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Effect of mineral matter on the combustion curve of chars

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Abstract

In this study, the effect of mineral matter content on the combustion curve of the chars produced from 25 lignite samples originating from different parts of Turkey was investigated using differential thermal analysis (DTA).

During the DTA studies, original and demineralized lignite samples were carbonized under identical conditions in nitrogen atmosphere up to 1423 K and, after cooling to the room temperature under nitrogen flow, they were heated at a constant rate of 40 K min^{-1} in flowing air up to 1273 K. The DTA combustion curves of the char samples produced from the original and demineralized lignites and their heat release rates are compared and discussed.

It was observed that the shapes of the DTA combustion curves of the chars were strongly affected by the demineralization process. In particular, the burn-out times and the heat release rates changed markedly.

Keywords: Coal; Combustion; DTA; Mineral matter

1. Introduction

The combustion efficiency of coal in a furnace depends on a number of factors, some related to the operating conditions, others to the coal properties.

The combustion of coal involves the following three stages: the release of volatile matter, the burning of volatile matter in the gas phase, and the burning of the residual char. These processes occur sequentially to some extent; however, overlapping of these three stages depend, phenomenologically as well as kinetically, upon particle size, heating rate and char porosity [1]. A rapid loss of volatile matter occurs within a few seconds; the combustion of the remaining solid residue proceeds within minutes.

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Hence, the chemical reactivity of the char becomes the most important parameter governing the burn-out behaviour of coal.

The reactions of char with oxygen have generally been described as being governed by the following controlling processes [2]:

1. Mass transfer (by diffusion) of oxygen to reaction sites.
2. Chemisorption of oxygen on the carbon surface, reaction of chemisorbed oxygen with carbon to form products, and desorption of products from the carbon surface.
3. Mass transport of the gaseous products from the carbon surface.

Char oxidation depends on a number of factors including coal structure, diffusion of reactants, particle size, pore diffusion, catalysis by minerals, changes in surface area during the reactions, fragmentation of char, temperature and pressure [3].

In this study, attention has been directed to the effect of the mineral matter content on the combustion behaviour of chars produced from 25 lignite samples originating from various parts of Turkey. The DTA combustion curves and the heat release rates determined as a function of temperature for the char samples produced from original and demineralized lignite samples are compared and discussed.

2. Experimental

The proximate analysis and the calorific value measurements of the lignite samples were performed according to ASTM standards [4].

The lignite samples were demineralized by treatment with hydrochloric and hydrofluoric acids. Determination of the total mineral matter content of the lignite samples was carried out according to the ISO-602 standard [5].

Differential thermal analysis (DTA) was carried out using a Shimadzu DTC 40 analyser. Lignite samples (30 mg) ground to pass a 0.25 mm sieve were heated at a constant rate of 10 K min^{-1} in nitrogen flowing at a rate of 40 cm^3 min^{-1} up to 1423 K during the carbonization process. After cooling to room temperature under the nitrogen flow, they were heated at a constant rate of 40 K min^{-1} in a 40 cm^3 min^{-1} flow of dry air up to 1273 K and held for 30 min at this constant temperature.

The DTA combustion curves of the char samples produced from the original and demineralized lignite samples were obtained under identical conditions.

3. Results and discussion

The proximate analyses, the net calorific values and the total mineral matter content of the lignite samples are given in Table 1. As shown, the mineral matter content of the lignite samples used in this study varies between 7.68 and 47.97%.

Thermal analysis plays an important role in the determination of the combustion characteristics of coals. Coal DTA curves obtained in the presence of air are called combustion curves. It was observed that there are important differences between the

Table 1
Proximate analyses, calorific values and total mineral matter contents of the lignite samples

