ISSN 2176-3135

THE INFLUENCE OF LATERAL SHRINKAGE AND COMPRESSIBILITY OF COKE CAKE ON PUSHING FORCE FROM OVEN CHAMBER HAVING WALL SURFACE IRREGULARITY[1]

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Abstract
This presentation will show the influences of the lateral shrinkage of coke and the compressibility of coke cake on the pushing force of coke cake from the oven chamber which has irregularity on the wall surface. The pushing force of coke cake can be determined by the clearance between the coke cake and the wall surface, which is controlled by the lateral shrinkage of coke, and the irregularity of the wall surface (concavity and convexity), which are commonly observed in coke oven chambers which operate for a long period. If the achieving temperature at center of coke cake is not enough comparing to the one in the normal operation, the pushing force is affected by the compressibility of the coke cake.
Key words: Coke; Pushing force; Coke-oven; Coal carbonization; Irregularity; Compressibility.

[1] *Technical contribution to the 6th International Congress on the Science and Technology of Ironmaking – ICSTI, 42nd International Meeting on Ironmaking and 13th International Symposium on Iron Ore, October 14th to 18th, 2012, Rio de Janeiro, RJ, Brazil.*
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ISSN 2176-3135

1 INTRODUCTION

Over many years of coke oven operation, the wall surfaces of coking chambers become uneven with many protrusions due to carbon deposition and depressions by brick spalling. The force required for pushing coke cake out of a coking chamber when the wall surfaces are in such a condition has been known to be in good correlation with a friction coefficient indicating the irregularity of the wall surface.[1]
It has been known, on the other hand, that coke pushing force is influenced also by the gap between the coke cake and the chamber walls.[2,3] In coke ovens operating for a long period, the flue temperature sometimes becomes lower than prescribed, owing to local instability of combustion, which leads to the partially insufficient coking of the cakes. The gaps between the coke cake and the chamber walls are smaller at such portions than where the coking process advances normally, and it is feared that this is likely to increase the coke pushing force.
In consideration of this, the authors conducted laboratory tests to clarify the effects of the wall/cake gaps over the coke pushing force when the wall surfaces of the coking chambers were irregular. This paper thus reports the results.

2 EXPERIMENTAL

2.1 Measurement of Coke Pushing Force

Figure 1 is a schematic plan view of the test equipment that the authors used for the present study. Two hydraulic presses (3a and 3b) were provided on both the ends of a coke cake (1); the one on the left side (3a) pushed the cake, while the other (3b) applied a prescribed reaction force in a constant manner. Rigid walls (7) were provided to prevent sidewalls (6) from moving during the pushing. A protrusion (2) with a slanted end was fixed to one of the sidewalls (6) to simulate the narrow of a coking chamber. The force to push the coke cake through the narrow, the reaction force, and the loads on the sidewalls were measured using load cells (4).

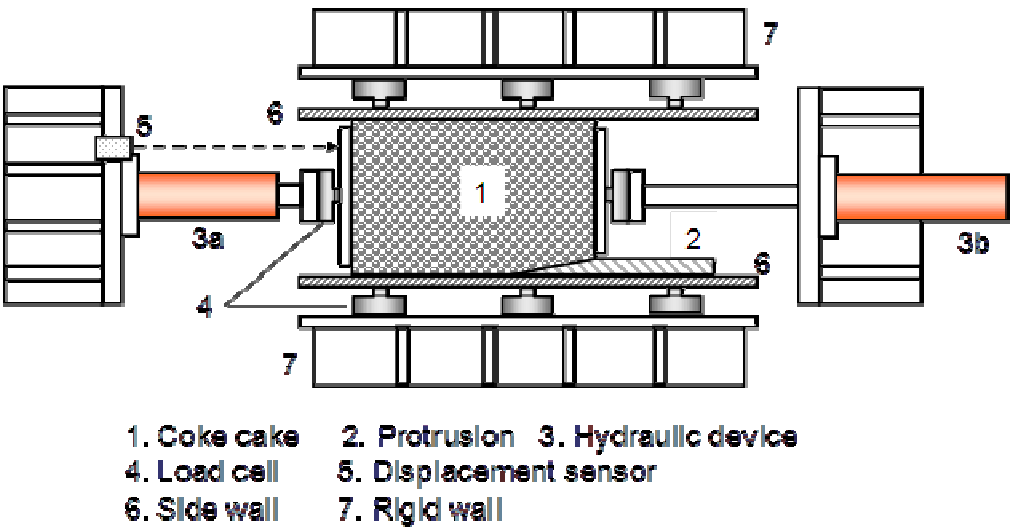


Figure 1. Top view of experimental apparatus.

