Mineral Matter and Rank Effects on the Self-Heating Rates of Callide Coal
(Poster Paper)

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Abstract

Borecore samples from two pits at Callide have been assessed using the R_{70} self-heating test. The highest R_{70} value recorded to date is 16.22°C/h in Pit 1, which is consistent with the subbituminous rank of the coal. Pit 2 has a lower maximum R_{70} value of 11.79°C/h for a similar ash content. This is due to an increase in the rank of coal in Pit 2. There is a strong negative correlation between ash content and self-heating rate in Pit 1 that is related to the presence of kaolinite in the coal acting as a heat sink. This relationship can be used to model the self-heating hazard of the pit. In Pit 2, quartz and siderite are present in the coal, but are less effective heat sinks for lowering the self-heating rate of the coal.

Introduction

The self-heating of coal is due to a number of complex exothermic reactions. Coal will continue to self-heat providing there is a continuous oxygen supply and the heat produced is not dissipated. The parameters that control a coal's propensity for self-heating have been the subject of many investigations. Some relationships between coal properties and self-heating rates have been published in previous studies using adiabatic techniques (Beamish et al., 2001; Ren et al., 1999; Humphreys et al., 1981; Vance et al., 1996). Most of these have confirmed effects of rank, maceral composition and moisture content of the coal. Much less is known about mineral matter effects on coal self-heating, other than the presence of pyrite is often cited as an accelerant of the process.

Adiabatic testing procedures are being used at The University of Queensland to study coal from the Callide Coalfield. This paper presents results from tests on core samples from two pits at Callide. These results show significant differences in self-heating rates related to coal rank and mineral matter composition.

Experimental

Coal Samples

The coal samples used in this study were obtained from a recent drilling program at Callide Coalfield, Queensland. To date samples from two pits have been tested for their self-heating propensity. The cores selected for testing were firstly wrapped in plastic cling wrap then aluminium foil and an outer layer of masking tape before being frozen on-site. The cores were then transported to The University of Queensland on ice in an esky. On arrival, the cores were transferred to a freezer for storage until adiabatic testing took place. These precautions were taken to preserve the intact core and minimise pre-oxidation effects before testing.

For testing in the adiabatic oven the core samples were halved longitudinally using a bandsaw. One half was rewrapped and returned to the freezer as a backup. The other half was crushed, ground and sieved to <212μm.

Adiabatic Testing Procedure

A full description of the adiabatic testing procedure is outlined in Beamish et al. (2000). However, it should be noted that a different drying oven and vessel has been incorporated into the current procedure for the drying process. Adiabatic testing with this new combination still exhibits very good repeatability and has increased sample throughput.

The adiabatic testing procedure essentially involves a 150g sample of the <212μm material, firstly being dried at 110°C, under nitrogen, in the drying oven for approximately 16-24 hours. Whilst still under nitrogen the coal is cooled to 40°C and transferred to the adiabatic oven. Once the coal temperature has equilibrated at 40°C under a nitrogen flow, oxygen is passed through the sample at 50ml/min. A data logger records the temperature rise due to the self-heating of the coal. The average rate that the temperature rises between 40°C and 70°C gives the self-heating rate index (R_{70}). This value indicates a coal's propensity for self-heating, and can be compared with the coal properties.

Ashing and XRD Analysis

At this stage a high temperature ash analysis has been conducted on all samples. To complement this data the samples have also been subjected to X-Ray Diffraction analysis to establish the mineral matter composition of the coal, as it is this and not the ash which will affect the self-heating of the coal.

Results and Discussion

R_{70} values obtained from adiabatic testing of the coal samples for the two different pits are shown in Table 1. The moisture content (% as-received), ash content (%, dry basis) and the dominant mineral matter type for each sample are also presented in Table 1. The as-received moisture is indicative of the subbituminous coal rank of the coal and the lower values for Pit 2 indicate the coal is slightly higher in rank than Pit 1. The samples from Pit 1 cover a significant ash content range from 9.8% to 62.2%. However, the samples from Pit 2 have a very narrow ash content range. The highest R_{70} value of 16.22 °C/h for Pit 1 is approaching the values obtained by Beamish et al. (2001) for similar rank New Zealand coals.