Sample code	Moisture (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Net calorific value/(MJ kg^{-1})	Total mineral matter (%) (Dry basis)
L01	10.5	32.2	25.1	32.2	10.7	41.90
L02	4.4	22.2	32.8	40.6	14.5	44.37
L03	15.7	36.1	16.4	31.8	11.8	46.22
L04	9.6	39.2	40.2	11.0	22.0	11.92
L05	10.5	36.8	40.6	12.1	21.0	16.51
L06	19.9	30.3	35.8	14.0	17.4	16.42
L07	27.6	39.8	22.8	9.8	17.6	12.30
L08	24.2	38.4	31.2	6.2	17.8	7.68
L09	2.0	32.0	51.6	14.4	27.1	17.04
L10	14.0	36.1	23.3	26.6	14.6	34.72
L11	7.2	46.4	39.1	7.3	26.2	12.46
L12	25.3	28.7	16.7	29.3	12.2	38.34
L13	16.2	40.9	10.3	32.6	12.5	44.14
L14	15.9	41.0	36.4	6.7	20.4	13.67
L15	35.4	32.2	23.4	9.0	14.3	15.27
L16	12.5	32.3	32.3	22.9	19.5	27.66
L17	17.9	37.3	26.1	18.7	16.6	28.88
L18	27.0	34.4	18.0	20.6	15.3	26.80
L19	14.1	33.4	39.8	12.7	20.0	15.14
L20	13.9	24.6	22.3	39.2	12.5	47.97
L21	40.4	32.1	12.3	15.2	13.8	35.60
L22	6.4	28.6	37.4	27.6	19.1	33.94
L23	5.9	31.8	53.4	8.9	27.8	8.84
L24	27.5	34.4	24.0	14.1	12.9	27.62
L25	48.0	28.2	11.8	12.0	10.8	30.24

combustion curves of the chars produced from original and demineralized lignites. Since the char samples produced from lignites under nitrogen atmosphere contain mineral matter and fixed carbon, their combustion characteristics are dependent on the physical and chemical properties of these components.

The DTA combustion curves obtained for the char samples produced from 5 original and 5 demineralized lignite samples are shown in Figs. 1–5. The combustion curves of the char samples contain only one exothermic peak.

The burn-out times of the char samples were strongly affected by the demineralization process. It is clearly observed that the combustion times of the chars produced from the demineralized lignite samples are longer than those of the chars of the original lignite samples (Figs. 1–5).

The heat release rate of coal is as important for coal-fired boiler furnaces as its heat content. The area under the exothermic peak of the combustion curve is proportional to the heat released. Therefore it can be used to determine the heat release rate of a coal. The heat release rates of the char samples were determined as a function of temperature. The heat release rates of the chars produced from the demineralized lignite samples and

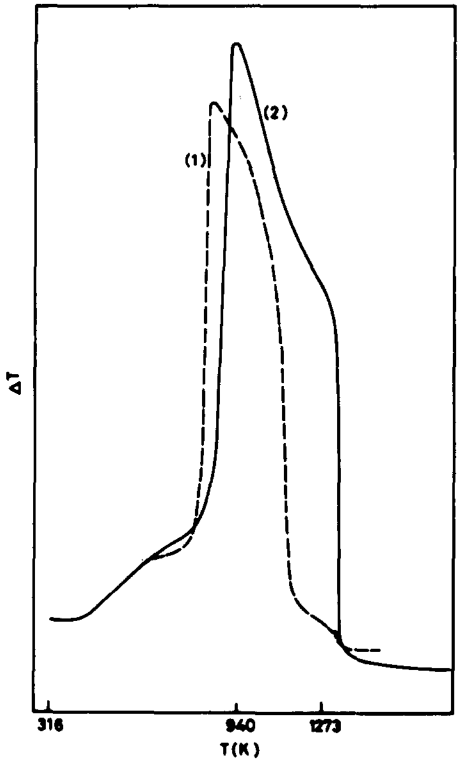

Fig. 1. The combustion curves of the chars produced from the lignite sample L01 before (1) and after (2) mineral matter removal.

their dependence on temperature are considerably different from those produced from the original lignite samples. In Figs. 6–9, the heat release rate curves prepared for 8 char samples can be seen. The char produced from the original lignite sample L03 loses 70% of its calorific value up to 925 K, but after demineralization this occurs up to about 1105 K (Fig. 6). The char produced from the original lignite sample L10 loses 70% of its calorific value up to 875 K, but after demineralization this occurs up to about 1073 K (Fig. 7). The original char samples produced from L13 and L17 lose 70% of their calorific values up to 890 K, but after mineral matter removal these temperatures increase to 1030 and 1025 K, respectively (Figs. 8 and 9). As shown, the mineral matter contained in the char influences the rate of combustion by increasing it catalytically.

