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# The effect of binder (coal tar and pitch) on coking pressure

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ABSTRACT

In order to develop a technology for reducing coking pressure, the effect of the addition of binder (coal tar and pitch) on coking pressure was investigated from the viewpoint of plastic coal layer permeability, internal gas pressure generated in a pilot scale oven and coke quality. We also studied the selective addition of binder to high coking pressure coal as a method to decrease coking pressure effectively. In the plastic coal layer permeability experiment, the addition of binder greatly decreases $\Delta P_{max}$ of high coking pressure coal HP and fine solid binder reduces $\Delta P_{max}$ more than coarse solid binder. The addition of binder decreases internal gas pressure and the finer the particle size of solid binder is, the smaller the internal gas pressure becomes. Moreover, in the case of the same addition ratio of binder, the selective addition of binder to high coking pressure coal can reduce coking pressure more effectively than the uniform addition. The addition of binder to coal blend is promising in the point that it can improve coke quality as well as reduce coking pressure.

## 1. Introduction

Coking pressure, which is defined as a load exerted on coke oven wall during carbonization, has been considered one of the most important subjects for commercial cokemaking process. Since stable coke oven operation is hindered by hard pushes or stickers caused by the generation of high coking pressure, it is of great importance to control and reduce coking pressure. Therefore coking pressure have been studied widely from the viewpoint of the mechanism of coking pressure generation, the measurement methods of internal gas pressure in coal plastic layer which is the cause of coking pressure both in a laboratory scale and a commercial scale, the effect of coking pressure on coke oven operation and coke quality and the technology to control and decrease coking pressure [1–18].

On the other hand, in the face of the future depletion of hard coking coal that forms high-strength coke, it is of great importance to develop a technology to increase the use of semi-soft coking coal that produces coke of lesser quality as coal blend for metallurgical coke production. Semi-soft coking coal is inferior in caking property such as dilatation to hard coking coal, however, increasing bulk density can make up for the lack of dilatation and contribute to the production of high strength coke [13]. To cope with this problem, dry coal charging processes such as CMC (Coal Moisture Control) [19] and DAPS (Dry-cleaned and Agglomerated Precompaction System) [20,21] have been developed and commercialized by Nippon Steel and Sumitomo Metal Corporation. With the coal moisture being reduced to 5–7 mass% with CMC and 2–4 mass% with DAPS, the advantages of less heat consumption for carbonization, higher productivity and more usage of semi-soft coking coals were gained. A decrease in coal moisture leads to an increase in coal bulk density in the coke oven chamber, which contributes to the improvement of coke quality on one hand, however, on the other hand, increases coking pressure. Therefore, it is quite important to control coking pressure in the dry coal charging processes [13].

The authors have studied the technologies to reduce coking pressure by adjusting the blending ratio of low-rank semi-soft coking coal [13] and selective crushing of high coking pressure coal [17]. As coke oven batteries are aging and become more fragile, further development of the technology to decrease coking pressure more is demanded. Moreover, the deterioration of coke oven batteries is likely to reduce the productivity of coke oven. In order to meet the shortage in supply of coke and to increase coke production, coke oven managers choose to increase the blending ratio of low volatile coal, some of which generates dangerously high coking pressure. Therefore, the technology to decrease coking pressure as well as increase the blending ratio of low volatile high coking pressure coal is demanded.

One way to reduce coking pressure is to add inert material such as coke fines in the blend [1,2,16,18]. While coke fines greatly reduce coking pressure, they are likely to worsen coke quality. Then additives which can reduce coking pressure without worsening coke quality are favorable.

Coal tar pitch and other additives are known to improve caking property of coal and coke quality and have been studied as a technology to increase the use of semi-soft coking coal. As for an additive for improving coal caking property (hereinafter referred to as a binder),

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**Table 1**
Characteristics of the coals.

| Coal | Proximate analysis (mass% db) | | Dilatometry | Gieseler plastometry | | | | Petrographic analysis | |
|---|---|---|---|---|---|---|---|---|---|
| | VM | Ash | Total dilatation (vol.%) | Maximum fluidity (log MF/ddpm) | Softening temp. (°C) | Max. fluidity temp. (°C) | Resolidification temp. (°C) | Reflectance (%) | Total inerts (%) |
| HP | 18.4 | 9.4 | 50 | 1.17 | 454 | 487 | 507 | 1.69 | 22.4 |
| C1 | 19.3 | 9.2 | 63 | 2.09 | 427 | 473 | 503 | 1.59 | 37.0 |
| C2 | 20.6 | 9.7 | 24 | 1.20 | 436 | 473 | 495 | 1.43 | 42.3 |
| C3 | 21.0 | 9.5 | 29 | 1.68 | 429 | 470 | 494 | 1.40 | 37.9 |
| C4 | 21.1 | 9.7 | 105 | 2.61 | 418 | 465 | 499 | 1.44 | 32.8 |
| C5 | 22.3 | 9.4 | 41 | 1.69 | 426 | 465 | 492 | 1.30 | 37.4 |
| C6 | 24.0 | 8.3 | 99 | 2.96 | 407 | 461 | 497 | 1.27 | 38.0 |
| C7 | 24.1 | 8.9 | 95 | 2.95 | 408 | 454 | 493 | 1.22 | 36.9 |
| C8 | 25.1 | 8.9 | 66 | 2.16 | 420 | 444 | 472 | 1.15 | 32.1 |
| C9 | 32.9 | 6.8 | 182 | 4.10 | 387 | 446 | 474 | 0.95 | 21.7 |
| C10 | 35.1 | 7.1 | 40 | 2.29 | n.a. | n.a. | n.a. | 0.68 | 26.9 |
| C11 | 35.4 | 9.1 | 34 | 2.05 | 394 | 435 | 459 | 0.78 | 26.6 |