ISSN 2176-3135

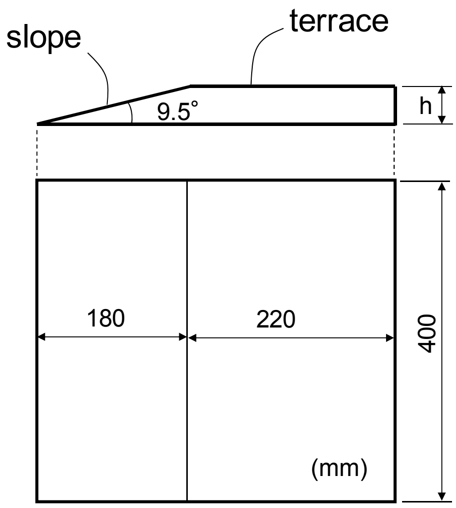


Figure 2. Specifications of protrusion on the side wall.

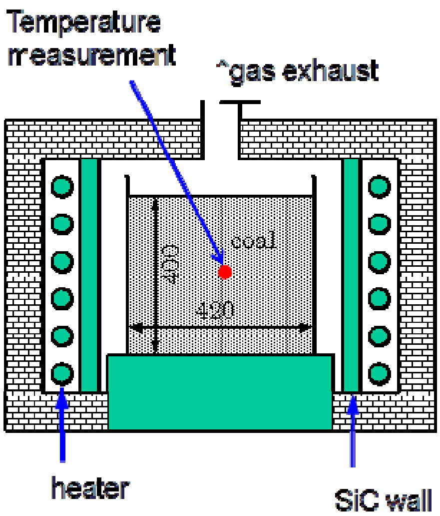


Figure 3. Schematic representaion of electric furnace.

To prevent the coke cake from swelling upward during the pushing through the narrow, a weight of 170 kg was placed on the top face of the cake. Figure 2 shows the detailed dimensions of the protrusion (2) fixed to the sidewall (6).

2.2 Coke Cake Specimens

Coke cake specimens for the test were prepared using a mixture of four coal brands as the raw material. Each of the brands was dried to a moisture content of 4.5 mass percent, and crushed such that grains 3 mm or less in size accounted for 85 mass percent. Then, the coal mixture was packed in metal containers, 420 mm in width, 400 mm in height and 610 mm in length each, made of 0.5-mm thick sheets, to a bulk density of 800 kg/m^3. The packed coal was then heated in an electric furnace of a two-sided heating type, as shown in Figure 3,and made into coke cakes. The temperature was measured during the heating process using metal-sheathed thermocouples buried at the center of the packed coal. The center of charged coal is normally heated to 1,000°C over a heating time of 18.5 h. The heating time was shortened for some packed coals in order to make insufficient coking state. After the

ISSN 2176-3135

center temperature has reached respectively prescribed temperatures, the coke cakes, still in the containers, were removed from the furnace to a specially designed cooling box and cooled to room temperature in an atmosphere of inert gas (nitrogen).

3 RESULTS AND DISCUSSION

3.1 Effects of Transverse Gaps on Coke Pushing Force

There are two different types of gap in the width direction of a coke cake- those between the cake and the sidewalls (6 in Figure 1) and that at the cake center. The force required for pushing a coke cake through a narrow formed by a protrusion is likely to decrease as the total of these gaps increases. To verify this, the authors measured the coke pushing force by changing the gaps between the cakes and the sidewalls and those at the cake center. Figure 4 shows the results. The total gap in the width direction and the coke pushing force corresponded well with each other. The total gaps of specimens (d) and (e) were substantially the same, but the center gap of specimen (d) was 14 mm while that of specimen (e) was 5 mm. This indicates that the force required for pushing a coke cake through a narrow changes depending not on either of the gaps between the cake and the sidewalls or that at the center but on the total of them.

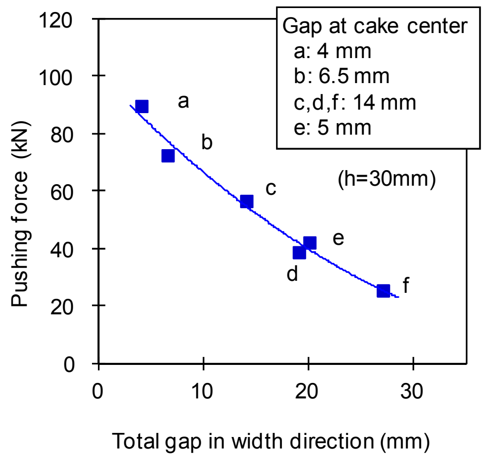


Figure 4. Relationship between the total gap in cake width direction and pushing force.