The demineralization process caused an increase in the temperatures at which the combustion heat release occurred for lignites and their char samples. For char samples, this increase is more than for the lignites, since the mineral matter concentrations of the chars are higher than those of the original lignite samples due to the evolution of volatile matter during carbonization [6].

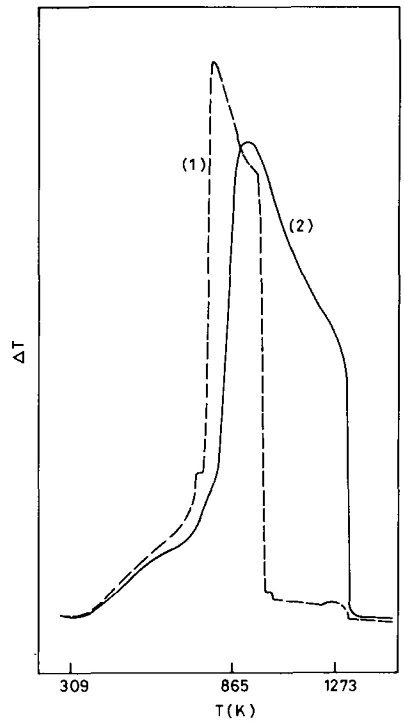

Fig. 2. The combustion curves of the chars produced from the lignite sample L10 before (1) and after (2) mineral matter removal.

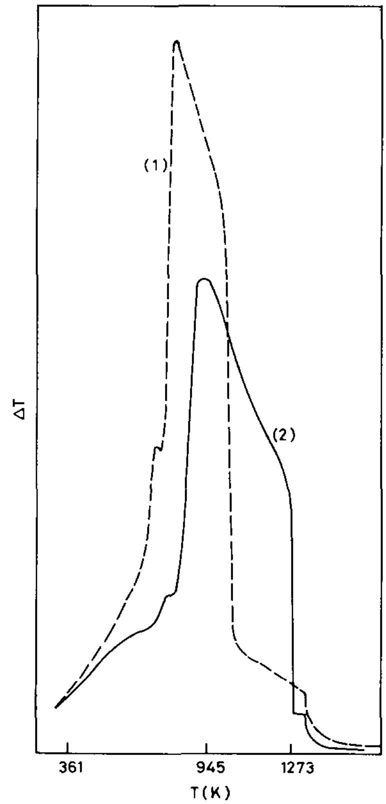

Fig. 3. The combustion curves of the chars produced from the lignite sample L13 before (1) and after (2) mineral matter removal.

4. Conclusions

In this study, the effect of mineral matter content on the combustion curve of the chars produced from 25 lignite samples was investigated using DTA. It was observed that there are important differences between the DTA combustion curves of the char samples produced from original and demineralized lignite samples under identical conditions. The heat release rates determined as a function of temperature for the char samples were strongly affected by the demineralization process. It is clearly observed that the burn-out times and temperatures at which the combustion heat is released for the chars produced from the demineralized lignite samples are longer than those for the chars of the original lignites. Data indicate that the mineral matter contained in the char influences the rate of combustion by catalytically increasing the rate.

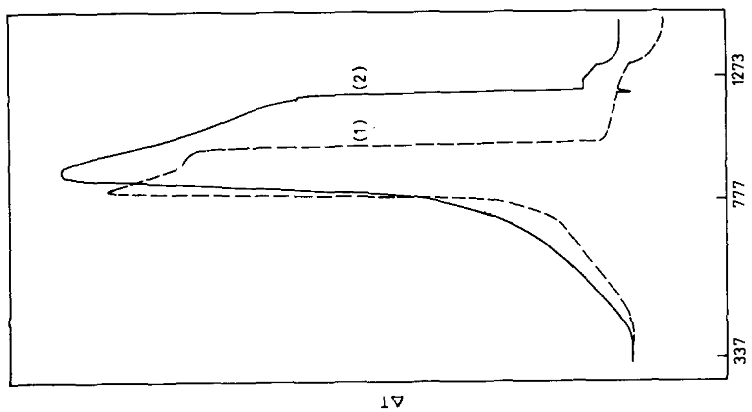

Fig. 4. The combustion curves of the chars produced from the lignite sample L21 before (1) and after (2) mineral matter removal.

