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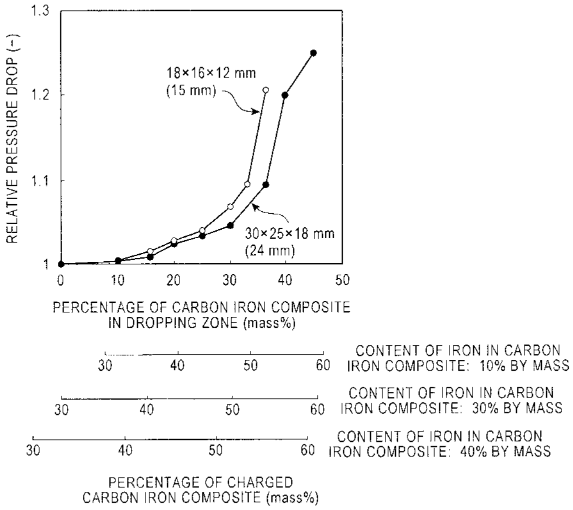
(54) METHOD FOR OPERATING BLAST FURNACE

(57) The amount of a carbon iron composite used is appropriately adjusted when the carbon iron composite is used in a blast furnace, whereby a stable operation is provided. Ore and coke including the carbon iron composite and conventional coke are charged into the blast furnace. The percentage of the carbon iron composite used is 2% to 50% by mass of the coke. The percentage of the carbon iron composite used is preferably 25% by mass or more. The carbon iron composite preferably has a particle size of 15 mm to 40 mm. The carbon iron composite preferably has an iron content of 10% to 40% by mass.

FIG. 1



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Description

Field of the Invention

[0001] The present invention relates to a method for operating a blast furnace using a carbon iron composite (ferrocoke) produced by briquetting and carbonizing a mixture of coal and iron ore.

Description of the Related Art

[0002] A technique for lowering the temperature of a thermal reserve zone formed in a blast furnace is effective in lowering the reducing agent rate of the blast furnace (see, for example, Non-Patent Literature 1).

[0003] An example of the technique for lowering the thermal reserve zone temperature is to lower the beginning temperature of a coke gasification reaction (endothermic reaction) represented by the following equation:

$$CO_2 + C \rightarrow 2CO \quad (1).$$

If the beginning temperature of the coke gasification reaction is lowered, then a temperature region where this reaction occurs is expanded and therefore the reaction rate of gasification is increased. A carbon iron composite produced by carbonizing briquettes obtained by briquetting a mixture of coal and iron ore can increase the reactivity of coke by the catalytic action of reduced iron ore and can lower the reducing agent rate because of the lowering of the thermal reserve zone temperature (see, for example, Patent Literature 1).

[0004] A method for producing a carbon iron composite is supposed to be, for example, a process including a step of mixing coal, iron ore, and several mass percent of a binder to homogenize the mixture, a step of producing briquettes by pressing the mixture with a double-roll press having a dimple, and a step of carbonizing the briquettes in a vertical furnace. In this case, the carbon iron composite has a shape suitable for the above roll pressing as shown in Fig. 2.

[0005] The carbon iron composite is supposed to be produced by a method, similar to a method for producing conventional coke, using a mixture of coal and iron ore. Since an ordinary chamber coke oven is made of silica bricks, iron ore charged thereinto reacts with silica, which is a major component of the silica bricks, to produce fayalite, which has a low melting point. This may possibly damage the silica bricks. In this case, particles of the carbon iron composite have an irregular shape and the range of the particle size is determined by sieving.

[0006] Coke gasification reactions occurring in a blast furnace include the following reactions represented by Equations (2) to (5) below in addition to the reaction represented by Equation (1):

the reaction of carbon with oxygen in a tuyere zone as represented by Equation (2);
the reaction of carbon with FeO as represented by Equation (3);
the reaction of carbon with steam in a shaft zone as represented by Equation (4); and
the reaction of carbon with a non-ferrous oxide as represented by Equation (5). In Equation (5), M is Si, Mn, Ti, P, or the like.

In the operation of blast furnaces, the amount of carbon consumed in the gasification reactions other than the reaction represented by Equation (2) is conventionally referred to as the amount of solution loss carbon (hereinafter referred to as the solution loss amount) and is given by Equation (6) below. The amount of carbon gasified in front of a tuyere is calculated from the amount of oxygen in an air blow by Equation (2). The amount of carbon in a top gas is calculated from the amount of the top gas, the concentration of each of CO and CO_2 in the top gas. In the case of using a carbon iron composite, the reaction represented by Equation (1) is promoted and the reaction represented by Equation (3) is, however, significantly suppressed because the reduction of iron oxide by gas, that is, a reaction represented by Equation (7) is promoted. As a result, the solution loss amount is probably lowered. The contribution of the reaction represented by Equation (4) to the solution loss amount is small and therefore the solution loss amount is usually supposed to be the amount of coke gasified in a region close to a furnace top and a cohesive zone.

