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New Technologies for Prolonging Coke Oven Life*

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New technologies were developed to protect coking chamber bricks from damage caused by hard-deposited carbon. A glass coating on the wall bricks and a wall cleaner installed on a pusher ram are used to prevent carbon from being deposited to the wall bricks. Coating can be carried out in a few minutes via a throughwall chamber with a special glaze that is applied by a newly developed spraying device. The glazed layer is automatically cleaned by a high-velocity air blast during coke pushing. The life of the glassy layer is estimated to be over two years. A supplementary burner system at end flues and a pressure control system at goosenecks were also developed to prevent pushing emissions and stack emissions respectively.

1 Introduction

More than half of the coke batteries presently in operation in Japan have already been in use for 25 years or more and it is expected that a decrease in productivity due to the deterioration in refractory brickwork and environmental problems will become increasingly serious in the future[1,2]. In recent years, coke oven life has been extended owing to advances in the flame gunning repair techniques for coking chamber walls[3-5], yet oven damage has been steadily progressing as refractory brickwork ages. Therefore, it is urgent to develop techniques for both preventing oven damage and making refractory repairs. However, there have been few reports from this viewpoint, with most discussions focusing on the enhancement of operating management and refractory maintenance in the field.

Against this background, this paper examines the challenges posed in the prevention of oven damage and the environmental problems arising from the deterioration of refractory brickwork. It also reports on a technique for oven life extension, which was put into practical use in the coke batteries at the Mizushima Works.

2 Challenges in Oven Life Prolongation

2.1 Oven Life

It is difficult to uniformly describe the life of all coke ovens, since many ovens apparently become unproductive in a short time and the authors consider that the great factor which determines oven life is the environmental problems. Since oven damage is closely related to environmental pollution, as will be discussed later, the authors believe that oven life can be extended by steadily carrying out environmental improvements and refractory repairs while preventing oven damage.

2.2 Causes of Oven Damage and Challenges

The most important part of the coke oven is the coking chamber and the direct cause of the damage to wall bricks is mainly the abnormal wall pressure that occurs during coke pushing. In actual ovens, the phenomenon whereby coke cannot be pushed due to abnormal wall pressure is called sticker. Nishioka et al. ascertained by model experiments that abrupt changes in wall pressure are produced when obstacles of more than 10 mm are present on the oven wall and considered the main causes in actual ovens to be carbon deposits and cracks in wall bricks. Carbon deposits are generated during carbonization and form layers over a long time, becoming hard-deposited carbon. Since the cracks in wall bricks provide especially hot spots, the rate of carbon deposition, which has been estimated to be about 0.2 mm/d in a laboratory study, is quite high[6]. According to one calculation[7], the deposition rate in 15 mm deep cracks, for example, is 1.1 times the level on the surface.

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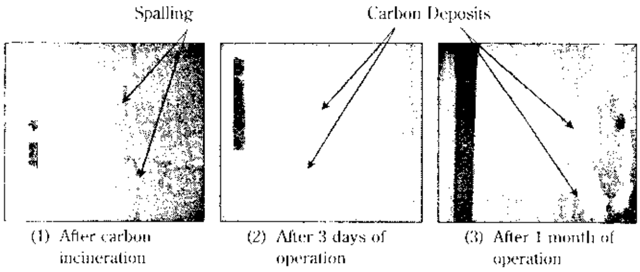