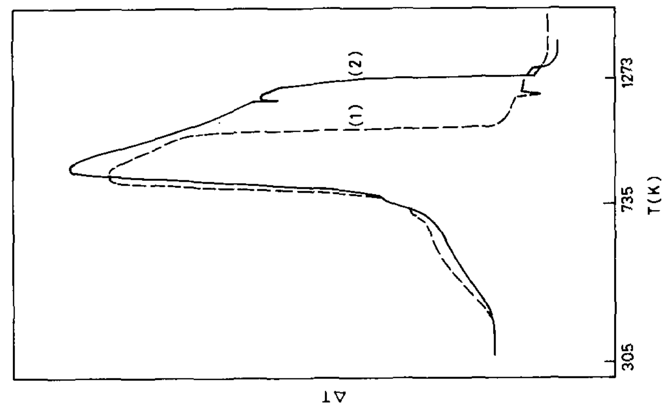

Fig. 5. The combustion curves of the chars produced from the lignite sample L25 before (1) and after (2) mineral matter removal.

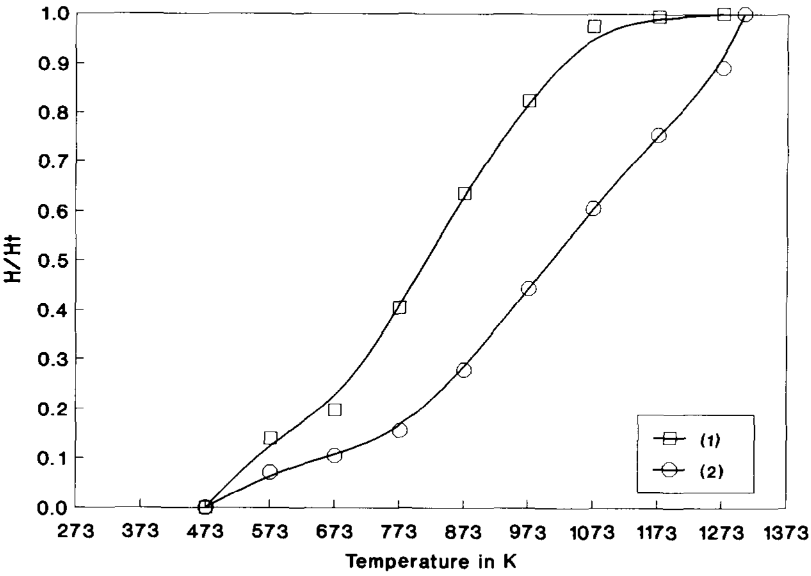

Fig. 6. Effect of temperature on the heat release rates of the chars produced from the lignite sample L03 before (1) and after (2) mineral matter removal (H_t is the net calorific value; H the heat released up to temperature T).

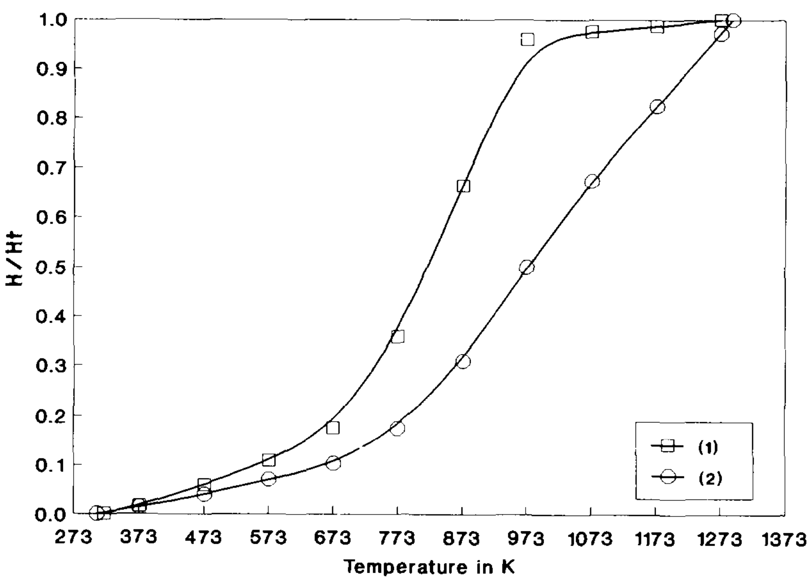

Fig. 7. Effect of temperature on the heat release rates of the chars produced from the lignite sample L10 before (1) and after (2) mineral matter removal (H_t is the net calorific value; H the heat released up to temperature T).

