The Dependence of Coal Properties on Heat Consumption for Carbonization

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Introduction

It is necessary to evaluate the true value of coal quantitatively because our country imports many kinds of coals for metallurgical coke from several foreign countries. Heat consumption for carbonization is one of the most important evaluating factor for coal, besides coke strength and the yield of the products.

In the present report, estimation of heat consumption (Net-HC) from sensible heat of their carbonization products, and heat of reaction calculated from the difference of enthalpy between coal and its products about many kinds of single coals is proposed. This method is different from other previous procedure reported,[1-5] at the point that the mass balance of every carbonization was done exactly based on small test oven. Heat consumption on 26 single coking coals were estimated by means of this method. It was found that Net-HC decreased with the rank of coal and can be estimated by VM and H/C of the coal.

The Estimation of Sensible Heat and Heat of Reaction

The Sensible heat of dry coal can be calculated by the following equation (1).

$$S = \Sigma(Yp \times Cp \times Tp) - Yc \times Cc \times Tc \qquad (1)$$

where S = sensible heat (kcal/kg); Yp = the yield of each coking product (kg/kg); Cp = the specific heat of each coking product (kcal/kg°C); Tp = the temperature of each coking product (°C); Yc = coal weight (1kg); Cc = the specific heat of coal (kcal/kg°C); Tc = the temperature of coal (°C). The temperature of coal, coke, and other coking products was defined 20°C, 1050°C, and 850°C respectively. The heat of reaction of dry coal can be calculated by the following equation (2).

$$H = \Sigma(Yp \times Ep) - Yc \times Ec + \Sigma(LYp \times Lp) \qquad (2)$$

where H = heat of reaction (kcal/kg); Ep = the enthalpy of each coking product (kcal/kg); Ec = the enthalpy of coal (kcal/kg); LYp = the yield of each liquid coking product (kg/kg); Lp = the latent heat of each liquid coking product (kcal/kg).

Measurement the yields of coking products was explained as follows. Sample coal of 300g (<5.66mm) was heated at the heating rate of 5°C/min from room temperature to 900°C and held for 45 min at the temperature. Subsequently, the carbonized coke was cooled at the room temperature and measured the yield. Volatile substance generated from coal during carbonization was contacted to alumina ball charged in secondary pyrolytic furnace (temperature; 750°C). The yields of tar, water, NH_3, light oil, H_2S, and gas from volatile substance were determined after they were caught by each trap and gas holder.

Results and Discussion

Sensible Heat

The values of sensible heat of dry coal were in the range from 400 to 420 kcal/kg (average 418kcal/kg). Sensible heats were almost constant with no relation to the volatile matter of coal as shown in Fig. 1. Sensible heats for cokes from high rank coals are more than those from low rank coals, in contrast to sensible heats for other coking products from high rank coals are less than those from low rank coals. On the other hand sensible heats from low rank coals have opposite tendency compared with high rank coals. It is believed that the difference of sensible heats was not recognized by the different rank coals as described above.

Heat of Reaction

Heat of reaction (exothermic reaction) decreased with increase in volatile matter, and had exothermic tendency with the rank of coal as shown in Fig. 2. This may be because endothermic reaction is induced by depolymerization and pyrolysis of side chain bonded to aromatic compound, and exothermic reaction is the result of polycyclic and laminated reaction from aromatic compounds. Generally, almost of coking coals have exothermic characteristic as shown in Fig. 2. This is because the total value for exothermic reaction is generally more than that for endothermic reaction during carbonization, within the range of coking coals.

Coking is generally occured by polycycling and laminating of aromatic compounds and, in addition, volatile matter of coal is closely related to coke yield. Since low rank coals have poor aromaticity in coal structure compared with high rank coals, it is thought that polycyclic and laminated amounts, which convert coal into coke, in low rank coals may be much compared with those in high rank coals. In addition, aromaticity of coal may be represented by the H/C of coal. Volatile matter and H/C of coal can be related to heat of reaction as described above.

Heat of reaction of dry coal can be represented by the following regression equation (3) which has proved to give the best agreement between estimated and predicted results, using volatile matter and H/C of coal.

$$H = 22.4(VM) - 1548(H/C) + 402 \quad (3)$$
$$r = 0.914 \quad V = 25 \quad n = 26$$

where VM = volatile matter of coal (%, dry base); H/C = atomic ratio of hydrogen and oxygen of coal; r = correlation coefficient; V = standard deviation (kcal/kg, dry base); n = number of sample.

Net-HC

The total of sensible heat and heat of reaction was regarded as Net-HC. The values of Net-HC of 8 main coals in 26 single coking coals were given in Table 1. Net-HC of dry coal were in the range from 270 to 430 kcal/kg and decreased with the rank of coal. Besides Net-HC can be estimated efficiently by the following equation (4) that is the total value for the average value of sensible heat added to the equation (3).

$$\text{Net-HC(kcal/kg)} = 22.4(VM) - 1548(H/C) + 820 \quad (4)$$

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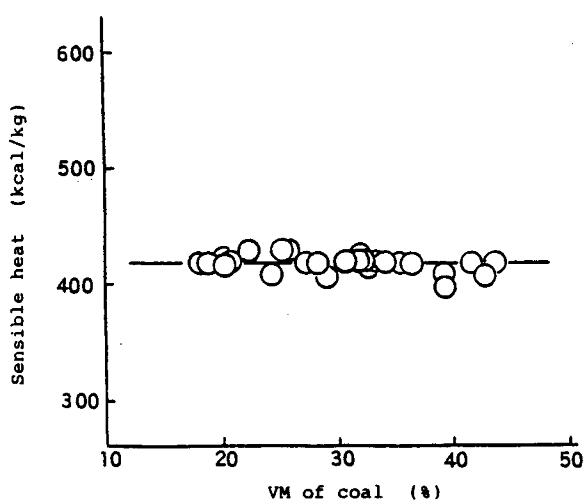

Figure 1. Relation between VM of coals and sensible heat

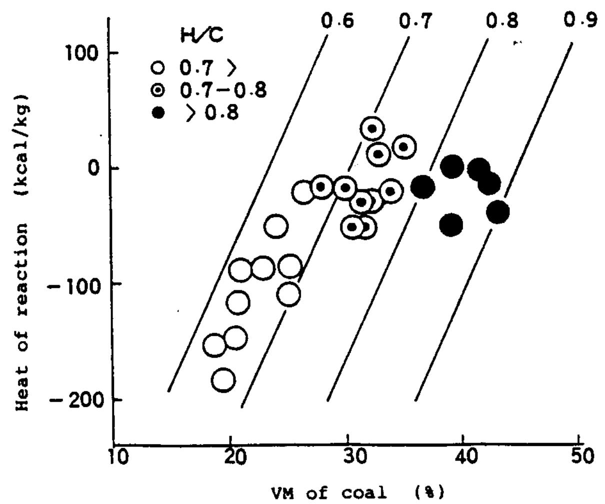

Figure 2. Effect of VM and atomic ratio (H/C) of coals on heat of reaction

Table 1. Characteristics of coal and Net-HC for main coals

Sample	Coal VM (%)	Coal H/C	Calory Sensible Heat (kcal/kg)	Heat of Reaction (kcal/kg)	Net-HC (kcal/kg)
Mettiki	20.7	0.65	420	-150	270
Fording River	22.5	0.65	420	-80	340
Black Water	26.6	0.67	420	-20	400
Pittston	30.4	0.72	420	-60	360
kellerman	31.4	0.73	420	-30	390
Lemington	33.3	0.77	420	10	430
Sufco	39.4	0.80	400	0	400
Miike	41.8	0.87	420	0	420