Photo 1 Carbon deposits on the oven wall

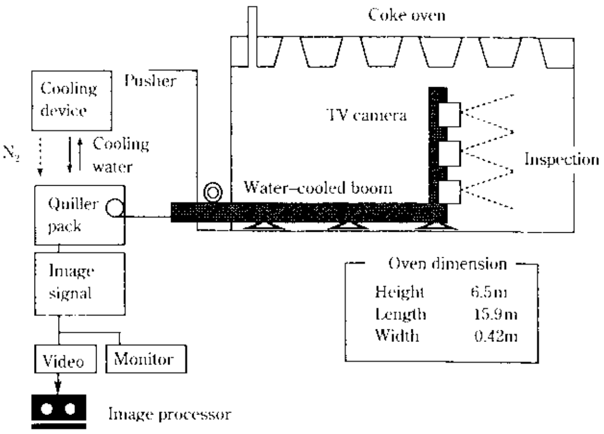

Fig. 1 Oven wall video-inspecton system

Photo 1 shows an example of carbon deposition photographed using the diagnostic device[8] shown in **Fig. 1**, which was developed to observe the damage to oven walls and the condition of carbon deposits. From the results of an image analysis it was estimated that carbon deposition begins mainly from the cracks in wall bricks, growing to 10–20 mm within a month. As shown in Photo 1, carbon is widely distributed and it can be easily thought that this causes sticker. The occurrence of sticker increases not only wall pressure, but also the damage to oven walls due to the extra work required for discharging the stuck coke. In other words, it might be thought that carbon deposits, sticker and brick damage are correlated to each other, forming a vicious circle as shown in **Fig. 2**.

Usually, carbon burning is conducted in an empty oven in order to remove carbon deposits. In this work, the coking chamber is kept empty and carbon in burned by longtime natural drafts. Although production stops while the ovens are not in operation, the greatest disadvantage lies in the fact that the cooling of bricks has a tremendous impact in the areas with no carbon deposits, generating open joints, fissures and cracks. In order to compensate for this disadvantage, a method for shortening the carbon burning time has been developed. In this method, forced drafts generated using a large-volume air blower[9,10] are used. However, to selectively burn only

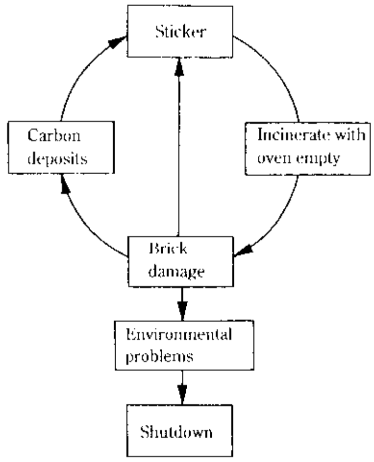

Fig. 2 Vicious circle for shortening coke oven life

carbon deposits is still difficult and it may be impossible to completely eliminate open joints or the necessity for carbon burning in an empty oven.

If such oven damage progresses, irregularity in wall temperature distribution generates green coke, resulting in an increases in emissions during coke pushing. In open joints of bricks, raw gas leaks from the coking chamber into the heating flue, causing incomplete combustion. As a result, generated soot accumulates in the regenerator, etc., and also generates black smoke from the stack, thus polluting the air. It may be said, therefore, that the most important challenge in oven life extension is to end the vicious circle shown in Fig. 2.

3 Techniques for Preventing Carbon Deposition

Carbon deposition can be prevented by using both a technique for rapid glass coating of the silica brick surfaces of a coking chamber wall and a technique for the automatic cleaning of the coating surfaces for each coke pushing operation. These techniques are described below.

3.1 Glass Coating Method

The glaze on the porcelain surface is a hard glassy layer and does not allow gas or liquid to penetrate[11]. However, because application using a brush at room temperature and delicate control of burning temperature are impossible in the coking chamber of a coke oven, it is necessary to develop (1) a coating agent that permits hot spray coating and forms a glassy layer in a short time at normal oven temperatures and (2) a device for spraying the coating agent on the wall brick surface at high temperatures in a short time.

3.1.1 Coating agent

An example of coating agent properties that meet the above requirements is shown in **Table 1**. **Figure 3** shows the relationship between the heat treatment temperature 1 h after coating and the melting point of the formed glassy layer. It is apparent that a glassy layer with a melting point of 1 500°C is formed at 1 200°C, which is the normal wall surface temperature of the average coking chamber of a coke oven.

