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# Combustion possibility of low rank Russian peat as a blended fuel of pulverized coal fired power plant

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ABSTRACT

Combustion possibility of Russian peat as a blended fuel of commercial thermal power plant was investigated by thermogravimetric analysis (TGA), drop tube furnace (DTF) and ignition temperature (IT) tester. TGA results showed that the linear regression for the Arrhenius plot to the experimental data is very good, and activation energies for overall combustion of bituminous C & A (Coal & Allied, Australia coal name) and peat are 66.83 and 25.05 kJ/mol, respectively. It was derived that activation energies of 30%, and 50% blends produced through mixing of peat of 30%, and 50% to Design C & A (design criteria coal of 500 M coal fired power plant) are 27.76 and 24.22 kJ/mol in reciprocal proportion to blending ratio. The conversion behavior of the samples observed in DTF was similar to that reflected in TGA. DTF studies showed that the combustion of all blends was also completed at residence time of around 1 s, set temperature range of 1200 °C similar to commercial coal fired plant. Although the peat has the highest conversion than the blends, it was not appropriate as the single pulverized fuel of coal fired plant because its initial deformation (IDT) and ignition temperatures of about 1160 and 240 °C, respectively, were too low to cause the slagging in boiler, and the firing at pulverizer. The IDT and FT of the blends ashes of peat of less than 30% was about 1260 and 1410 °C, respectively, and was not expected to be associated with slagging and fouling in pulverized coal fired systems. The liability of spontaneous combustion of coal samples was increased with increasing the moisture and volatile contents whereas the same of peat was the lowest due to the high volatile content and specific heat (*Cp*). It was therefore proposed that the combustion of blends of peat with less than 30% was the most appropriate for the prevention of slagging and spontaneous combustion at the pulverized coal fired boilers, and has the excellent combustion efficiency.


## 1. Introduction

Peat is a combustible fossil formed through natural atrophy and incomplete disintegration of dead plants under excess humidity and limited air supply conditions. Peat is the product of the first stage of coal forming process and used as fuel, raw materials for chemical industry [1]. Use of peat fuel therefore provides additional and cumulative economic benefits. Peat is an economically better fuel than wood fibers. Peat fuel can be used directly as a substitute for coal in power generating stations [2]. Peat fuel has many environmental and economic benefits, such as low sulphur content, minimal mercury content, low ash content, energy values equivalent to coal, less expensive than oil and natural gas and price competitive with other biofuels, minor engineering retrofit needed when substituted for, or blended with, coal.

Russia is geographically near to Korea and Russian peats were distributed in about 0.6 million square kilometer (3% of the Russia's land area, 1.6% of the world's peat land area). Russia peat has low heating values primarily due to high moisture and oxygen contents. This results in high transportation cost per thermal unit of coal. Although natural dried peat of moisture has valuable heat calories, they are not used for the pulverized coal combustion power plants in Korea because they do not have combustion experiences. The Korea power generation companies have recently investigated utilization of Russian peat of natural drying from 86–95% moisture of the total mass in natural state to 30–40% as a pulverized fuel of coal power plant [3]. It is, therefore, of great importance to clarify the combustion characteristics of the high moisture peat, and blends of peat as a basis for the design of C & A bituminous coal. Thermogravimetric analysis, besides providing a means for the preliminary assessment of fuel values in coal allows for a priori knowledge of initial and final temperatures for their combustion as well as other relevant data such as maximum reactivity temperature or total combustion time. The combustion

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**Acronyms**

| | |
|---|---|
| BET | Brunauer, Emmett, Teller |
| C&A | coal & allied, Australia coal name |
| CPT | cross point temperature |
| DTF | drop tube furnace |
| DTG | derivative thermogravimetry, % $min^{-1}$ |
| FT | fluid temperature, °C |
| GGH | gas to gas reheater |
| HT | hemispherical temperature, °C |
| IT | initial deformation temperature, °C |
| LOI | loss on ignition, % |
| RBA | ratio of base to acid, % |
| ST | softening temperature, °C |
| TGA | thermogravimetric analysis |

*Nomenclatures*

| | |
|---|---|
| $A$ | exponential kinetic factor, $s^{-1}$ |
| $Cp$ | specific heat, J $g^{-1}$ $K^{-1}$ |
| $E$ | activation energy, kJ $mol^{-1}$ |
| $R$ | gas constant, J $mol^{-1}$ $K^{-1}$ |
| $T_f$ | final temperature of combustion, °C |
| $T_m$ | maximum temperature of combustion rate, °C |
| $T_v$ | onset temperature of volatile release, °C |
| $t_q$ | time interval between Tv and Tf, s |

*Subscripts*

| | |
|---|---|
| f | final temperature |
| m | maximum temperature |
| p | constant pressure |
| v | volatile release |

kinetic parameters such as activation energy and kinetic constants for the VESTA program [4] which evaluates the effect of fuel change on the heat transfer and boiler efficiency in 500 MW boilers, are also measured by TGA. DTF reactors that closely simulate the combustion conditions in commercial pulverized fuel boilers may be more appropriate for studying coal combustion behaviors, such as coal ignition, burnout, combustion efficiency, SOx, NOx and ash formation [5]. It is also necessary to ascertain the ignition characteristics of coals because of the firing risk at the pulverizer and storage field. These information can then be used to forecast combustion efficiency, residence time of pulverized fuel, ash fusion temperature, the firing possibility, etc. [6]. Therefore, KEPCO'RI (Korea Electric Power Corporation's Research Institute) has investigated the utilization possibility of Russian peat as blended fuel for commercial coal fired power plant using TGA/DTF and IT tester.

