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The effect of mineral matter on the combustion characteristics of some Turkish lignite samples

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Abstract

In this study, the burning profiles of twenty-five lignite samples originating from different parts of Turkey were obtained using a thermogravimetry technique (TGA). In the light of these profiles, the effect of the mineral matter content on the combustion behaviour of the lignite samples is discussed. The DTG curves of the lignite samples before and after mineral matter removal were obtained from TG applications under the same working conditions.

Plots of the weight loss differences between the original and demineralized lignite samples against temperature were derived from TG applications. The relationship of the weight loss (calculated on a dry, ash-free basis) differences between the original and demineralized lignite samples at 1273 K with the mineral species was investigated. All correlations were developed by means of regression analysis.

Experiments have shown that the mineral matter content of the lignite samples plays an important role in determining the combustion characteristics. Data indicate that the effects of the mineral species on the combustion characteristics are more pronounced at higher temperatures.

Keywords: Lignite; Combustion; Mineral matter

1. Introduction

Coal is a complex heterogeneous material which contains a variety of organic and inorganic compounds that affect its properties and consequently its potential for utilization [1]. The combustion efficiency of coal depends on a number of factors, some related to the operating conditions, others to the coal properties. When pulverized coal

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particles are injected into a hot gaseous environment, two processes occur, often with considerable overlap. The first of these processes is the thermal decomposition of the coal, producing combustible gases (volatiles), and the second involves the slower reaction of the residual char with the oxidant [2].

In the design of industrial coal-fired boiler furnaces, it is necessary to have an assessment of the reactivity and burning characteristics of the coal. Non-isothermal thermogravimetry has been widely used for evaluating the burning properties of coals [3–8]. Thermogravimetric analysis is a rapid and cost-effective technique which monitors coal burning profiles.

Mineral matter is generally considered to be the sum of all inorganic minerals and elements that are present in coal. Thus, all elements in coal except organically combined C, H, N, O and S are classified by this definition as mineral matter [9].

In this study, the effect of the mineral matter on the combustion properties of some Turkish lignites was examined. Thermogravimetric analysis was used to characterize the combustion of the original and demineralized lignite samples.

2. Experimental

In the experiments, twenty-five lignite samples originating from different areas of Turkey were used. Samples were ground and sieved into a powder with a particle size of 250 μm.

Chemical analyses of the ashes produced from lignite samples according to the ASTM standards have been determined [10]. Determination of the total mineral matter content of 25 lignite samples was carried out according to the ISO-602 standard [11]. The demineralization of the lignite samples was performed by treatment with hydrochloric and hydrofluoric acids under the conditions described in the ISO-602 standard.

Thermogravimetric analysis was carried out using a Shimadzu TG 41 thermal analyser. Lignite samples (40 mg) were spread uniformly on the bottom of the crucible made of alumina. The temperature was raised with a heating rate of 40 K min^{-1} to 1273 K and held at this temperature until the weight was constant. During the studies, the flow rate of the air was fixed at 40 cm^3 min^{-1}. The chart speed was selected as 5 mm min^{-1}.

3. Results and discussion

The chemical composition of the lignite ashes and the total mineral matter content of the lignite samples are given in Table 1.

The DTG curves showing weight loss rates versus temperature are derived from the curves obtained through TG analysis of the original and demineralized lignite samples. A plot of the rate of weight loss against temperature while burning a sample in air has been referred to as a "burning profile" [1]. The DTG curves (burning profiles) of the lignite samples before and after mineral matter removal show significant differences.

Table 1
The mineral matter content% of the lignite samples (dry basis) and the composition of the ashes