Figure 4 shows the results of a comparison of the abrasion loss of glassy layer conducted by the rotation test using chamotte bricks. It is apparent that abrasion resistance is substantially improved by coating. **Figure 5** shows Na_2O content in glass coating layer on silica brick. The Na_2O content decreases to below the original Na_2O in silica brick after a dozen or so hours and the Na content of the coating agent apparently has no effect on the silica bricks.

Table 1 Glaze characteristics and content

Density	(g/cm³)	1.5	Sodium silicate
Viscosity	(Pa · s)	0.13	Sodium phosphate
			Sodium borate
Melting point of glazed layer	(°C)	> 1 500	Alkaline earth metal compounds

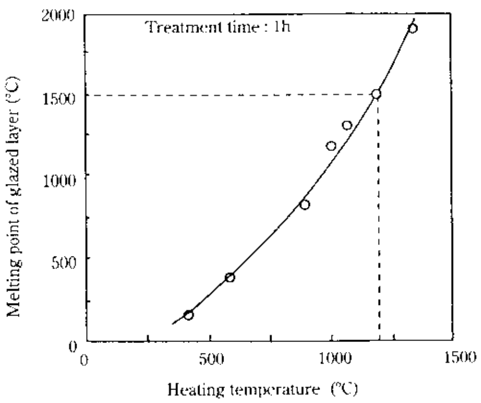

Fig. 3 Relationship between the melting point of the glazed layer and the temperatures of heat treatment

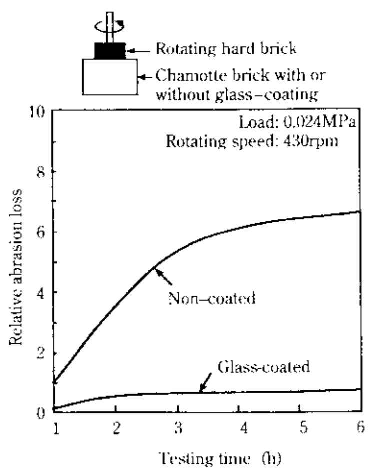

Fig. 4 Comparison of the abrasion loss between non-coated and glass-coated bricks

3.1.2 Coating device

The device developed to spray the above coating agent on the coking chamber wall is shown in **Fig. 6**. The spraying device comprises a water-cooled triple tube mounted on an existing pusher car. The amount of sprayed coating agent per unit oven wall area has an effect on the uniformity of the formed glassy layer. Therefore, an actual oven experiment was conducted by changing the amount of sprayed coating agent per unit oven wall area, with a variable lance traveling speed. The results of this experiment are shown in **Fig. 7**. Nonuniformity occurs in the glassy layer when the amount of sprayed glaze is 1 ℓ/m^2 or less, while runs occur and spray losses increase when it is 1.5 ℓ/m^2 or more. Thus it became apparent that the optimum amount of sprayed glaze ranges from 1.0 to 1.5 ℓ/m^2.

It takes 3 min to spray the coating agent on both coking chamber wall surfaces (200 m^2). The coating agent consumption is 200–300 ℓ/oven. A pan to recover lost spray is installed beneath the lance, which protects the oven sole. The coating agent remaining in the lance after spraying is automatically returned to the chemical tank.

