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AN INVESTIGATION INTO THE COMBUSTION CURVES OF LIGNITES

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Abstract

In this research, combustion curves of seventeen lignite samples from the Thrace basin (Turkey) were analysed using thermal analysis (TG/DTG) techniques. A comparative analysis was performed considering the relationship between peak temperature, burn-out temperature, moisture content, ash, volatile matter, fixed carbon and calorific values of the samples studied and the results are discussed.

Keywords: burning profile, lignite, proximate analysis, thermogravimetry

Introduction

In the investigation of fossil fuels, thermogravimetry (TG/DTG) and differential scanning calorimetry (DSC) techniques have been found to be useful in aspects related to proximate analysis, characterisation, pyrolysis, combustion and coal reactivity. TG/DTG and DSC have proved to be easy, rapid and convenient tools for the characterisation of fossil fuels. In addition, small amounts of samples required could be an advantage, when only a small representative sample is available. Coals contain mineral components contributing to their thermal behaviour. Endothermic reactions due to the decomposition of the mineral matter during the combustion reduce the exothermic peak area resulting from the combustion of the organic part. Therefore, the combustion curves are representative of both endo- thermic and exothermic reactions in coal combustion [1, 2]. Gold [3] has demonstrated the occurrence of exothermic reactions associated with the production of volatile matter in or near the plastic region of coals studied. He concluded that both the temperature and the magnitude of the exothermic peak were strongly affected by the heating rate, sample mass and particle size. Jayaweera *et al.* [4] have studied by thermal analysis, the effect of particle size on the percentage mass loss of a low quality bituminous coal during combustion in air. It was found that the method of sieving, used to prepare samples of different particle size have a significant effect on the results. Shah and Ahmed [5] have studied combustion of different size coal samples. The results revealed that reduction of particle size caused a decrease of the ignition temperature. Morris [6] found a correlation between the yields of hydrogen and methane and the particle size and final temperature, and also between the yields of carbon monoxide and carbon dioxide and the par-

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Table 1 Properties of the lignite samples

Sample	Moisture content/	Ash content/	Volatile matter/	Fixed carbon/	Organic sulphur/	Inorganic sulphur/	Total sulphur/	Calorific value*/	Calorific value**/
	%							$kJ\ kg^{-1}$	
Sample-01	20.39	30.03	22.89	26.69	2.50	0.56	3.06	12040	13120
Sample-02	27.84	14.73	23.61	33.82	1.24	0.26	1.50	14998	16320
Sample-03	28.31	15.07	24.35	34.15	1.36	0.28	1.64	15450	16538
Sample-04	27.05	14.15	23.15	33.24	1.20	0.22	1.42	14968	16328
Sample-05	31.95	19.05	23.42	25.58	0.79	0.64	1.43	11966	13300
Sample-06	28.36	16.82	27.43	27.39	1.04	0.40	1.44	14118	15460
Sample-07	27.56	25.29	23.49	23.66	0.82	0.22	1.04	11234	12464
Sample-08	27.17	17.67	25.70	29.46	1.30	0.22	1.52	13586	14875
Sample-09	28.32	16.45	26.92	26.25	1.14	0.42	1.56	11828	12770
Sample-10	34.96	12.53	24.85	27.66	1.41	0.77	2.18	12702	14155
Sample-11	15.96	12.70	30.26	41.08	0.65	0.35	1.00	19464	20670
Sample-12	22.45	14.70	23.25	21.56	1.15	0.28	1.43	14068	15500
Sample-13	24.10	15.07	25.15	22.41	0.95	0.31	1.26	14946	16370
Sample-14	19.70	13.68	27.45	28.10	0.78	0.27	1.05	15742	16642
Sample-15	16.75	12.47	31.56	39.22	0.61	0.22	0.83	18346	19565
Sample-16	19.60	21.42	26.35	31.75	1.10	0.47	1.57	16160	17165
Sample-17	16.40	14.35	30.15	39.05	0.76	0.42	1.18	16390	17982

*Low heating value: heat transfer with vapor H_2O in the products
**High heating value: heat transfer with liquid H_2O in the products

ticle size. Smith *et al.* [7] investigated the burning process of different coal samples, from lignite to black coal, and found that the burning temperature of these coal types is linearly dependent on their concentration. Morgan and Robertson [8] determined coal-burning profiles by thermogravimetric analysis. They claimed that kinetic parameters from Arrhenius plots could not readily be related to any specific stage of the combustion process. However, some features of the profiles are clearly related to coal properties, and a correlation exists between amount of fixed carbon, as predicted from high temperature oxidation rates, and a characteristic temperature of the thermogravimetric profile. Crelling *et al.* [9] determined the combustion properties of separate single coal maceral fractions from a rank series of coals, then tried to predict the combustion behaviour of various whole coals on the basis of their maceral composition and rank.