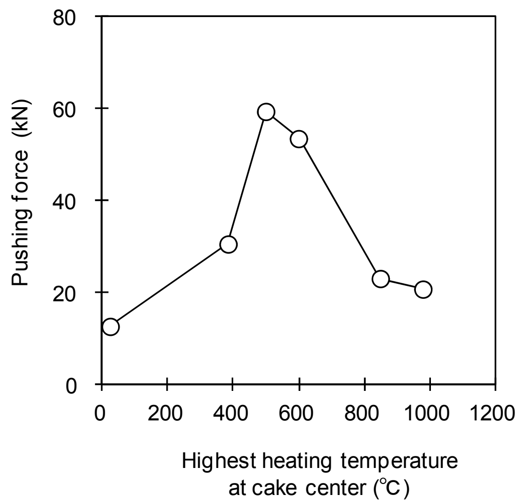
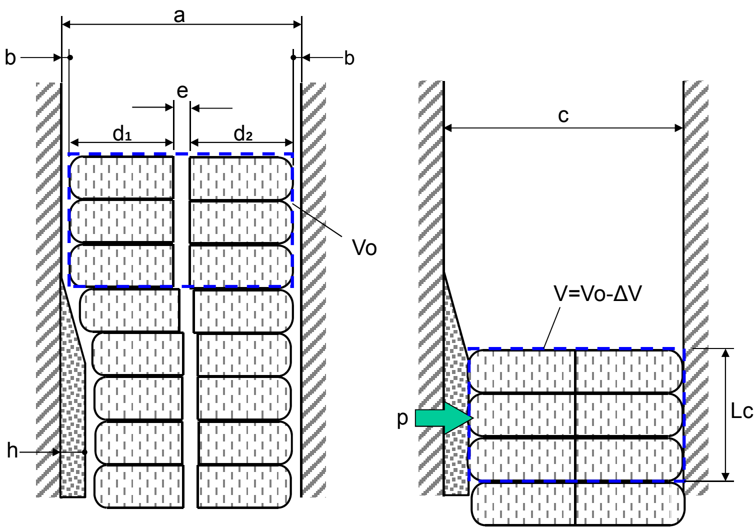


Figure 5. Change in pushing force with highest heating temperature at cake width center.

ISSN 2176-3135

3.2 Effects of the Highest Heating Temperature at the Cake Width Center on the Coke Pushing Force

The highest heating temperature at the center of the packed coal was adjusted by changing the resident time in the furnace, with the heating pattern of the furnace being the same, and the coke pushing force was measured with coke cakes heated to different temperatures. In the cases of the two specimens, the centers of which were heated to 25 and 400°C, respectively, while the coal in the portions near the heaters of the furnace turned into coke, the coal at the center of the specimen heated to 25°C was still coal, and that heated to 400°C was in the softening and cohesive state. Figure 5 shows the measurement results. It is clear from the graph that the force required for pushing a coke cake through a narrow changes depending significantly on the highest heating temperature at the cake center. In the cases of the cakes heated to 500 to 600°C, in particular, the required force was nearly three times that of the cakes heated according to the normal coking process to 1,000°C. This is presumably because, after heating only up to 500°C or so, although the maximum gas pressure of the plastic zone has disappeared, coke shrinkage at the center has not begun, and as a result, virtually there were no gaps in the cake width direction.



(a) before the test (b) after the test

Figure 6. Schematic representation of the coke cake arrangements before and after the test.

3.3 Relationship between the Compressibility of Coke Cake and the Coke Pushing Force

When a coke cake is pushed through a narrow formed by a protrusion, strong compressive force is applied to it in the pushing direction of the hydraulic press as well as in the direction perpendicular to it (Figure 6). It seems to follow, therefore, that the force required for pushing a coke cake through a narrow is smaller when it is easily deformable. In relation to this, as an indicator of the deformability of a coke cake, the authors assumed an apparent volume elasticity coefficient K (Pa) expressed by Equation 1.

ISSN 2176-3135

$$K\ (Pa) = \Delta p/(\Delta V/Vo) \qquad (1)$$

- $\Delta p = p$ = [(force required for pushing coke cake through narrow) / (Hc*Lc)]
- $\Delta V = Vo - (c - h)*(Hc*Lc) = Hc*Lc*\ \{a - (2b+e) - (c - h)\}$
- $Vo = \{a - (2b+e)\}\ *(Hc*Lc)$
- $\Delta V/Vo = \{a - (2b+e) - (c - h)\}\ /\ \{a - (2b+e)\}$,

Where: a is the distance between the sidewalls before the test;

- b is the gap between the coke cake and a sidewall;
- c is the distance between the sidewalls after the test (= a);
- d is the coke cake length;
- e is the cake center gap width;
- p is the pressure on the terrace face of the protrusion;
- Vo is the coke cake volume before compression;
- V is the coke cake volume after compression;
- ΔV is the difference in the cake volume;
- Hc is the coke cake height; and
- Lc is the contact length of the coke cake with the sidewall after compression.