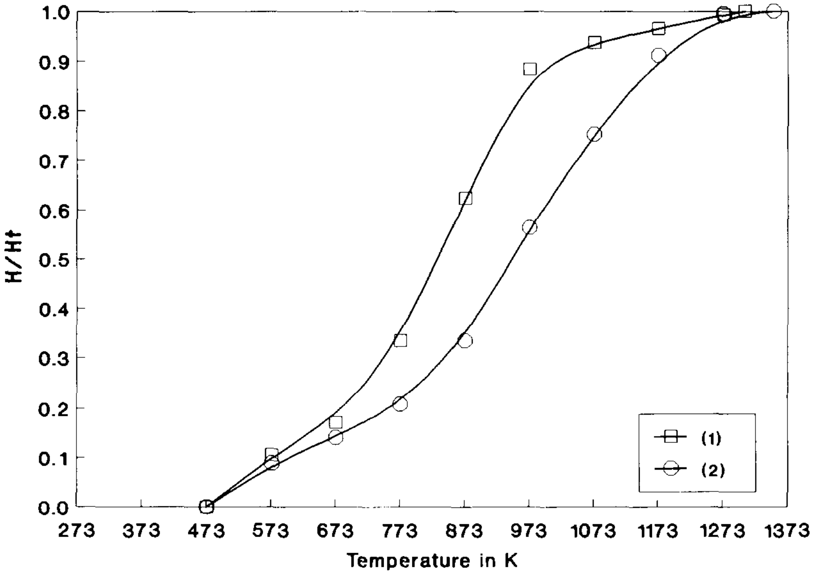

Fig. 8. Effect of temperature on the heat release rates of the chars produced from the lignite sample L13 before (1) and after (2) mineral matter removal (H_t is the net calorific value; H the heat released up to temperature T).

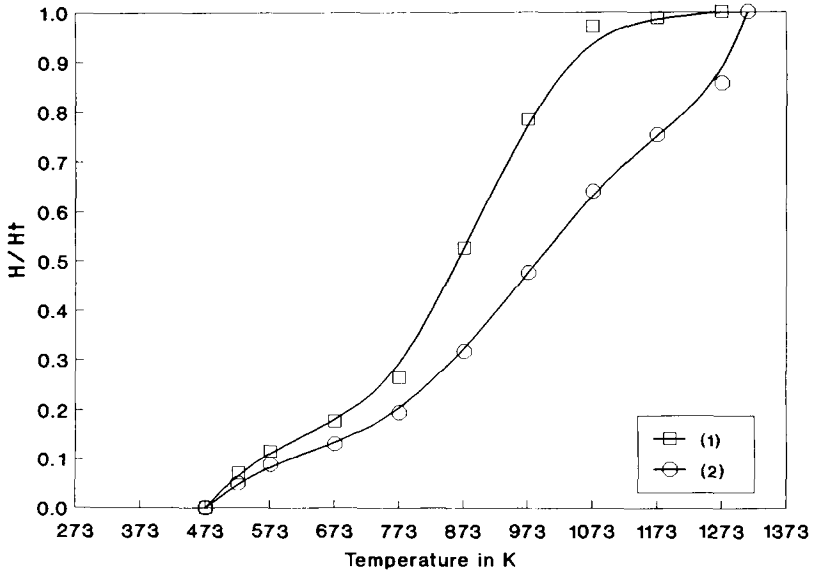

Fig. 9. Effect of temperature on the heat release rates of the chars produced from the lignite sample L17 before (1) and after (2) mineral matter removal (H_t is the net calorific value; H the heat released up to temperature T).

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