Table 2 Peak and burn-out temperatures of the samples/K

Sample	Peak temperature/K (I. Region)	Peak temperature/K (II. Region)	Burn-out temperature/K
Sample-01	688	728	753
Sample-02	633	–	723
Sample-03	648	–	728
Sample-04	681	703	783
Sample-05	638	–	723
Sample-06	653	–	763
Sample-07	655	–	728
Sample-08	658	–	773
Sample-09	643	–	783
Sample-10	693	803	833
Sample-11	653	678	763
Sample-12	668	–	763
Sample-13	673	–	738
Sample-14	653	681	773
Sample-15	648	678	768
Sample-16	643	–	723
Sample-17	638	–	763

Experimental

In this investigation, thermogravimetric (TG/DTG) experiments were performed with a DuPont 9900 thermal analysis system. The lignite samples studied in this research were from the Thrace basin and were prepared according to ASTM Standards (ASTM D 2013-72) and with a particle size <60 mesh. It is assumed that for such a small particle size the effect of temperature distribution within the sample particle is eliminated. It was also essential to calibrate the thermobalance for buoyancy effects in order to allow quantitative estimation of mass changes. This effect was measured during heating run with silver, which has a melting point of 1235 K. The TG/DTG curves were obtained using the following experimental conditions: atmosphere: nitrogen; flow rate: 50 ml min^{-1}; sample size: 10 mg; heating rate: 10 K min^{-1}; temperature range: 295–875 K. All the experiments were performed twice for reproducibility.

Results and discussion

Proximate analysis of coals includes the determination of moisture, volatile matter, fixed carbon and ash contents. Proximate analysis, total sulphur and calorific values of the samples are determined by standard methods [10] and are presented in Table 1. The proximate analysis of the samples shows the following ranges: moisture content 15.95–34.96%, ash content 12.47–30.03%, volatile matter 22.89–31.56%, fixed carbon 21.56–41.08%, and total sulphur 0.83–3.06%. The calorific values of the samples were measured by using a bomb calorimeter and the calorific values were in the range of 12460–20660 kJ kg^{-1}.

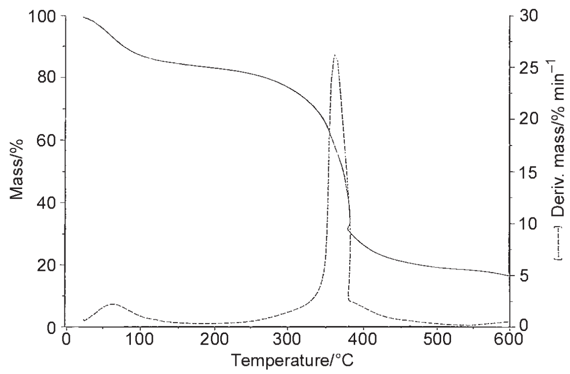

Fig. 1 Combustion curve of lignite (sample-9)

Combustion profiles of selected lignite samples are shown in Figs 1 and 2. Initially the DTG curves show a small peak, due to the water loss, and one or two peaks, due to the combustion of volatile matter released on heating, followed by burning of the residual solid. Raw coal exhibits a single combustion profile in case of the samples 2, 3, 5, 6, 7, 8, 9, 12, 13, 16 and 17 while double DTG peaks are observed for samples 1, 4, 10, 11, 14 and 15. The second DTG peak appears as a shoulder and becomes more pronounced in some samples. The appearance of a shoulder in DTG peak for the lignite suggests the presence of at least two types of combustibles. Two portions of combustibles burn in two distinct stages with different peak temperatures. The peak temperature is the temperature at which the rate of mass loss is at its maximum. Burn out temperatures indicate a complete sample oxidation. Peak and burn out temperatures of the samples are given in Table 2. The combustion profile of lignite

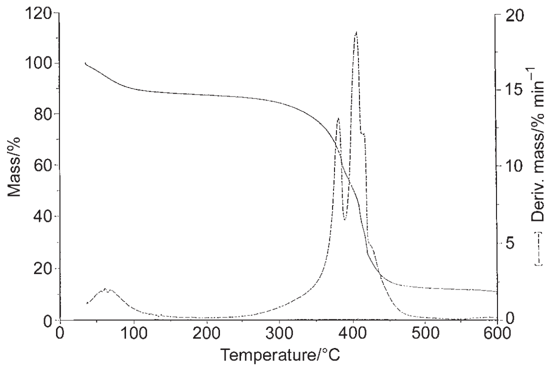

Fig. 2 Combustion curve of lignite (sample-14)

samples with a high fixed carbon content generally show two separate peaks, but the combustion curves of the lignite samples with a low fixed carbon content show only one peak. Neither the peak temperatures nor the burn-out temperatures change significantly with different coal compositions.

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