Figure 7 shows the relationship between the apparent volume elasticity coefficient and the highest heating temperature at the cake center. Here, the larger the coefficient, the more force is required for compressing the cake. In the temperature range from 25 to 600°C, the coefficient increases as the highest heating temperature goes up, but in the range from 600 to 1,000°C, it decreases as the heating temperature becomes higher. This is presumably because, in the lower temperature range, the volume percentage of grainy portion (non-coked coal) that can absorb the compressive force decreases and that of hard coke increases as the heating temperature becomes higher, but in the higher temperature range, in contrast, the lateral shrinkage of coke increases and the center gap develops as the heating temperature rises. As a result, external (compressive) force is absorbed more easily.
Figure 8 shows the relationship between the apparent volume elasticity coefficient and the coke pushing force. When the highest heating temperature at the cake center was 500°C or lower (coal or semi-coke range) as well as when it was 600°C or higher (semi-coke or coke range), the coke pushing force increased as the coefficient increased.

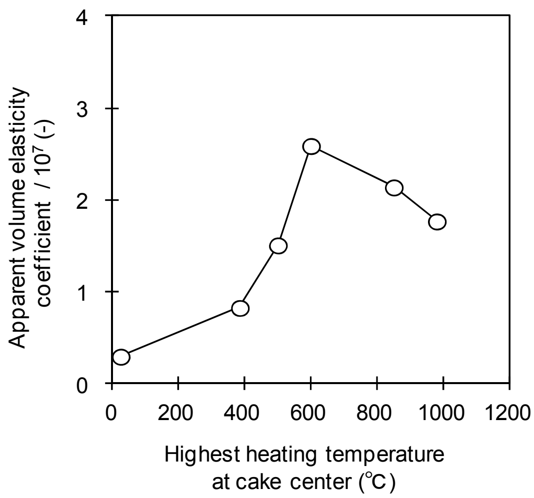


Figure 7. Change in apparent volume elasticity coefficient with highest heating temperature at cake center.

ISSN 2176-3135

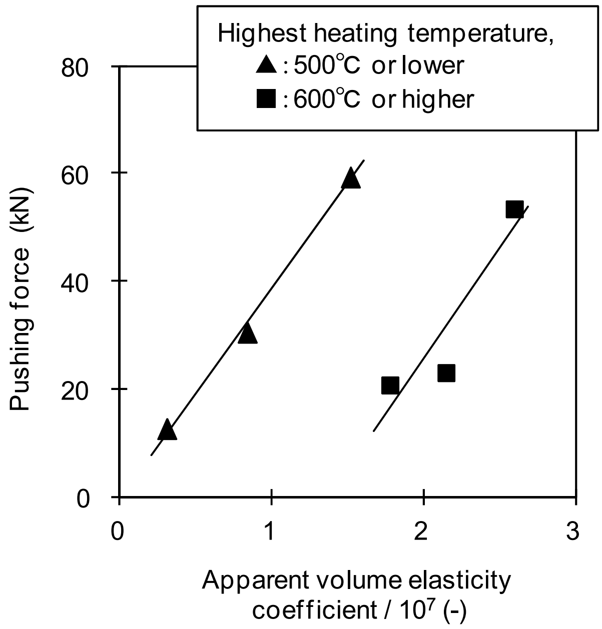


Figure 8. Relationship between apparent volume elasticity coefficient and pushing force.

On the other hand, with the same values of the coefficient, when the highest heating temperature was 500°C or lower, the coke pushing force was higher than that for the cakes that was heated to 600°C or higher. This is presumably because, in the former temperature range, the coke cakes included grainy (non-coked coal) portions, and as a consequence, a large fraction of the force imposed on the cake in the pushing direction was diverted in the lateral direction.[4]

4 CONCLUSIONS

The authors experimentally studied the force required for pushing coke cake through the narrow of a coking chamber due to a protrusion on a chamber wall and obtained the following findings:

- In the case of a coke cake that has been heated during the coking process to approximately 1,000°C as measured at the width center, the coke pushing force corresponds well with the total gap in the chamber width direction or with the total of the gaps between the cake and the chamber sidewalls and that at the cake center. In addition, the effects that the gaps between the cake and the sidewalls have on the coke pushing force are evaluated as equivalent to those the gap at the cake center does.
- the coke pushing force is highest when the heating temperature at the cake center is 500°C. This is probably because the coke has not contracted at the cake center, and as a result, the total gap in the chamber width direction is small.
- the coke pushing force changes in good correspondence to the apparent volume elasticity coefficient, which was defined for the purpose of the present study as an indicator of the compressibility of a coke cake. The correspondence holds true with coke cakes that was heated to 500°C or lower at the center and that contain portions that have not turned into coke as well as with those heated to 600°C or higher.

ISSN 2176-3135

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