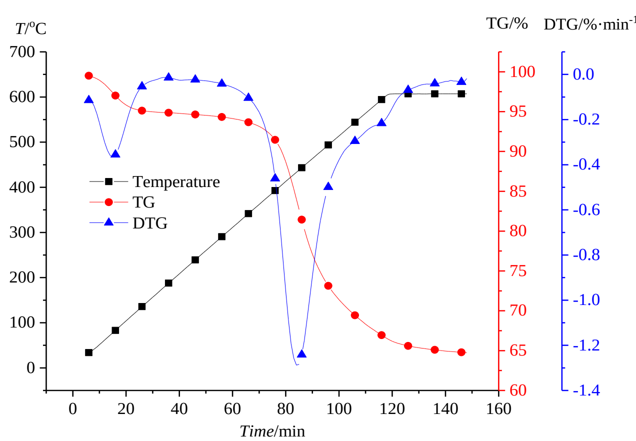

Fig. 4. The thermal reactivity of tar-rich coal in N_2 atmosphere at a final duration temperature of 600 °C

With a rise of pyrolysis temperature, more volatile matter is discharge with less solid residue left. If the temperature is elevated, it is easier to reach the unchanging mass condition with the duration of final heating temperature. In addition, the effects of limited oxygen on mass loss behaviors during pyrolysis of tar-rich coal were also further explored.

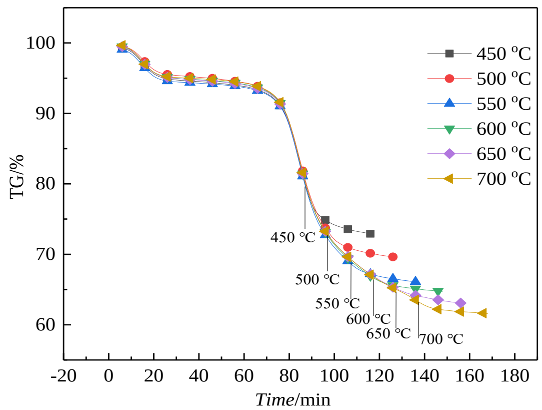

Fig. 5. The influences of pyrolysis tempeature on mass loss of tar-rich coal

4. CONCLUSION

The pyrolysis and mild oxidation behaviors of tar-rich coal were evaluated using thermogravimetric analysis. The pyrolysis behaviors are greatly temperature dependence. Higher temperature results in less solid residue but more volatile release. It should be noted that oil component perhaps further decomposes into gaseous phase at excessive high temperature. The existence of oxygen promotes the thermogravimetric process and can offer certain heat for in-situ pyrolysis, but the precise control of proceeding extent is a great challenge especially under complex underground conditions.

The distributions of gaseous, tar, and solid derived from pyrolysis of tar-rich coal are need to further explored, especially the yield and properties of the coal-based oil with the variation of in-situ pyrolysis conditions. In addition, the underground pressure and complex heating case should be simulated in experiments to evaluate the technique feasibility and determine the optimal industrial parameters.

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