$$C + 1/2O_2 = CO \qquad (2)$$

$$FeO + C = Fe + CO \qquad (3)$$

$$H_2O + C = H_2 + CO \qquad (4)$$

$$MO_n + C = M + CO_n \qquad (5)$$

$$\text{solution loss amount} = \text{amount of carbon in top gas} - \text{amount of carbon gasified in front of tuyere} \qquad (6)$$

solution loss

$$FeO + CO = Fe + CO_2 \qquad (7)$$

[0007] In the case of lowering the temperature of a thermal reserve zone by increasing the amount of the carbon iron composite used, the solution loss amount, that is, the amount of coke gasified in the region close to the furnace top and the cohesive zone is lowered and it is predicted that the amount of carbon in the carbon iron composite exceeds the solution loss amount under certain conditions. A so-called dropping zone located below the cohesive zone is filled with coke that is not gasified nor lost by a solution loss reaction in the region close to the furnace top and the cohesive zone. Even if the carbon iron composite is gasified prior to conventional coke because the carbon iron composite is higher in reactivity than conventional coke, a portion of the carbon iron composite is not lost by gasification and therefore remains in the dropping zone when the amount of carbon in the charged carbon iron composite exceeds the amount of gasified carbon. The term "conventional coke" refers to coke which is produced by carbonizing coal in a coke oven or the like, which is usually charged into a blast furnace, and which is used as a coke source material. When the carbon iron composite has a particle size less than that of conventional coke or strength less than that of conventional coke, the excessive presence of the carbon iron composite in the dropping zone may possibly deteriorate the gas or liquid permeability of a furnace bottom section. Therefore, there is probably an upper limit to the amount of the carbon iron composite used.

Citation List

Patent Literature

[0008]

PTL 1: Japanese Unexamined Patent Application Publication No. 2006-28594

Non Patent Literature

[0009]

NPL 1: The Iron and Steel Institute of Japan, "Tetsu-to-Hagane" 87, 2001, p. 357
NPL 2: The Iron and Steel Institute of Japan, "Tetsu-to-Hagane" 79, 1993, N618
NPL 3: KAWASAKI STEEL GIHO, 6 (1974), p. 16

Summary of the Invention

Technical Problem

[0010] There is probably an upper limit to the amount of a carbon iron composite used as described above. Accordingly, it is an object of the present invention to solve such a conventional technical problem and to provide a stable operation in such a manner that when a carbon iron composite is used in a blast furnace, the amount of the carbon iron composite used is appropriately adjusted. Solution to Problem

[0011] The present invention has features below for the purpose of solving such a problem.

(1) A method for operating a blast furnace includes charging ore and coke including a carbon iron composite and conventional coke into the blast furnace, wherein the percentage of the carbon iron composite used is 2% to 50% by mass of the coke.
(2) In the blast furnace-operating method specified in Item (1), the carbon iron composite has a particle size of 15 mm to 40 mm.
(3) In the blast furnace-operating method specified in Item (2), the carbon iron composite has a particle size of 20 mm to 35 mm.
(4) In the blast furnace-operating method specified in Item (1), the percentage of the carbon iron composite used

is 25% to 50% by mass of the coke.

(5) In the blast furnace-operating method specified in Item (4), the percentage of the carbon iron composite used is 30% to 50% by mass of the coke.

(6) In the blast furnace-operating method specified in Item (1), the carbon iron composite has an iron content of 10% to 40% by mass.

[0012] The above problem can be solved by inventions below.

(7) A method for operating a blast furnace using a carbon iron composite includes charging a coke source material containing the carbon iron composite and conventional coke into the top of the blast furnace, wherein the percentage of the carbon iron composite used is 2% to 50% by mass of the amount of the coke source material used.

(8) In the blast furnace-operating method specified in Item (7), the percentage of the carbon iron composite used is 35% by mass or less of the amount of the coke source material used.

(9) In the blast furnace-operating method specified in Item (7) or (8), the carbon iron composite has a particle size less than the particle size of conventional coke that is charged into the blast furnace alone without being mixed with ore.

[0013] The term "ore" as used herein collectively refers to sintered ores produced from iron ores, lump ores, and mixtures containing one or more of iron-containing materials, such as pellets, charged into blast furnaces. Ore layers stacked in blast furnaces contain an auxiliary material, such as limestone, for adjusting a slug component in addition to ores in some cases.

Advantageous Effects of Invention

[0014] According to the present invention, a stable operation can be achieved in such a manner that when a carbon iron composite is used as a portion of a coke material in the operation of a blast furnace, the upper limit of the amount of the carbon iron composite used is set.