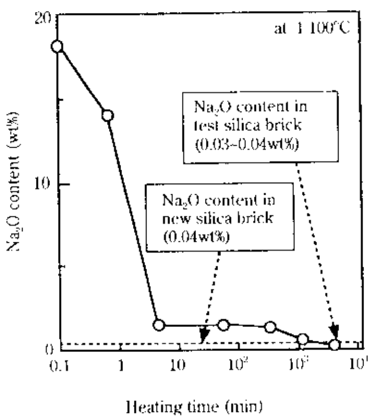

Fig. 5 Na_2O content in the glass coating layer

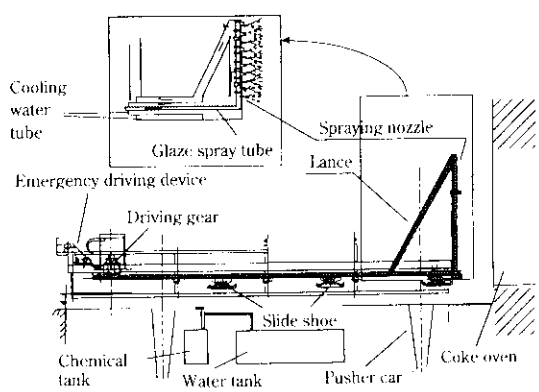

Fig. 6 Spraying equipment

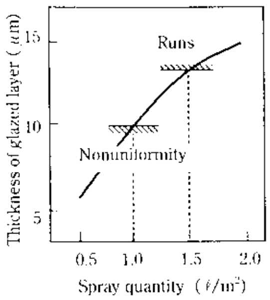

Fig. 7 Optimum amount of sprayed glaze for glass coating

In case of power failure, an emergency retractor can pull the lance out of the chamber.

3.1.3 Effect of coating

In order to ascertain the effect of the glass coating on the prevention of carbon deposits in actual ovens, test-piece bricks were inserted into the space at the top of a coking chamber. The bricks were recovered after one coking cycle (17 h) and examined. The carbon deposited on recovered bricks is shown in **Fig. 8**. In the figure, the thickness of glazed layer "0" means a non-coated brick and other thicknesses are the result of the adjustment of the amount of sprayed coating agent to obtain the specified thicknesses of the coated layer. This figure also shows the result of blasting compressed air on the surface of recovered bricks for about 5 s from a distance of 10 cm. When the blasting with compressed air was not conducted, the effect of the glass coating was such that the deposited carbon decreased to 50-60%. A comparison made after the blasting with compressed air revealed that the deposited carbon decreased to 5–10% after the blasting with 0.3 MPa air and to 0% after the blasting with 0.6 MPa air.

Photo 2 shows the polarization microphotographs of the cross section of the surface of recovered bricks. Carbon penetrated into the non-coated brick like roots,

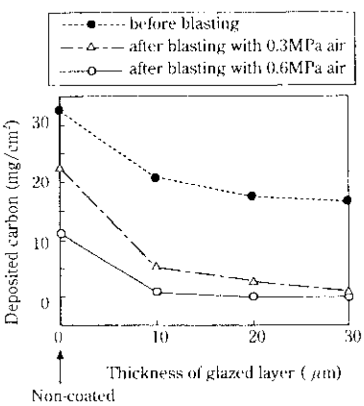

Fig. 8 Effect of the glass coating on carbon deposits before and after blasting air

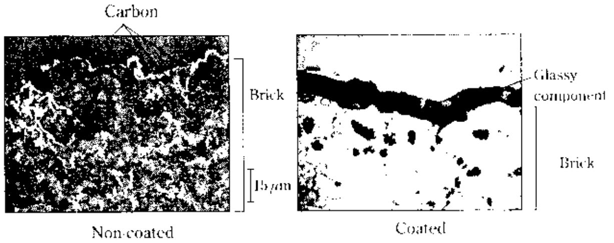

Photo 2 Polarization microphotograph of the cross section of the surface of test bricks

while carbon is not observed on the surface of glazed layer. This indicates that the effect of the glass coating is such that even if carbon is deposited, it adheres weakly and only to the surface, and can be completely removed by blasting with 0.6 MPa air.

3.2 Wall-Cleaning Device

The device for cleaning the glassy layer with compressed air is shown in **Fig. 9**. This device is equipped with air nozzles and is installed on an existing pusher ram so that the cleaning work can be performed simultaneously with the coke pushing operation. High-velocity air blasting can be conducted on the entire oven wall at an air pressure of 0.6 MPa, an air velocity of 340 m/s and an air volume of 30 Nm^3/oven.

