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Development of Dry-cleaned and Agglomerated Pre-compaction System (DAPS) for Metallurgical Cokemaking

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Abstract

In the field of cokemaking, the Japanese steel industry has concentrated research and development efforts on objectives such as effective use of coal resources, improvement in coke quality and productivity and decrease in heat consumption. The dry-cleaned and agglomerated pre-compaction system (DAPS), commercially applied at Oita Works in 1992, is a typical technology for effective use of coal resources. The process makes it possible to increase the mixing ratio of non- or slightly-caking coals by approximately 20% from that by the DAPS process without deteriorating coke strength.

1. Introduction

In the field of cokemaking, the Japanese steel industry has concentrated research and development efforts on objectives such as effective use of coal resources, improvement in the coke quality and productivity of coke ovens and decrease in heat consumption. The dry-cleaned and agglomerated pre-compaction system (DAPS) is a typical technology that aims at effective use of coal resources.

Nippon Steel Corporation developed the process aiming mainly at enhancing the coke strength even with increased use of low quality coal brands by agglomerating fine coal and improving environmental friendliness of cokemaking by suppressing the dust emission at the charging of coal into coke ovens, and applied the technology at Oita Works in 1992[1,2]. The DAPS was developed as an improvement of the conventional coal moisture control (CMC) process[3], which reduces coal moisture to roughly 5 to 6% before charging into coke ovens. The DAPS equipment is continuing smooth and stable operation, significantly contributing to the effective use of coal resources[4,5].

This paper presents the development of the DAPS as an example of the R&D activities of Nippon Steel in the field of cokemaking.

2. Need for Agglomeration of Fine Coal

Coal drying technologies such as the CMC process have been developed and commercially applied as the pretreatment of the feedstock of coke ovens aiming at reducing heat consumption, enhancing coke quality and improving the productivity of the plant.

The CMC process reduces the moisture content of feedstock coal from 9 - 10% to 5 - 6% utilizing the heat of the exhaust gas from the ovens, and thus reduces the heat consumption of cokemaking by 60 to 80 Mcal per ton of coal[3]. However, if the coal moisture is lowered excessively, fine coal is emitted to the environment during the transportation and charging into coke ovens, and this leads to problems such as the deterioration of work environment, operation trouble due to carbon deposition on coking chamber walls and poor quality of tar, a by-product of cokemaking.

To evaluate the dust occurrence during the coal transportation from a coal dryer to coke ovens, an investigation was made into the relationship between the coal moisture and dust occurrence using a dust occurrence tester[1]; **Fig. 1** schematically illustrates the tester. Sample coal 1 kg in weight was put into the tester from the top, the coal particles floating inside the tube were sucked by a blower until the tube inside became visually clear of the particles, and the quantity of the particles collected was measured.

Fig. 2 shows the results: the dust occurrence increased as the moisture of coal decreased. **Photo 1** shows photomicrographs of coal grains with different moisture contents[1]. With a high moisture content, fine particles either adhere to coarse grains or cohere with each other to form pseudo-particles with water serving as a binder, and the dust occurrence is low. On the other hand, when the coal is dried for pretreatment, the pseudo-particles disintegrate into fine

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particles and the dust occurrence increases. **Fig. 3** shows the relationship between the fraction of fines 74 μ m or less in size in feedstock coal and dust occurrence[1]. The graph shows a close correlation between the two, and it was presumed that the coal particles 74 μ m or less in size were mainly responsible for the dust occurrence.

From the above, it was concluded that in order to operate the coal preheating process stably it was important to agglomerate fine coal by pressing to reduce the dust occurrence[6].