Sample Code	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	Mineral Matter
L01	49.70	27.77	7.28	2.90	0.92	9.94	0.97	41.90
L02	54.40	21.20	12.49	4.12	2.15	1.67	1.99	44.37
L03	37.40	33.36	12.02	11.75	0.74	0.40	1.96	46.22
L04	12.02	30.41	45.05	5.42	1.89	4.05	0.44	11.92
L05	30.17	35.23	24.63	7.76	0.30	0.97	0.12	16.51
L06	28.30	30.79	16.08	15.88	4.04	2.93	0.44	16.42
L07	33.28	29.74	12.36	15.77	2.12	1.31	0.44	12.30
L08	29.40	34.40	10.62	15.86	1.64	0.55	0.39	7.68
L09	33.05	33.46	23.11	7.24	0.51	0.30	1.42	17.04
L10	33.59	28.62	21.19	8.79	2.85	0.52	3.21	34.72
L11	16.08	38.69	34.48	6.51	1.22	0.77	1.15	12.46
L12	41.18	22.91	13.68	7.40	1.74	10.70	2.46	38.34
L13	19.39	20.44	20.36	23.54	1.04	0.37	1.12	44.14
L14	13.25	24.52	18.79	23.62	12.37	0.25	0.18	13.67
L15	27.84	20.46	26.02	11.89	7.84	0.96	0.46	15.27
L16	48.61	35.60	9.64	2.92	0.70	0.51	1.24	27.66
L17	23.67	20.44	22.14	15.63	3.26	0.92	0.70	28.88
L18	35.22	24.79	13.42	13.68	2.06	0.81	1.30	26.80
L19	32.57	27.72	18.16	9.03	4.74	2.32	0.89	15.14
L20	60.14	17.38	14.01	0.86	4.56	0.35	1.19	47.97
L21	30.00	19.44	20.30	15.26	3.38	0.40	1.14	35.60
L22	54.48	28.58	8.03	1.08	0.98	0.71	2.32	33.94
L23	29.20	28.00	30.41	9.01	0.31	0.29	0.91	8.84
L24	28.46	22.59	25.54	13.08	2.04	1.47	0.60	27.62
L25	18.50	17.59	13.18	22.64	6.64	1.11	1.09	30.24

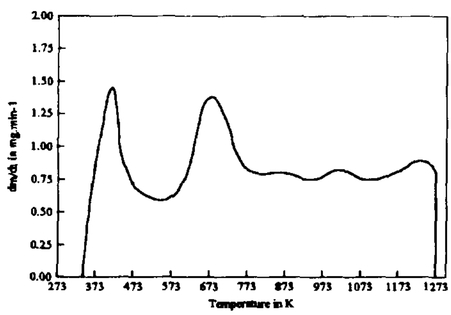

Fig. 1. DTG curve of the lignite sample L01.

The curves obtained for two of the samples are shown in Figs. 1–4. The DTG curves of the original lignite samples generally have the shape of a curve with two maxima, corresponding to water release followed by progressive combustion. The DTG curves of the demineralized lignite samples contain a small maximum peak due to the moisture

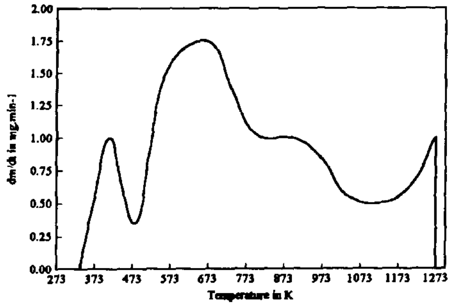

Fig. 2. DTG curve of the demineralized lignite sample L01.

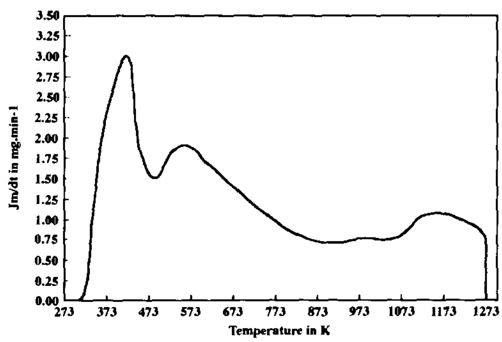

Fig. 3. DTG curve of the lignite sample L21.

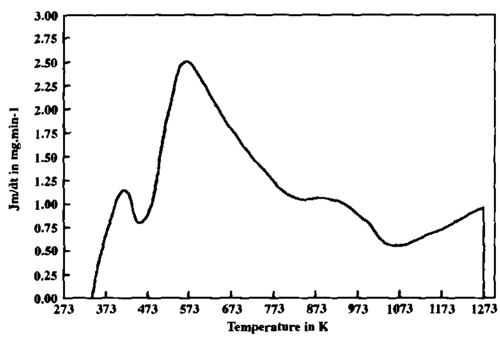

Fig. 4. DTG curve of the demineralized lignite sample L21.

released. Weight loss rate starts to increase at approximately 473 K; and after reaching a maximum the weight loss rate decreases up to a temperature between 1000 and 1070 K, and again shows an increase. Lignite samples were kept at 1273 K until the weight was constant and it was observed that an important weight loss occurred for demineralized lignites.

