



Research paper

An investigation of the evaporation behavior of bioliquid in the pores and its application to hybrid coal combining biomass with coal



Jong-Soo Bae ^a, Dong-Wook Lee ^b, Young-Joo Lee ^a, Se-Joon Park ^a, Ju-Hyoung Park ^{a, d}, Joeng-Geun Kim ^c, Choon Han ^d, Young-Chan Choi ^{a, *}

^a Clean Fuel Laboratory, Climate Change Research Division, Korea Institute of Energy Research (KIER), Republic of Korea

^b Advanced Materials and Devices Laboratory, Energy Materials and Process Research Division, Korea Institute of Energy Research (KIER), Republic of Korea

^c Energy Saving Laboratory, Energy Efficiency Research Division, Korea Institute of Energy Research (KIER), Republic of Korea

^d Department of Chemical Engineering, Kwangjuon University, 447-1, Wolgye-dong, Nowon-gu, Republic of Korea

HIGHLIGHTS

- Evaporation temperature variation was investigated in silica and activated carbon pores.
- Evaporation temperature of hydrophilic bioliquid increased in silica pore.
- Most pores of the coal originated from ash, such as silica.
- Only evaporation temperature of hydrophilic bioliquid increased in the coal pores.

ARTICLE INFO

Article history:

Received 17 November 2014

Accepted 25 March 2015

Available online 2 April 2015

Keywords:

Hybrid coal

Evaporation temperature

Glycerol

Palm oil residue

ABSTRACT

In this study, the evaporation temperature behaviors of various liquids in silica and activated carbon pores were investigated, and applicability of bioliquid in coal pores was reported. In countries around the world, to reduce the potential carbon dioxide, solid phase biomasses, such as wood chips and pellets, have been mixed with coal to make fuel for coal-fired power plants. However, the liquid phase biomass (bioliquid) has a phase different from coal in atmospheric conditions and evaporates at a relatively low temperature. As a result, it has been difficult to use biomass in the existing coal-fired power plants due to a number of problems, such as fuel injection, the reduction of combustion efficiency in coal, spontaneous combustion, and the risk of explosion during drying. To address these challenges, evaporation behaviors of bioliquids were evaluated using silica and activated carbon that have various pores and surface characteristics. The impregnation of bioliquids was accelerated on a support that had the same hydrophilic or hydrophobic characteristics, and the evaporation temperature increased at the hydrophilic surfaces or in small pores. In addition, evaporation behaviors were assessed by filling bioliquids into coal pores that originated from ash and fixed carbon. These results increase understanding of coal pore characteristics and will enable better choices of bioliquids that can be used together with coal in the existing coal-fired power plants.

© 2015 Published by Elsevier Ltd.

1. Introduction

As oil price hikes and instability of nuclear power plants have persisted recently, the volume of coal in use has been on a constant rise due to a relatively smooth supply and fewer problems arising from its use [1,2]. However, the continued use of coal in coal-fired

power plants for energy generation will constantly increase the emissions of carbon dioxide and other pollutants and ultimately accelerate global warming [3,4]. To solve these problems, many countries around the world are recommending blending biomass and coal for co-combustion by means of regulations such as a Renewable Portfolio Standard (RPS) and the emission trading scheme (ETS) [5,6]. Consequently, woody biomass in the solid phase, such as wood chips and pellets, are most used as a fuel for co-combustion [7,8]. However, co-combustion from woody biomass and coal gives rise to two serious problems. First, due to

* Corresponding author.

E-mail address: youngchan@kier.re.kr (Y.-C. Choi).

Nomenclature

D	average pore diameter, nm
S.A. _{BET}	BET surface area, m ² /g,
S.A. _{me}	mesopore surface area, m ² /g
S.A. _{mi}	micropore surface area, m ² /g
V _{tot}	total pore volume, cm ³ /g
V _{mi}	micropore volume, cm ³ /g
xD	dried x coal,
x-ash	ash from x coal

Abbreviation

A.C.	activated carbon
BET	Brunauer–Emmett–Teller
BJH	Barrett–Joyner–Halenda
ETS	emission trading scheme
FTIR	Fourier transform infrared spectroscopy
ICP–AES	inductively coupled plasma–atomic emission spectroscopy
KDCC	Kideco coal
RPS	renewable portfolio standard
SOC	Shievee Ovoo coal
TEOS	tetraethyl orthosilicate
TGA	thermal gravimetric analysis

the low density of woody biomass, the heating value per unit volume of blending fuel falls to a significantly low level [9]. Second, coal and woody biomass become ignited in different temperature zones, and the high combustion efficiency of wood might hinder the combustion of coal when a certain level of heat is applied [10]. Therefore, it is necessary to find measures to prevent such problems when these materials are used in the existing coal-fired power plants, and to develop technologies to apply not to only solid-phase biomass but also to only liquid-phase biomass for the diversification of biomass.