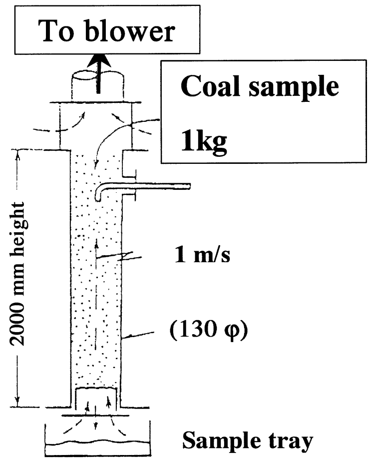

Fig. 1 Experimental apparatus for dust occurrence measurement

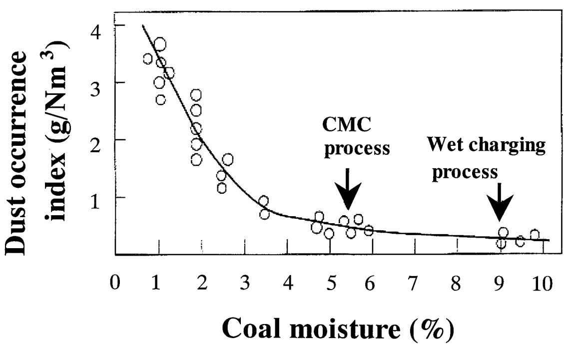

Fig. 2 Relationship between dust occurrence index and coal moisture

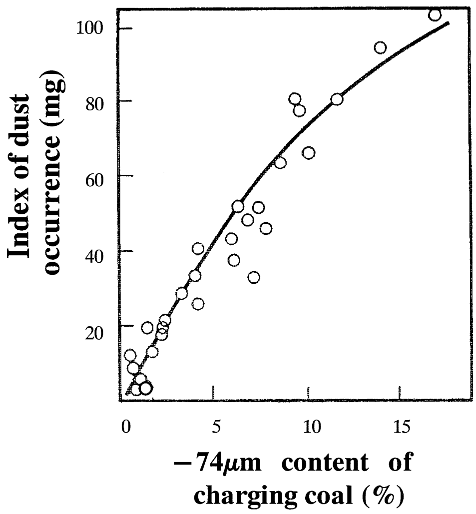

Fig. 3 Relationship between dust occurrence index and content of − 74 μ m of charging coal

3. Development of DAPS

3.1 Influence of agglomeration of fine coal over coal properties

Fine coal forms during the exploitation, screening and washing at mines, transportation to steelworks, and crushing at cokemaking plants. The fine coal that forms during the exploitation, screening, washing and transportation oxidizes and its caking property deteriorates because the surface area is large and the time of exposure to the atmosphere is long. On the other hand, the size of the fine coal that forms during the crushing tends to be small and its dilatation under heating is small.

Of the micro-components of coal, vitrinite, which has a good caking property, easily turns into fines, and for this reason, it tends to concentrate in fine coal. **Fig. 4** shows the relationship between the bulk density and dilatation of fine coal 0.3 mm or less in size[1,2]. The graph indicates that it is possible to recover the caking property of fine coal by agglomerating it to a high density. From the above, it became clear that compaction of fine coal into agglomerate makes it possible to improve its caking property, enhance the bonding of coal grains during the cokemaking process, and at the same time, suppress the dust occurrence due to fine coal[6-8].

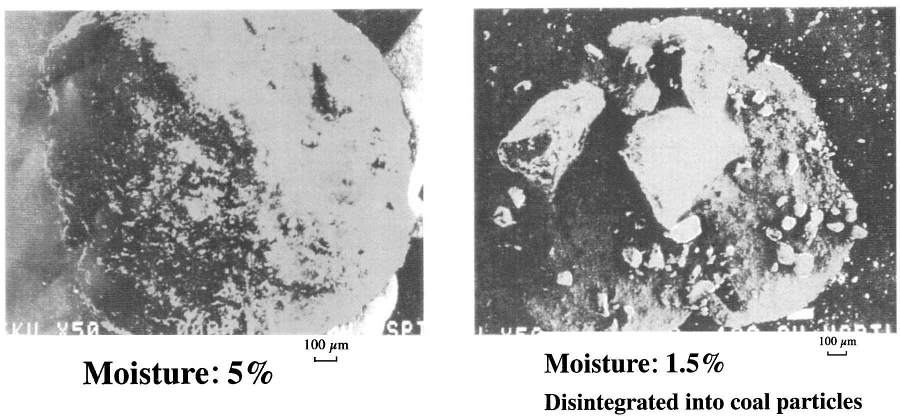

Photo 1 Coal particles in charging coal (SEM)