After demineralization, the burning profiles of the lignite samples are shifted to higher temperatures. The relationship of the total weight loss percentages of the original and demineralized lignite samples with the increasing temperatures is shown in Figs. 5 and 6. As shown, the weight loss percentages of the original lignite samples are greater than that of the demineralized samples at the same temperatures. Even though there is a little difference in the weight loss between the original and demineralized lignite samples at low temperatures, this difference increases with increasing temperature. The weight loss differences between original and demineralized lignite samples were plotted against temperature. As shown in Figs. 7–9, these differences showed a rapid increase starting at approximately 973 K.

It is clear that the catalytic effects of the mineral matter content on the combustion of coal are more pronounced at higher temperatures.

The combustion of the original lignites was almost completed at 1273 K; however for demineralized lignite samples, important weight losses were observed when keeping at this temperature, until the weight loss was constant. Plots of the total weight loss percentages of original and demineralized lignite samples against burn-out time were also prepared (Figs. 10 and 11). An increase (up to 100%) in burn-out times occurred after the demineralization process.

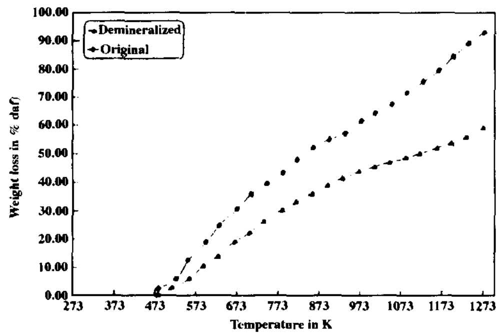

Fig. 5. Weight loss percentages of the lignite sample L01 before and after mineral matter removal versus temperature.

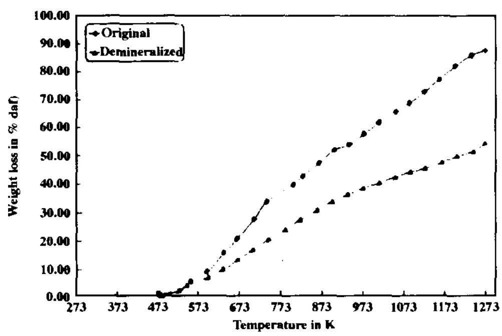

Fig. 6. Weight loss percentages of the lignite sample L20 before and after mineral matter removal versus temperature.

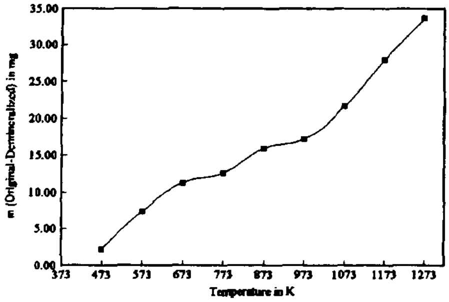

Fig. 7. Relationship of the weight loss differences for the lignite sample L01 with temperature.

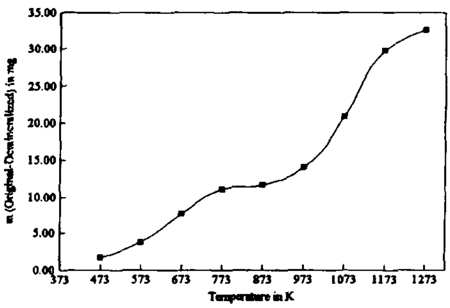

Fig. 8. Relationship of the weight loss differences for the lignite sample L03 with temperature.

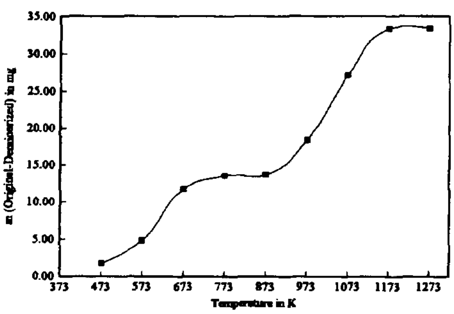

Fig. 9. Relationship of the weight loss differences for the lignite sample L24 with temperature.