3.3 Results of Actual Operation

Figure 10 shows the results of an investigation of the rate of increase in the pushing force due to the deposition of carbon. There is no difference between coated and non-coated chambers for about 20d after glass coating. After that, the pushing force increases abruptly in non-coated chambers, while an increase in the pushing force is very small in coated chambers. In uncoated chambers, once carbon begins to deposit on the wall, the amount of deposited carbon increases abruptly around the initial deposits and grows to form a hard carbon layer. However, the formation of this hard carbon layer might be suppressed in coated chambers. The life of the glass coating layer is estimated to be at least two years because the gloss of the glassy layer has been observed on oven walls even after two years of operation while

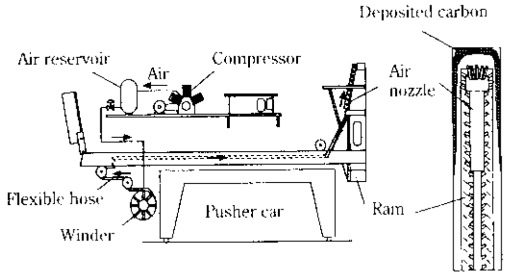

Fig. 9 Coke oven wall cleaner

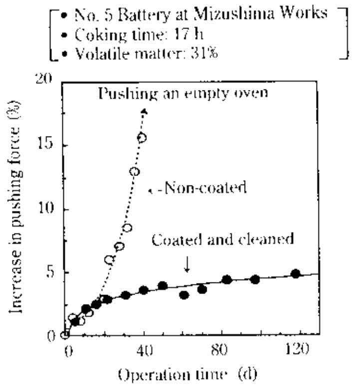

Fig. 10 Effect of the glass coating and wall cleaner on coke pushing force

carbon deposits and an increase in the pushing force have not been observed after this period.

4 Techniques for Preventing Environmental Pollution

The environmental problems of coke ovens are diverse. This chapter mainly describes techniques for preventing the air pollution caused by the insufficient carbonization in the coking chamber due to the deterioration in refractory brickwork.

4.1 Supplementary End Flue Burner System

The end flue is in contact with the air and has a lower temperature than the inner flues. Damage to the bricks near doors is apt to occur owing to the repetition of cooling by the air during the opening of doors for each pushing operation. In older ovens, the damage spreads to end flue bricks and the decrease in the flue temperature is greater. As a result, dust emissions and sticker are caused by the green coke near doors. While measures are taken to raise the set flue temperature, they are limited because excessive heating tends to occur in the center.

It is apparent that as shown in **Fig. 11**, a temperature rise of about 150°C is possible at a gas flow rate of about 5 Nm^3/h if burners for independently heating the end flue are installed in the lower part of the flue chamber as a means of solving the above problem. At the Mizushima Works, all coke batteries are equipped with the supplementary end flue burner system[12] shown in **Fig. 12** in order to compensate for the temperature decrease at the end flue (**Fig. 13**). As a result, a +10% improvement in the coke strength TI_6^{400} for the coke near doors and a +16% improvement in the lump coke yield over 25 mm have been observed. Thus the problems of green coke near doors and pushing emissions can be solved at the same time.

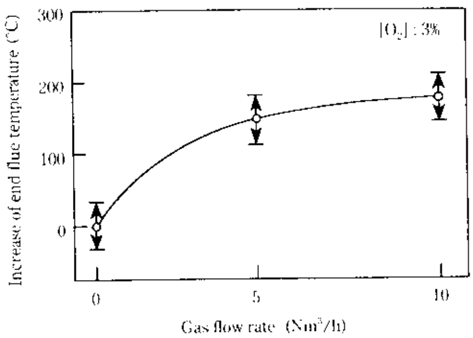

Fig. 11 Relation between increase of the end flue temperature and the gas flow rate