In a previous study, glycerol-impregnated hybrid coal was developed by impregnating glycerol into coal pores and thereby reconstructing glycerol to have the characteristics of the artificial volatile matter of coal [11]. That study suggested a method of shifting evaporation temperature of glycerol, which usually evaporates at a temperature below 200 °C, to the combustion zone of coal, thereby allowing for co-combustion of glycerol and coal in the existing coal-fired power plants. In this context, researchs behind the alteration of glycerol must be conducted. Based on the revealed mechanism, it is vital to investigate evaporation variations of glycerol and many other bioliquids, and then assess the applicability of its use with coal. However, to the best of our knowledge, no study has been conducted on the impregnation efficiency of liquid materials in pores and their evaporation temperature variations.

Simply blending coal with bioliquids such as glycerol and palm oil residue for co-combustion causes problems in injecting fuel because bioliquids coat the coal surface and coal particles form an aggregation in pulverized-coal power plants. Furthermore, most bioliquids evaporate at a temperature lower than the coal combustion zone, which impedes the combustion of coal. Therefore, in this study, evaporation temperature variations were investigated by introducing a variety of hydrophilic and hydrophobic bioliquids into supports such as silica and activated carbon that have different pore properties and surface characteristics. Since most bioliquids evaporate at a temperature below 200 °C, it has been difficult to combust with coal. However, investigating the mechanism of variations in evaporation temperature of bioliquids, as conducted in

this study, will make it possible to blend bioliquids and coal with different phases and use them in the existing coal-fired power plants.

2. Experimental

2.1. Preparation of porous silica and activated carbon

To evaluate the evaporation temperature of various liquids in the pores, porous silica was synthesized as in reported previous studies [12]. To prepare the silica sol, a precursor (tetraethyl orthosilicate, TEOS) was added to the ethanol as a co-solvent, and then the mixture was stirred vigorously for 10 min. Subsequently, ammonia was dissolved in distilled water, and that mixture was dropped into the mixture of TEOS and ethanol, which was then stirred at 450 rpm and 50 °C for 3 h. From the silica sol, the pore properties of the silica could be controlled by changing the ratio of sucrose as a pore-forming agent. Different weight of sucrose template were added and mixed in each solution, and then the silica-sucrose solution was aged at 100 °C for 3 h to remove the solvent and obtain the precipitate. Finally, porous silica was synthesized after the silica-sucrose composite was calcined at 550 °C for 2 h. To evaluate the evaporation temperature in pores with various pore size distributions, this study obtained not only synthesized silica, but also commercial silica. In addition, activated carbon was also used as a support to compare the characteristics in hydrophilic and hydrophobic pores.

2.2. Preparation of porous materials impregnated with bioliquid

To evaluate the evaporation characteristics of the bioliquid in the pores, various bioliquids were employed: soy bean oil, rapeseed oil, palm oil and palm oil residue, glycerol and molasses. For the various porous materials impregnated with bioliquid, a 10 wt% bioliquid dissolved solution was prepared by determining the water volume permeating through the silica and activated carbon, and various porous materials were impregnated with the bioliquid solution. Finally, the porous materials impregnated with bioliquid were dried at 105 °C to remove the water and improve the diffusion of the bioliquid in the pores. To apply and confirm the evaporation characteristics of the bioliquid in the coal pores, Indonesian Kideco coal (KDCC) and Shievee Ovoo coal (SOC) were impregnated with typical bioliquids, glycerol and palm oil residue. The as-received lump coals were pulverized with a jaw crusher for coarse crushing and a pin mill type crusher for fine grinding to sort coal particles smaller than 75 μm. Bioliquid was impregnated in coal pores by the same method when preparing the silica and activated carbon impregnated with bioliquid.

2.3. Characterization

To evaluate the evaporation characteristics, this study conducted thermal gravimetric analysis (TGA), nitrogen sorption tests, Fourier transform infrared spectroscopy (FTIR), proximate analysis, elemental analysis, calorimetric analysis and ash component analysis. The evaporation characteristics were determined by TG/DTG at a heating rate of 10 °C/min and 100 ml/min of air with a TGA Q500. Before the TG/DTG test, all samples were dried at 100 °C for 2 h, and then 10 mg of the sample were sorted. To observe the pore properties, nitrogen sorption tests were carried out using a Micromeritics ASAP 2020. Before the nitrogen sorption tests, all the samples were degassed for 7 h at 100 °C to empty the pores. The surface area was calculated from the slope and intercept of the BET equation, and the mesopore surface area was obtained from the slope of the t-plot. The single point total pore volume was taken

Download English Version:

<https://daneshyari.com/en/article/7048826>

Download Persian Version:

<https://daneshyari.com/article/7048826>

[Daneshyari.com](https://daneshyari.com)