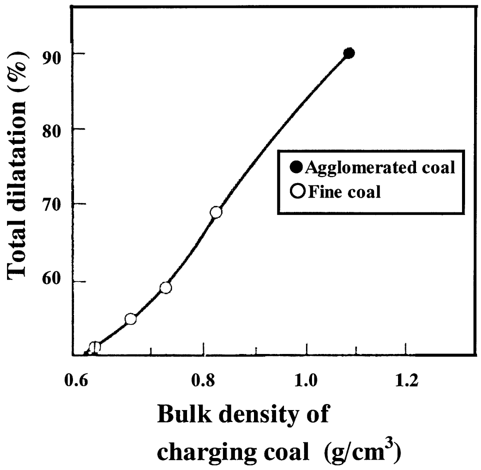

Fig. 4 Relationship between bulk density and total dilatation coefficient of fine coal

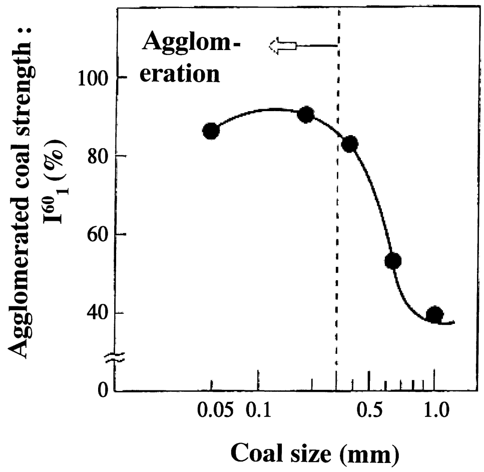

Fig. 6 Relationship between agglomerated coal strength and coal size

3.2 Drying and classification of fine coal

The application of the fluidized bed method for the drying and classification of fine coal in cokemaking was studied as the first case in the world, and a fluidized-bed coal dryer was developed that is capable of efficiently drying and classifying roughly 6,800 t/day of coal (see **Fig. 5**)[4,5].

3.3 Agglomeration of fine coal

Methods such as pelletizing and briquetting are commonly employed to agglomerate fine coal, but these methods use water or a binder. In the development of the DAPS, methods for agglomerating fine coal in dry, without the addition of a binder, were studied, and a roll compactor was selected as the agglomerating apparatus[1,2].

Coal agglomerate formed by a roll compactor was put into an I-type drum tester, after 60 revolutions in the tester, the specimen was classified using a 1 mm screen, and the strength of the agglomerate was evaluated in terms of the fraction of the oversize. **Fig. 6** shows the relationship between the size of coal and the strength of coal agglomerate: the strength of the agglomerate decreased as the grain size of coal increased[1,6,7]. The principal reason for this is presumably that, as the grain size becomes larger, while the compressibility of coal increases, the number of contact points between coal grains per unit volume decreases, and the cohesion strength between the grains decreases owing to their cracking. Fig. 6 indicates that the strength of the agglomerate tends to decrease significantly when the coal grain size is 0.3 mm or larger[1,2]. Thus, it was understood that it was possible to produce strong coal agglomerate without using a binder by press forming fine coal 0.3 mm or less in size.

In addition to the above, for the design of the commercial equipment, a studied was done on issues such as the pressure of the press forming, the diameter of the forming rolls and the deaeration conditions for the forming[7,8].

4. Development of Commercial Equipment for DAPS

4.1 Process of DAPS

The DAPS was developed as a new coal pretreatment process for cokemaking to enhance coke strength and suppress dust occurrence to improve the environment friendliness of cokemaking by drying coal, separating fine coal from lump coal and forming the fine coal into agglomerate in dry. **Fig. 7** outlines the process flow of the DAPS and **Table 1** the main specification of the equipment[4]. By the DAPS process, coal is dried in a fluidized-bed dryer, fine coal grains 0.3 mm or less in size are separated from coarser grains by the gas flow, collected by a cyclone separator, formed into agglomerate by a roll compactor, mixed with the coarser grains, and charged into coke ovens. The mass fraction of the fine grains is approximately 30%. The capacity of the fluidized bed dryer is 284 t/h, and three units of roll-compactor type forming machines (forming roll diameter 1200 mm, width 910 mm, capacity 28.4 t/h each) are provided[4].