**Table 2**
Blend design and carbonization conditions for internal gas pressure measurement tests.

| Coal | Blend A | Blend B | Blend C | Blend D | Blend E | Blend F | Blend G |
|---|---|---|---|---|---|---|---|
| HP | 20% | 10% | 20% | 25% | 10% | 33% | 20% |
| C1 | 10% | | | | | | 25% |
| C2 | | | | | | | |
| C3 | | | | 25% | | | |
| C4 | | | | | 20% | | |
| C5 | 15% | 10% | | | | | |
| C6 | 15% | 30% | 30% | | | | |
| C7 | | | | | | 33% | 25% |
| C8 | | | | | 20% | | |
| C9 | | | | 25% | | | |
| C10 | | | | 25% | | | |
| C11 | 40% | 50% | 50% | | 50% | 34% | 30% |
| Weighted average property | | | | | | | |
| VM (mass% db) | 26.7 | 29.0 | 28.6 | 26.9 | 28.8 | 26.1 | 25.1 |
| Ash (mass% db) | 9.1 | 8.9 | 8.9 | 8.2 | 9.2 | 9.1 | 9.1 |
| Total dilatation (vol.%) | 51 | 56 | 57 | 75 | 56 | 59 | 60 |
| Maximum fluidity (log MF/ddpm) | 1.96 | 2.20 | 2.15 | 2.31 | 2.10 | 2.06 | 2.11 |
| Reflectance (%) | 1.19 | 1.07 | 1.11 | 1.18 | 1.08 | 1.23 | 1.27 |
| Total inerts (%) | 30.1 | 30.7 | 29.2 | 27.2 | 28.5 | 28.6 | 30.9 |
| Particle size (−3 mm%) | 85 | 85 | 85 | 85 | 85 | 85 | 80 |
| Bulk density (kg/m$^3$) | 850 | 850 | 850 | 850 | 850 | 750 | 750 |
| Binder | CP1 | CP1 | CP1 | CP1 | CP1 | CP3 | CP4 |
| Internal gas pressure without binder addition (kPa) | 22.8 | 3.1 | 7.6 | 23.5 | 9.4 | 8.9 | 6.4 |

**Table 3**
Characteristics of the binders.

| Binder | Softening point (°C) | Quinoline insoluble (%) | Toluene insoluble (%) |
|---|---|---|---|
| CP1 | – | 4 | 7 |
| CP3 | 32 | 7 | 15 |
| CP4 | 100 | 18 | 34 |
| PP | 240 | 20 | 45 |

many laboratory tests and some industrial operations have been made for coal tar pitch and other additives and it has been shown that the caking property and coke strength can be increased [1,22–26]. There have been many studies on the effect of various binders such as solvent refined coal (SRC) [27,28] produced by thermally reacting coal with hydrogen solvent, Hyper Coal [29] and thermal extracts from coal [30–32] on coal caking property and coke strength. However, as far as the effect of binder on coking pressure is concerned, although it has been reported that the addition of coal tar pitch increased coking pressure [1], it is still unclear.

Therefore, in this report, first we focused on the plastic coal layer permeability which is considered to be one of the dominant factors of coking pressure and investigated the effect of binder on the plastic coal layer permeability. Next, we investigated the effect of binder on internal gas pressure by using a pilot coke oven. Finally, we studied the selective addition of binder to high coking pressure coal as a method to decrease coking pressure effectively.

## 2. Experiment

### 2.1. Samples

The characteristics of the samples used in the experiment are shown in Table 1. Twelve coals (coal HP, coals C1 to C11) with the volatile matter ranging from 18.4 to 35.4% were used. Coal HP is a high coking pressure coal which shows maximum coking pressure of 160 kPa (at the bulk density of 825 kg/m$^3$) and 60 kPa (at the bulk density of 700 kg/m$^3$) in a pilot scale movable wall oven, corresponding to coal A in the previous study [16]. Seven coal blends (A to G) were prepared by crushing each coal and blending as shown in Table 2. Average characteristics of the coal blends are shown in the table. The characteristics of the binders used in the experiment are shown in Table 3. Binders