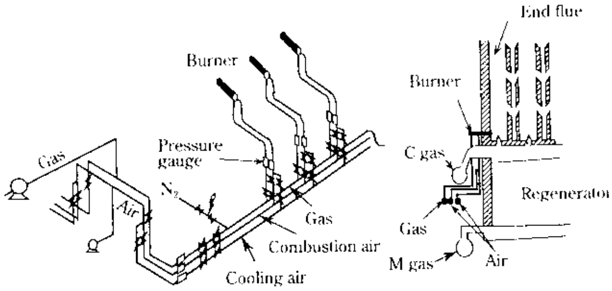

Fig. 12 Supplementary end flue burner system

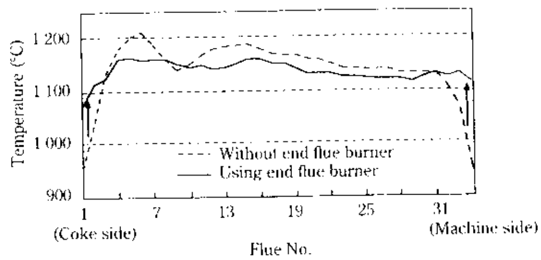

Fig. 13 Comparison of the cross-wall temperature before and after using the end flue burner

4.2 Chamber Pressure Control System

As brickwork expands over time, the expansion based on the temperature change of the coking cycle is a dominant factor. The mechanism is considered to be brick joints filling with carbon, which gradually expands the brickwork[7]. When such joints filled with carbon open, raw gas leaks from the coking chamber to the flue chamber, producing various problems. **Figure 14** shows an example of raw gas leakage calculated by analysis at the waste gas valve. As indicated by the symbol ○ in the figure, gas leakage at 1.7 Nm^3/min occurred immediately after coal charging and it is apparent that incomplete combustion for about 30 min occurred at an air ratio of 1.4. However, it is apparent that incomplete combustion can be suppressed by controlling the NH_3-

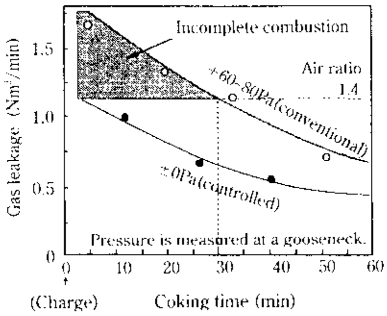

Fig. 14 Raw gas leakage from the coking chamber to the heating flue

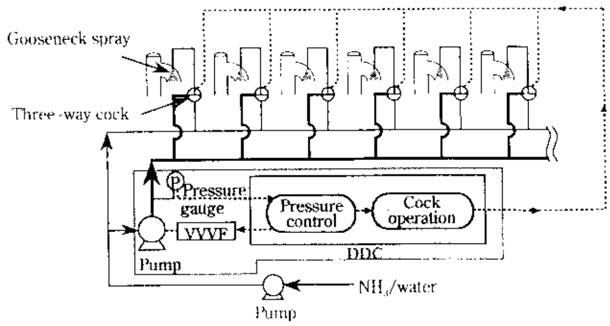

Fig. 15 Gooseneck pressure control system

water inflow in the gooseneck and the pressure to ±0 Pa in place of the normal level of +60 to +80 Pa (the symbol ● in Fig. 14).

This chamber pressure control system was easily realized as follows. The existing NH_3-water pump was converted to the rotating speed control type and the relationship between the number of ovens to be controlled and the rotating speed was programmed. The oven number, chamber pressure and control time were made capable of being arbitrarily set and the sequence of automatic control was determined for the changeover of the rotating speed of pump and three-way cock of NH_3-water spray. An overview of the chamber pressure control system is shown in **Fig. 15**. The incidence of incomplete combustion was substantially lowered by introducing this system.

5 Conclusions

(1) The glass coating method, (2) wall cleaner, (3) supplementary end flue burner system, and (4) chamber pressure control system, which were developed as measures for prolonging coke oven life, were described. As a result of their application in actual ovens, it became apparent that they can completely eliminate sticker and the need for carbon burning which are the main causes of oven damage and, at the same time, reduce pollution. The authors believe that the glass coating method will produce a particularly significant life extending effect since oven wall bricks are not directly exposed to tar or crude gas. Owing to stabilized operation and decreased heat consumption for carbonization, an energy saving of 84 MJ/t (dry coal base) was achieved as a secondary effect.

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