The charging density of coal after the commissioning of the DAPS

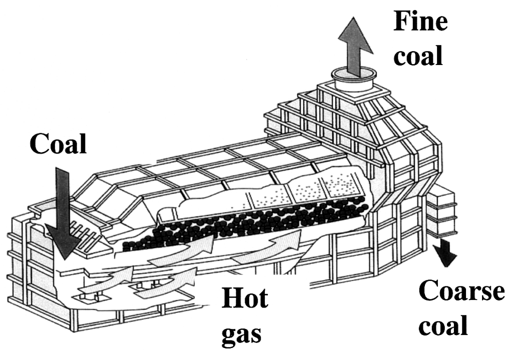

Fig. 5 Outline of fluidized bed dryer

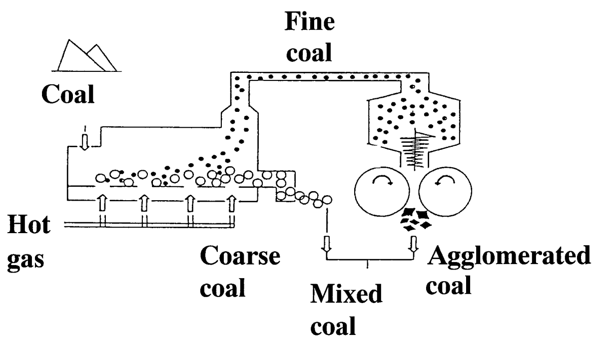

Fig. 7 Process flow of DAPS

Table 1 Main specification of DAPS

Main apparatus	Main specification
Fluidized bed dryer	284 t/h, Coal moisture: 9% → 1.8%
Hot gas generator	2930 × 10^4 kcal/h
Fine coal hopper	100 m^3
Briquetting machine	28.4 t/h, 3 units

equipment is 0.80 t/m^3; an even density distribution in a coking chamber has been maintained. In addition to suppressing the dust occurrence, the DAPS has improved the caking property of fine coal by increasing its bulk density[1,4].

4.2 Coke strength improvement effect

To evaluate the coke strength improvement effect of the DAPS, a comparison was made into the coke produced using the DAPS (hereinafter called the DAPS coke) and that produced using the conventional CMC process (hereinafter called the CMC coke) using the same blending of material coals; here the DI^{150}_{15} (under JIS K 2151) was used as the indicator of the strength. The strength of the DAPS coke proved to be markedly better than that of the CMC coke: the DI^{150}_{15} was higher by 1.5 points and the coke strength in reduction (CSR) by 4.5% (see **Figs. 8** and **9**)[1,4,5].

4.3 Mechanisms of coke strength improvement

The mechanisms of coke strength improvement by the DAPS are as follows[1,2]:

(1) Decrease in coke porosity and increase in cohesion strength between grains due to increased charging density

A comparison between the DAPS coke and CMC coke demonstrated that, owing to a higher charging density by the DAPS, the porosity of the former was smaller than that of the latter by approximately 3%. The higher charging density makes the distance between coal grains smaller, and this improves the cohesion strength of coal grains.

(2) Improvement in CSR due to lower CO_2 gas reactivity of coke

The increase in the CSR of the DAPS coke was due to a decrease in the CRI (an index of the reactivity of coke with CO_2) and the increase in the drum strength[8]. Using a theremobalance, a comparison was made of the DAPS coke with the CMC coke in terms of the reactivity with CO_2 and found that the reactivity of the DAPS coke was lower than that of the CMC coke (see **Fig. 10**)[1,2].

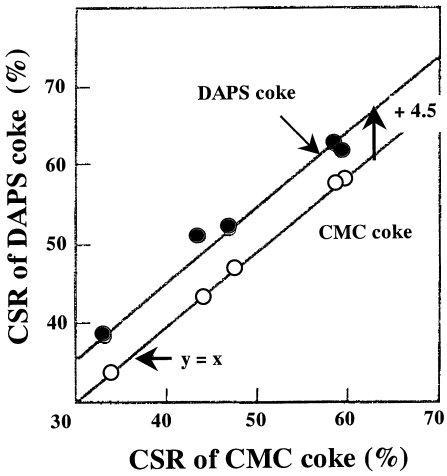

Fig. 9 Effect of DAPS process on CSR

The DAPS makes it possible to increase the mixing rate of non- or slightly-caking coals by 30% from that by the conventional wet coal charging process, and by approximately 20%, from that by the CMC process, without deteriorating the coke strength (see **Fig. 11**)[1,2].

