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Recent developments in cokemaking technologies in Japan

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ABSTRACT

Recently Japanese cokemaking industry have faced a lot of problems such as price increase and quality deterioration of metallurgical coal, coke oven aging and social demand for environmental contribution. To meet these challenges, Japan has developed various technologies, such as coal pre-treatment technology for utilizing low grade semi-soft coking coal (e.g. CMC, DAPS and SCOPE21), diagnosis and repair apparatus for coke oven chamber wall and a method to turn waste plastics into chemical raw materials using coke ovens. In this report, these progresses of cokemaking technology in Japan are reviewed.

1. Introduction

After 2000, the global steel industry changed drastically [1]. Firstly, iron ore suppliers were reorganized into three big companies, namely VALE, Rio Tinto and BHP-Billiton, together accounting for roughly 70% of the world iron ore supply. Secondly, world steelmakers were also reorganized into larger companies, Arcelor in 2002, JFE in 2002, Arcelor Mittal in 2006 and NSSMC (Nippon Steel and Sumitomo Metal) in 2012. Under the circumstances, Japanese cokemaking industry has faced three major problems. The first is availability of hard-coking coal. Japan depends on imports for coking coal for steel production. Before 2000, coking coal price and semi-soft coking coal price had been 50 and 40 $/t respectively for a long period of time. However, due to the strong demand for steel caused by the expansion of the global economy, the prices of raw material have increased drastically and now the coal prices are over 100 $/t. In accordance with the price increase, the quality of coking coal is deteriorating. Japanese steel industry needs to develop cokemaking technology to meet the challenge of low grade raw material. The second is the problem of aging coke oven. Many of the coke oven batteries in Japan were constructed in 1964 and 1973 which was the era of high-speed economic growth in Japan. The average age of these old coke oven batteries is now 46 years and it is very important to develop coke oven life extension technology. The third is the demand for CO_2 reduction.

To cope with these problems, Japan has developed various technologies. This article will conduct a general review of these newly developed cokemaking technologies. Mainly reported are the development and commercialization of 1) coal pre-treatment technology for utilizing low grade semi-soft coking coal (CMC, DAPS and SCOPE21), 2) diagnosis and repair apparatus for coke oven chamber wall (DOC) and 3) a method to turn waste plastics into chemical raw materials using coke ovens.

2. Utilization of semi-soft coking coal

Fig. 1 schematically shows the formation process of the pore structure of coke [2,3]. At the time of charging coal into a coking chamber, coal grains contact with each other only partially. When the temperature rises to roughly 400 °C, the grains soften and expand to fill the voids between themselves. When the expansion of the coal grains is larger than the volume of the voids between them, they fuse with each other in large contact areas to form strong bonding. On the other hand, when the expansion is smaller than the void volume, coal grains cannot form strong bonding between them, leaving incomplete filling of inter-particle void. Moreover expansion of coal particles is not restricted and connected pores are formed. Both inter-particle void and connected pores become defects in coke and the strength of the product coke is low. Generally speaking, hard coking coal show sufficient dilatation and inter-particle void is filled with coal swelling, then the coke becomes strong. On the other hand, semi-soft coking coals show insufficient dilatation and inter-particle void is not filled, then the coke becomes weak. Thinking as above, the initial bulk density and the dilatation property of coal are important for the fusion of coal grains. It is possible to produce strong coke by charging semi-soft coking coal showing insufficient dilatation at high bulk density instead of charging hard coking coal showing sufficient dilatation at low bulk density.

NSSMC developed dry coal charging processes for coke production. In coke oven, heat supplied by conduction is used for evaporating water, which is not energy efficient. In Japan, where energy cost is expensive, coal pre-treatment technology has been studied and developed

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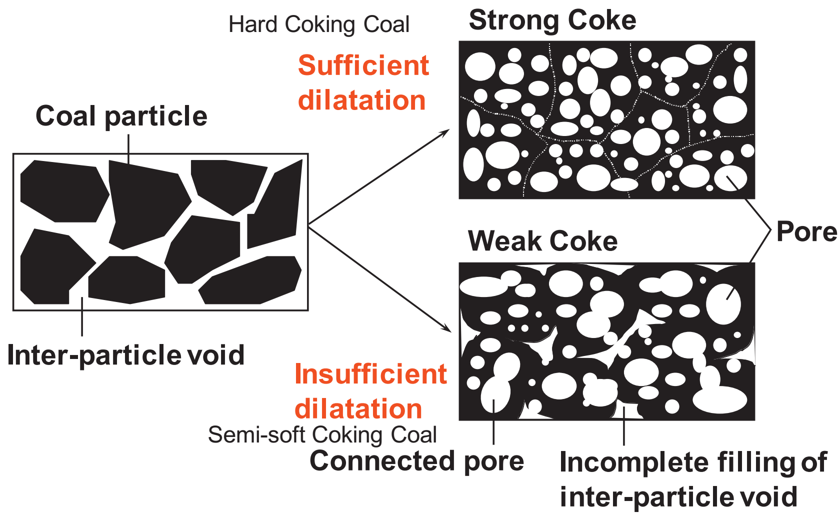

Fig. 1. Coal expansion and pore formation.