Brief Description of the Drawings

[0015]

Fig. 1 is a graph showing the relationship between the percentage of a carbon iron composite used and the pressure drop (relative pressure drop).

Fig. 2 is a schematic view showing the shape of a carbon iron composite.

Fig. 3 is a graph showing the relationship between the percentage of a carbon iron composite used and a reduction in reducing agent rate.

Fig. 4 is a graph showing the relationship between the percentage of a carbon iron composite used and the difference between the amount of carbon in a carbon iron composite and the solution loss carbon amount.

Fig. 5 is a graph showing the relationship between the percentage of a carbon iron composite used and percentage of the carbon iron composite remaining in a dropping zone.

Fig. 6 is a schematic view of a pressure drop-measuring unit.

Fig. 7 is a graph showing the relationship between the percentage of a carbon iron composite used and the pressure drop (relative pressure drop) of a packed bed of a mixture of conventional coke and a carbon iron composite.

Fig. 8 is a graph showing the particle size distribution of ore.

Fig. 9 is a graph showing the relationship between the particle size of a carbon iron composite and the pressure drop of an ore + carbon iron composite-mixed layer.

Fig. 10 is a graph showing reaction test conditions for measuring the reaction rate of coke.

Fig. 11 is a graph showing the relationship between the percentage of a carbon iron composite used and the relative reaction rate of carbon.

Fig. 12 is a schematic view showing the distribution of a material charged in a blast furnace in the case of using a carbon iron composite.

Embodiments for carrying out the invention

[0016] A carbon iron composite is produced in such a manner that briquettes are produced by briquetting a material principally containing coal and iron ore and the coal in the briquettes is carbonized by heating the briquettes. The term "principally containing coal and iron ore" means that main raw materials of the carbon iron composite are coal and iron ore. A material containing 70% by mass or more of a mixture of coal and iron ore is used to produce the carbon iron composite and a material containing 80% by mass or more of a mixture of coal and iron ore is usually used.

[0017] The higher the content of iron in the carbon iron composite, the more likely the effect of increasing the reactivity of coke is to occur. When the content of iron is 10% by mass or more, the effect is significant. When the content of iron is 40% by mass or more, the effect is saturated. Therefore, the content of iron is preferably 10% to 40% by mass.

[0018] The inventors have predicted changes in conditions for operating a blast furnace during the use of a carbon iron composite using a heat and material balance model based on a Rist operation diagram (see, for example, Non-Patent Literature 2) and have estimated the amount of the carbon iron composite remaining in a dropping zone from the solution loss amount and the amount of the carbon iron composite charged into the blast furnace.

[0019] If the carbon iron composite is gasified prior to conventional coke because the carbon iron composite is higher in reactivity than conventional coke, the amount of the carbon iron composite remaining in the dropping zone can be given by the following equation (8):

amount of carbon iron composite remaining in dropping zone = (amount of carbon in carbon iron composite charged into blast furnace - solution loss carbon amount) (8).

Herein, when the amount of carbon in the carbon iron composite charged into the blast furnace is less than or equal to the solution loss carbon, the amount of the carbon iron composite remaining in the dropping zone is regarded as zero. Preconditions to determine the balance of these materials are as follows: the content of iron in each carbon iron composite used is 10%, 30%, or 40% by mass (the remainder is coke) and the content of carbon in coke is 87.5% by mass.

[0020] The percentage of the carbon iron composite remaining in the dropping zone is given by the following formula (9):

amount of carbon iron composite remaining in dropping zone / (amount of carbon iron composite remaining in dropping zone + amount of conventional coke) (9).

Results of investigations performed using these formulas are shown in Tables 1 to 3 and Figs. 3 to 5. Table 1 shows examples in which the content of iron in a carbon iron composite is 10% by mass. Table 2 shows examples in which the content of iron in a carbon iron composite is 30% by mass. Table 3 shows examples in which the content of iron in a carbon iron composite is 40% by mass.

In Table 1, Base outlines a case where no carbon iron composite is used, Case 1 outlines a case where the carbon iron composite is used and the amount of carbon in the carbon iron composite charged into the blast furnace is less than the solution loss carbon amount, and Cases 2 and 3 each outline a case where the amount of carbon in the carbon iron composite charged into the blast furnace is more than the solution loss carbon amount. An increase in the content of iron in the carbon iron composite increases the reactivity of the carbon iron composite and the effect of lowering the temperature of a thermal reserve zone. Thus, the thermal reserve zone temperature and the amount of carbon derived from the carbon iron composite vary depending on the iron content thereof even at the same percentage of the carbon iron composite used. These variations affect the reducing agent rate and solution loss carbon. These phenomena are reflected in the results shown in Tables 1 to 3.