4.4 Productivity enhancement and energy saving effects

As stated earlier, the charging density of coal with the DAPS is approximately 0.80 t/m^3, and together with the reduction of coking time due to the decrease in coal moisture, the developed process improves productivity by 21% compared with the conventional wet coal charging process[4,5].

The DAPS decreases the moisture content of coal to lower than that by the CMC process and improves the productivity of coke ovens, and as a result, it decreases the heat consumption of cokemaking: at the same production rate, the heat consumption decreases by approximately 100 Mcal per ton of coal from that by the conventional wet coal charging process, which means an energy saving effect of approximately 15% (see **Fig. 12**)[4,5].

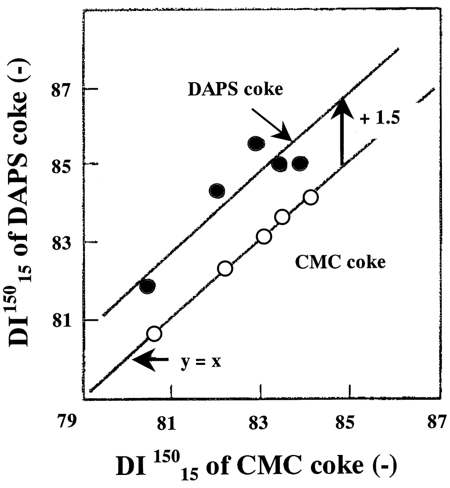

Fig. 8 Effect of DAPS process on DI^{150}_{15}

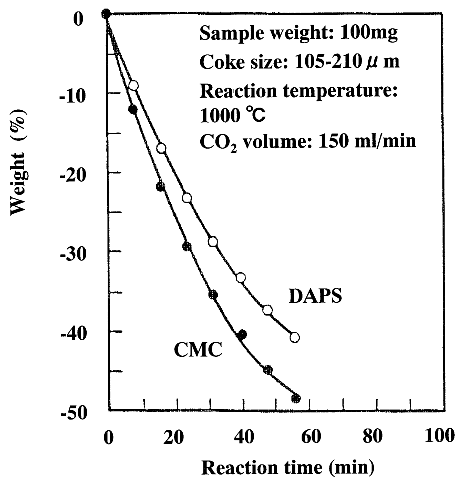

Fig. 10 Comparison of CO_2 gas reactivity between CMC-coke and DAPS-coke

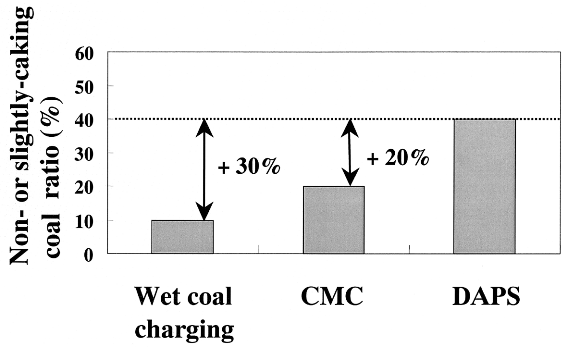

Fig. 11 Comparison of non- or slightly-caking coal ratio in charging coal

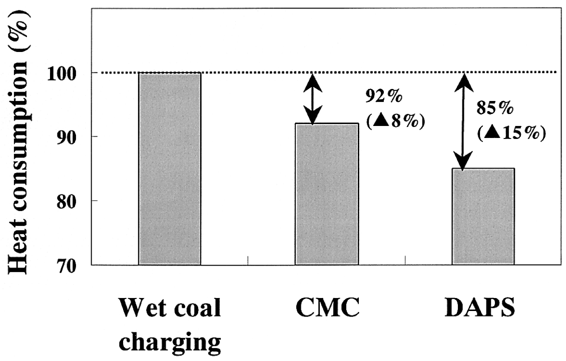

Fig. 12 Comparison of heat consumption

5. Conclusion

The DAPS, a new cokemaking process to agglomerate fine coal, was developed and commercially applied at Nippon Steel's Oita Works in 1992. The technology greatly contributes to the efficient use of coal resources and energy.

About 14 years have passed since the commencement of the fundamental technical development to the commissioning of the first commercial plant by the technology, and it is now widely known by the name of the DAPS process. Since the resources of high-quality coking coal are expected to become increasingly scarce, the DAPS technology will prove highly effective in the utilization of non- or slightly-caking coal resources.

References

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