Table 1 Sample properties and self-heating rates for fresh borecores from Callide

Samples	Moisture (%, ar)	Ash (%, db)	Dominant mineral matter	R70 (°C/h)
Pit 1				
1	12.3	39.1	kaolinite*	5.98
2	9.0	62.2	kaolinite*	1.69
3	14.5	19.2	kaolinite*	11.66
4	14.1	16.1	kaolinite*	14.05
5	14.2	9.8	kaolinite*	16.22
6	11.9	28.4	kaolinite*	9.31
Pit 2				
1	13.7	11.2	quartz/siderite#	10.48
2	13.1	13.8	quartz/siderite#	11.21
3	13.4	12.0	quartz/siderite#	11.79
4	13.1	11.4	quartz/siderite#	11.09
5a	12.0	12.4	kaolinite*	8.41
5b	12.8	13.0	kaolinite*	7.99

* > 75% kaolinite; # > 60% quartz/siderite

Self-heating curves for samples 1, 2, 3 and 5 from Pit 1 are contained in Figure 1. These show a significant decrease in the initial rate of self-heating and increase in the time to thermal runaway (140°C) as the ash content of the coal increases. At 9.8% ash content it takes three hours to complete the adiabatic test, whereas at 62.2% ash content it takes 44 hours to complete the test. There is a strong negative correlation between ash content and R_{70} for the Pit 1 samples and this is shown in Figure 2.

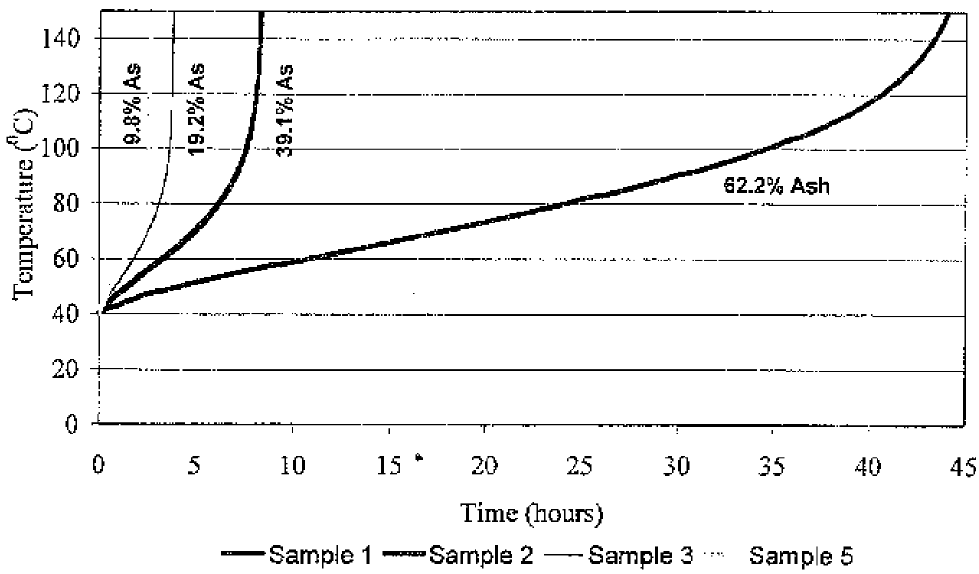

Figure 1. Self-heating curves for samples 1, 2, 3 and 5 from Pit 1.

