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Enhancement of slurryability and heating value of coal water slurry (CWS) by torrefaction treatment of low rank coal (LRC)

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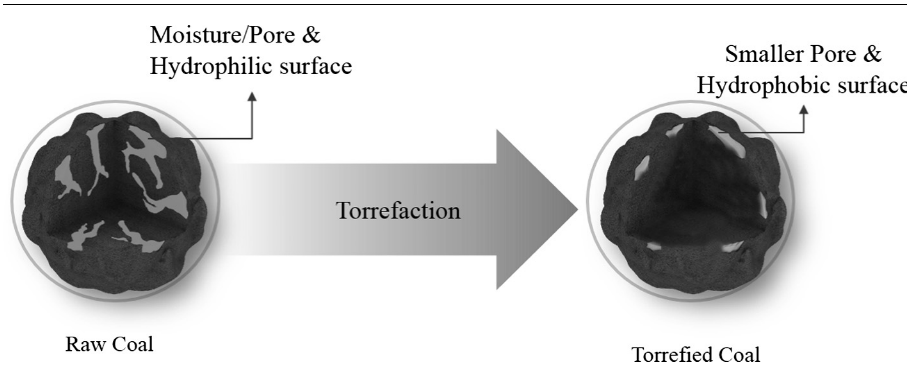
HIGHLIGHTS

- VM was partly removed, and FC content and calorific value increase through torrefaction.
- Coal surface turned hydrophobic and pore volume decreased through torrefaction.
- Torrefaction inhibits water reabsorption and reduces the water filled in void volume.
- Torrefaction of LRC was conducted to prepare CWS with a higher coal content.

GRAPHICAL ABSTRACT



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ABSTRACT

To improve cold gas efficiency of entrained-flow gasification, coal water slurry (CWS) as a fuel must have high heating value at low viscosity. Especially, considering unstable supply of bituminous coal, the preparation of CWS with high coal content from low-rank coal remains a challenging topic. In this study, we report a remarkable improvement in coal content of CWS at low viscosity (1000 cP) through torrefaction of low-rank coal. Compared to dried coal (moisture-free coal), the torrefaction of low-rank coal leads to an improvement in hydrophobic nature of coal surface and a decrease in coal porosity. The moisture readsorption ratio of the torrefied low-rank coal significantly decreases due to its high hydrophobic nature and low porosity. As a result, Kideco coal showed a 6% and 58.7% increase in the coal content and heating value of CWS after torrefaction at 300 °C in comparison to those of CWS made with dried coal. Ultimately, the torrefied coal-based CWS with enhanced coal content and heating value at low viscosity is expected to contribute to an increase in the efficiency of a gasifier and IGCC process.

1. Introduction

Coal still accounts for about 40% of fuel for global electricity generation, although coal-fired power plants emit huge amounts of greenhouse gases (GHGs) and air pollutants, such as particulate

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matter, nitrogen oxides, and sulfur oxides [1]. Thus Integrated Gasification Combined Cycle (IGCC) attracts great attention because it is a promising coal utilization technology to replace coal-fired power plants in the future, which can contribute to reducing the emissions of GHGs as well as primary and secondary air pollutants [2]. IGCC is a technology which uses an entrained flow gasifier to turn coal-based fuel into synthetic gas mainly composed of hydrogen and carbon monoxide at high temperature and under high pressure, and then electricity is generated from a gas turbine and steam turbine [3,4]. The entrained flow gasifier uses coal water slurry (CWS) as a fuel, which is a mixture of pulverized coal, water, and small amounts of surfactants and stabilizers.