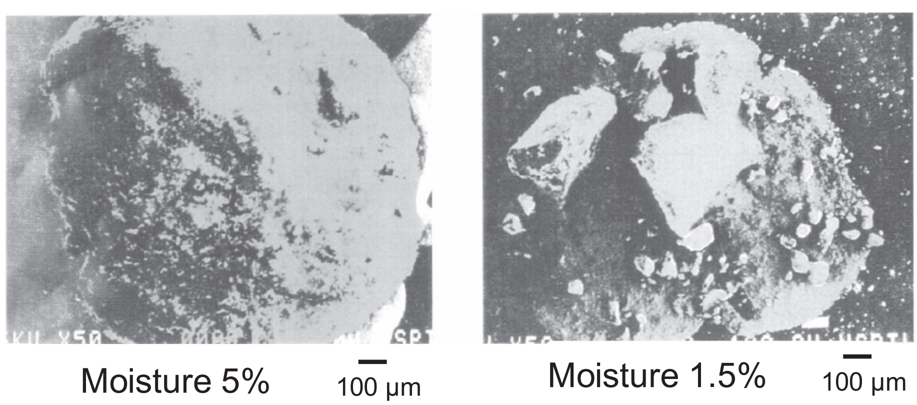

Fig. 2. Photographs of coal particles with different moisture contents.

to improve energy efficiency. The basic concept is to dry coal before it is charged into coke oven chamber. Two typical examples are CMC (the coal moisture control) [4] and DAPS (the dry-cleaned and agglomerated pre-compaction system) [5–7]. In CMC, coal is dried in steam tube dryer and the moisture decreases from 10% to 5–6%. The lower limit of the moisture in CMC process is determined by the emission level of coal fine dust. Fig. 2 shows the photographs of coal particles with different moisture contents [7]. With a high moisture content (5%), water functions as a binder and fine coal particles either adhere to the surface of coarse particle or cohere with each other to form pseudo-particles. On the other hand, when the coal is dried to the moisture of 1.5%, the fine coal particles come off from coarse particle and pseudo-particle

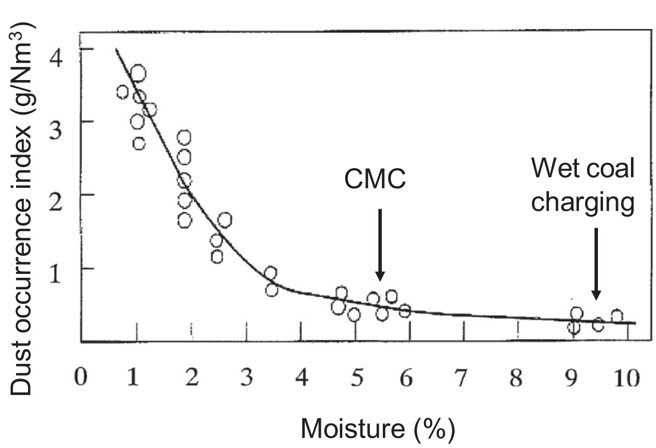

Fig. 3. Relationship between coal moisture and dust occurrence index.

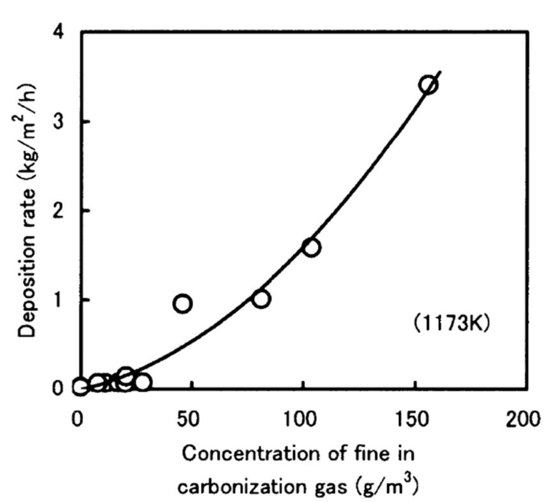

Fig. 4. Relationship between concentration of coal fine in carbonization gas and carbon deposition rate.