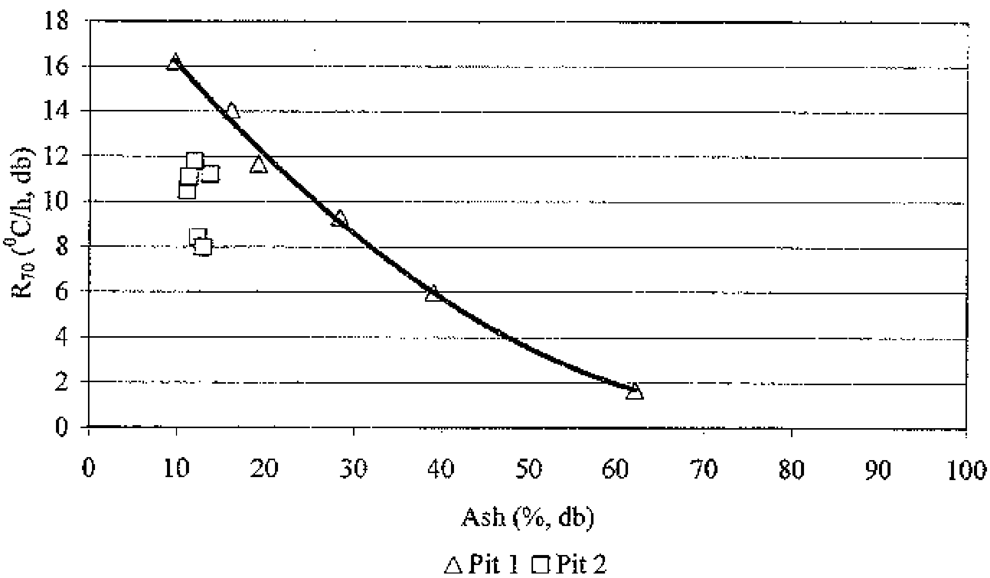

Figure 2. Relationship between ash content and self-heating rate of Pit 1 and Pit 2 coals.

The dominant mineral matter in the Pit 1 samples is kaolinite. Smith et al. (1988) discussed the thermal effects of additional mineral matter in coal and pointed out that assuming the additive is inert to the oxidiser, the additive acts as a heat sink. Consequently, the reaction rate is lowered, reducing the self-heating propensity of the coal. Humphreys et al. (1981) also proved this by adding ash to coals to test an equation for mineral matter free correction of the R_{70} value. Clearly, the kaolinite is acting as a natural inhibitor of self-heating in Pit 1.

The R_{70} values in Pit 2 are substantially lower than Pit 1 for the same ash content (Figure 2). This is due to the increase in rank of the coal in Pit 2 compared to Pit 1. Pit 2 samples also exhibit a more restricted ash range, however two R_{70} domains are evident (Figure 2). The higher R_{70} domain between 10 and 12 °C/h corresponds to a dominant mineral matter of quartz and siderite. The lower R_{70} domain at approximately 8 °C/h corresponds to a dominant mineral matter of kaolinite (similar to Pit 1). The difference in R_{70} between the two domains can be explained by the differences in heat capacity of the mineral constituents. At room temperature (25°C), the heat capacities of kaolinite, quartz and siderite are 950, 739 and 708 J/Kg/°C respectively. Therefore it can be seen that kaolinite is approximately 25% more effective as a heat sink than either quartz or siderite, and hence the lower R_{70} for sample 5 in Pit 2.

The mineral matter associations found in this study have significant implications for rating coals as to their propensity for self-heating. In Pit 1 a simplified correlation exists with ash content that could be used to model the self-heating hazard of the coal in advance of mining. The effects of change in mineral matter composition observed in Pit 2 make it possible to modify the predictive equation in Pit 1 in areas where mineral matter composition changes from kaolinite to quartz/siderite, although more testing is required to increase the confidence of this approach. It is interesting to note that the heat capacity of pyrite at room temperature is 517 J/Kg/°C. This implies that even if the pyrite in coal did not oxidise it is a poor heat sink and would not hinder coal self-heating as much as kaolinite, quartz or siderite purely on a thermodynamic basis.

Conclusions

Rigidly controlled sampling and testing procedures of fresh borecore from Callide Coalfield have been able to define significant inter- and intra-pit associations between coal composition and self-heating rates. Samples from Pit 1 display self-heating rates ranging from 30-90% higher than Pit 2 for the same ash content. This is due to Pit 1 being lower in rank than Pit 2.

The dominant mineral matter found in the core samples from Pit 1 is kaolinite (>75%). As the amount of kaolinite in the coal increases from an equivalent ash content of 9.8% to 62.2% the self-heating rate of the coal decreases from 16.22 to 1.69 °C/h. This is simply due to the kaolinite acting as a heat sink. The strong negative correlation obtained between ash content and self-heating rate enables pit modelling of the self-heating hazard in advance of mining using the geological database for the pit.

Changes in mineral matter composition found in the core samples from Pit 2 helps to distinguish two self-heating rate domains for this pit. The higher self-heating rates correspond to a quartz/siderite dominant mineral assemblage and the lower self-heating rates correspond to a kaolinite dominant mineral assemblage similar to Pit 1. These findings have significant implications for mining, transporting and storing of the coal. It is anticipated that additional testing of borecore samples from other pits across Callide Coalfield will help to confirm these mineral matter and rank effects found at Callide.

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