## 2. Experimental

### 2.1. Coal sample

Peat was obtained from slavo mines of TERRA TORF Company in Russia sakhalin. The Design C & A as design coal of commercial power plants was sampled from the pulverized fuel storage used at Dangjin thermal power plant of KEPCO. Blends of peat ranged from 10–50% versus Design C & A to see the blending effect of the Russian peat, and were prepared by a coal mixer. Samples covered five series with blending ratio of Russian peat of 10 (10% blends), 20 (20% blends), 30 (30% blends), 40 (40% blends), and 50% (50% blends), respectively. The proximate and ultimate analyses of samples are listed in Table 1. The as-received samples were crushed and sieved to a particle size below 74 μm before being tested.

Peat has relatively high volatile and moisture contents because of its lowered ash content. Clearly, it has lower content of fixed carbon than Design C&A, and high volatile fuel ratio [VM/(VM + FC)] to combustible material (volatile and fixed carbon). Especially, the volatile matter in peat is as high as 39.92%, and fixed carbon is significantly lower about 17.85% due to the much moisture in peat. In addition, blends originated from peat contain a high content of oxygen compared to Design C & A.

### 2.2. Experimental apparatus and procedures

Thermogravimetric experiments were carried out with a thermobalance coupled to a quadrupole mass spectrometer (STA PT-1000, Linseis Instrument Ltd.) shown in Fig. 1(a). Pure helium was used as a purge gas. The flow rate of the air gas was approximately 50 $cm^3$/min. Runs were performed in alumina crucible at a heating rate of 10 °C/min using a sample amount of 10 ± 0.2 mg based on calorific value with a particle size of less than 74 μm. The quadrupole mass spectrometer was connected to the thermobalance via an open coupling with a differential pressure reduction via an orifice. The coupling could be heated up to 900 °C to prevent condensation of the evolved products. The mass loss, time and temperature were recorded simultaneously to produce combustion profile. From combustion profile, the following thermal parameters were obtained: characteristic temperature, weight loss rate, and burning time.

$T_v$; onset temperature for volatile release and weight loss
$T_m$; temperature of maximum weight loss rate
$T_f$; final combustion temperature detected as weight stabilization
$DTG_{max}$; maximum weight loss rate; $t_q$ = burning time; time interval from the volatile release starts to final combustion of fixed carbon (the moisture evaporization zone was neglected because of the heat adsorption reaction)

The DTF used in the study consisted of a ceramic tube of length 600 mm and ID 30 mm having six zones [7]. All six zones were electrically heated by super Kanthal wire and the temperature in

**Table 1**
Proximate and ultimate analysis of coal samples.

| Symbol | Total moisture [%] | Proximate analysis (As air dry basis %) | | | | | Calorific value [kJ/kg,LHV] | Ultimate analysis (as upgrade basis, a.f. %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | VM | M | FC | Ash | [a]VR | | C | H | N | S | O |
| Peat | 40.12 | 39.92 | 38.06 | 17.85 | 4.17 | 0.69 | 18,368 | 53.80 | 6.09 | 1.08 | 0.18 | 32.11 |
| Design C&A | 7.52 | 31.31 | 4.01 | 49.42 | 15.26 | 0.39 | 26,848 | 72.77 | 4.29 | 1.63 | 0.51 | 4.90 |
| 10% Blends | 10.78 | 32.17 | 7.42 | 46.26 | 14.15 | 0.41 | 25,999 | 70.87 | 4.47 | 1.58 | 0.48 | 7.62 |
| 20% Blends | 14.04 | 33.03 | 10.82 | 43.11 | 13.04 | 0.43 | 25,154 | 68.98 | 4.65 | 1.52 | 0.44 | 10.34 |
| 30% Blends | 17.30 | 33.89 | 14.23 | 39.95 | 11.93 | 0.46 | 24,305 | 67.08 | 4.83 | 1.47 | 0.41 | 13.06 |
| 40% Blends | 20.56 | 34.75 | 17.63 | 36.79 | 10.82 | 0.49 | 23,456 | 65.18 | 5.01 | 1.41 | 0.38 | 15.78 |
| 50% Blends | 23.82 | 35.62 | 21.04 | 33.64 | 9.72 | 0.51 | 22,610 | 63.29 | 5.19 | 1.36 | 0.35 | 18.51 |

a.f.: ash free; VM: volatile matter; M: moisture; FC: fixed carbon. [a]VR: Volatile ratio in combustible matter (VM/VM + FC);