The relationship of the mineral species of the lignite samples with weight loss percentage differences between original and demineralized lignites was also investigated. The effects of CaO, $CaO + Na_2O$, $CaO + Na_2O + K_2O$ and $CaO + Na_2O + K_2O + MgO$ contents on the weight loss percentage differences (cal-

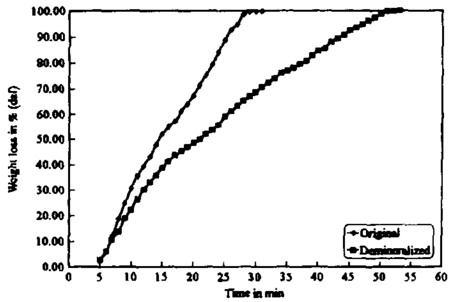

Fig. 10. Relationship of the weight loss percentage of the lignite sample L01 before and after mineral matter removal with time.

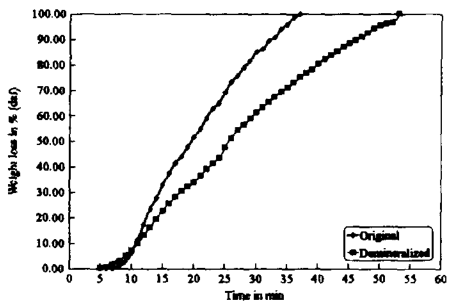

Fig. 11. Relationship of the weight loss percentage of the lignite sample L02 before and after mineral matter removal with time.

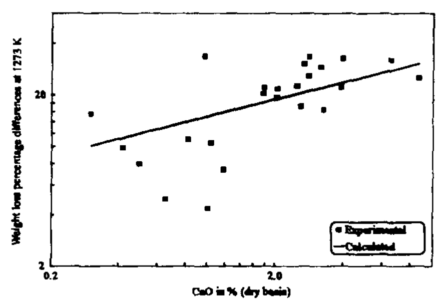

Fig. 12. Relationship of the weight loss percentage differences between original and demineralized lignite samples 1273 K with the CaO content.

culated on a dry, ash-free basis) at 1273 K are shown in Figs. 12–15. The correlation coefficients of the relations between the CaO, CaO + Na_2O, CaO + Na_2O + K_2O and CaO + Na_2O + K_2O + MgO contents of the lignite samples and their weight loss percentage dfferences at 1273 K were calculated as 0.6614, 0.7438, 0.7919 and 0.7887, respectively.

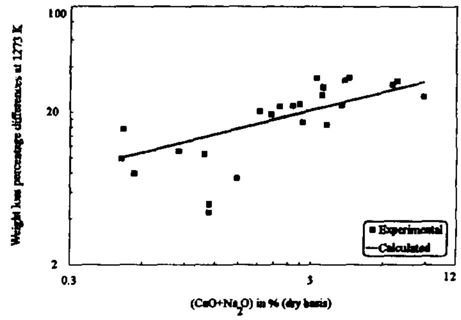

Fig. 13. Relationship of the weight loss percentage differences between original and demineralized lignite samples at 1273 K with the sum of the CaO and Na_2O contents.

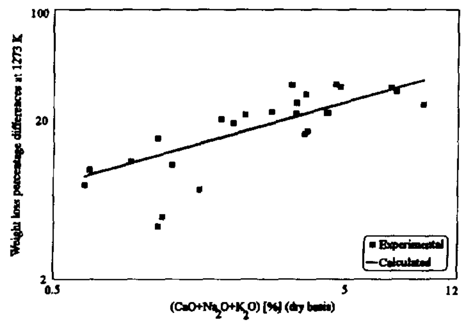

Fig. 14. Relationship of the weight loss percentage differences between original and demineralized lignite samples at 1273 K with the sum of the CaO, Na_2O and K_2O contents.

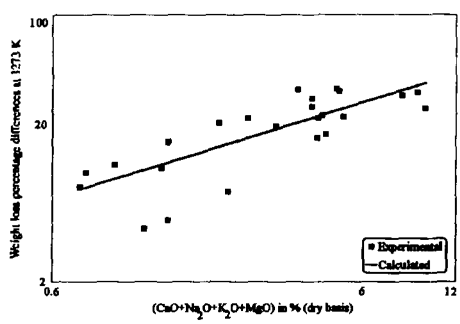

Fig. 15. Relationship of the weight loss percentage differences between original and demineralized lignite samples at 1273 K with the sum of the CaO, Na_2O, K_2O and MgO contents.

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