To improve cold gas efficiency of gasification simultaneously with well atomization of CWS, CWS must have high heating value and low viscosity simultaneously [5]. Therefore, it is a challenging topic to maximize the coal content of CWS while maintaining low viscosity [6]. The best way to maximize the coal content of CWS at low viscosity is to employ high-rank coal such as bituminous coal, however bituminous coal supply is unstable, resulting in undesirable utilization of low-rank coal like sub-bituminous coal and lignite as an alternative. However, it is difficult to prepare CWS of high coal content by using low-rank coal, because of its high moisture and ash content, and large porosity. In addition, it is very difficult to ignite low rank coal-based CWS (low coal content and

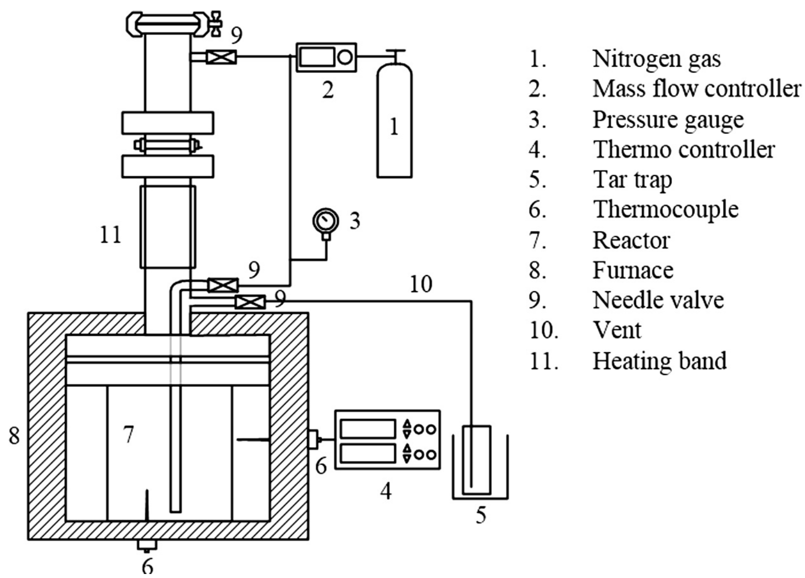

Fig. 1. Schematic diagram of torrefaction setup.

Table 1
Proximate analysis results and calorific value of raw and torrefied coal samples.

Sample	Proximate analysis (As received basis, wt%)				HHV	LHV	ACV	NCV
	Moisture	Volatile Matter	Ash	Fixed Carbon	[kcal/kg]			
BC-R	10.55	43.16	7.42	38.87	6200	5834	5546	5227
BC-200	0.77	42.45	6.63	50.15	6230	5968	6182	5934
BC-300	0.61	38.98	7.26	53.15	6370	6120	6331	6094
KC-R	16.91	45.18	7.00	30.91	5450	5083	4528	4221
KC-200	0.61	45.05	7.29	47.05	6180	5954	6142	5928
KC-300	0.60	39.36	7.55	52.49	6270	6068	6232	6041
RC-R	14.50	45.96	7.10	32.44	5710	5362	4882	4585
RC-200	0.42	45.07	7.46	47.05	6110	5889	6084	5874
RC-300	0.48	41.15	7.97	50.40	6250	6038	6220	6019

(HHV: Higher heating value, LHV: Lower heating value = HHV − 600 * {(9 * H + M)/100}, ACV: As-received calorific value = {HHV * (100 − M)}/100, NCV: Net calorific value = ACV − 5.72 * [{H * (100 − M)/100} + 0.1119 * M] * 9).

Table 2
Ultimate analysis results of raw and torrefied coal samples.

Sample	Ultimate analysis (dry basis, wt%)				
	C	H	N	O	S
BC-R	64.60	5.61	1.81	26.91	1.07
BC-200	71.40	4.77	1.25	21.54	1.04
BC-300	72.45	4.57	1.09	20.87	1.02
KC-R	68.15	4.92	1.33	25.43	0.17
KC-200	69.65	4.11	1.27	24.71	0.26
KC-300	70.95	3.67	1.29	23.96	0.13
RC-R	63.00	4.84	1.70	30.22	0.24
RC-200	68.70	4.05	1.19	25.88	0.18
RC-300	69.55	3.87	1.14	25.32	0.12