Fig. 3 is a graph showing the relationship between the percentage of the carbon iron composite used and a reduction in reducing agent rate. As is clear from Fig. 3, the higher the content of iron in the carbon iron composite and the higher the percentage of the carbon iron composite used, the lower the reducing agent rate. For example, in the case of using 25% by mass of the carbon iron composite with an iron content of 30% by mass, the reducing agent rate can be expected be lowered by 30 kg/t-p. In the case of using 30% by mass of the carbon iron composite with an iron content of 10% by mass, the reducing agent rate can be expected be lowered by 20 kg/t-p. The percentage of the carbon iron composite used (the percentage of the charged carbon iron composite) is the ratio of the mass of the carbon iron composite charged into the blast furnace to the sum of the mass of the carbon iron composite charged thereinto and the mass of conventional coke as given by the following equation and the mass of the carbon iron composite including iron is used:

carbon iron composite (including iron) / {carbon iron composite (including iron) + conventional coke} (10).

[0021]

Table 1

		Base	Case 1	Case 2	Case 3
Carbon iron composite rate	kg/t	0	101	167	204
Carbon in carbon iron composite	kg/t	0	80	132	161
Conventional coke rate	kg/t	359	247	174	131
Percentage of carbon iron composite	%	0	29	49	61
Pulverized coal rate	kg/t	126	126	126	126
Reducing agent rate	kg/t	485	464	450	441
Thermal reserve zone temperature	°C	1000	920	867	833
Solution loss carbon	kg/t	75	70	67	65
Carbon iron composite remaining in dropping zone	kg/t	0	12	81	122
Percentage of carbon iron composite in dropping zone	%	0	4	32	48

[0022]

Table 2

		Base	Case 1	Case 2	Case 3
Carbon iron composite rate	kg/t	0	104	171	212
Carbon in carbon iron composite	kg/t	0	64	105	130
Conventional coke rate	kg/t	359	251	181	130
Percentage of carbon iron composite		0	29	49	61
Pulverized coal rate	kg/t	126	126	126	126
Reducing agent rate	kg/t	485	450	426	412
Thermal reserve zone temperature	°C	1000	880	800	750
Solution loss carbon	kg/t	75	67	61	57
Carbon iron composite remaining in dropping zone	kg/t	0	0	72	120
Percentage of carbon iron composite in dropping zone		0	0	28	47

[0023]

Table 3

		Base	Case 1	Case 2	Case 3
Carbon iron composite rate	kg/t	0	105	179	223
Carbon in carbon iron composite	kg/t	0	55	94	117
Conventional coke rate	kg/t	359	257	186	143
Percentage of carbon iron composite	%	0	29	49	61

(continued)

		Base	Case 1	Case 2	Case 3
Pulverized coal rate	kg/t	126	126	126	126
Reducing agent rate	kg/t	485	445	419	403
Thermal reserve zone temperature	°C	1000	872	787	733
Solution loss carbon	kg/t	75	65	58	54
Carbon iron composite remaining in dropping zone	kg/t	0	0	67	121
Percentage of carbon iron composite in dropping zone	%	0	0	27	46

[0024] As is clear from Figs. 4 and 5, when the percent of the charged carbon iron composite is about 30% by mass, the amount of carbon in the carbon iron composite is equal to the solution loss amount. When the carbon iron composite charged into the blast furnace is more than 30% by mass, the amount of carbon in the carbon iron composite exceeds the solution loss amount and therefore the carbon iron composite remains in the dropping zone. The percentage of the carbon iron composite that is located at the intersection of the abscissa in Fig. 5 and each graphic line corresponds to the percentage of the carbon iron composite at an ordinate value of zero in Fig. 4.

[0025] The pressure drop of a packed bed of a mixture of conventional coke and a carbon iron composite was measured with a pressure drop-measuring unit shown in Fig. 6. The pressure drop-measuring unit 1 had a diameter of 400 mm and a height of 2,000 mm. Measurement was performed in such a manner that a pressure drop-measuring sample 2 was stacked to a height of 1,000 mm. The following materials were used: conventional coke with a particle size of 40 mm to 60 mm, a carbon iron composite with a size of 18 mm x 16 mm x 12 mm (a particle size of 15 mm), and a carbon iron composite with a size of 30 mm x 25 mm x 18 mm (a particle size of 24 mm). In the present invention, the size of each carbon iron composite is expressed in the form of A × B × C shown in Fig. 2 and the particle size of the carbon iron composite is calculated by the formula $(A \times B \times C)^{1/3}$. Fig. 7 shows pressure drop measurement results obtained by varying the percentage of the blended carbon iron composite. When the percentage of the blended carbon iron composite is more than 30% by mass, the pressure drop increases significantly. This is probably because the carbon iron composite has a smaller particle size and fewer irregularities as compared with the conventional coke and therefore has the effect of lowering the voidage of the packed bed.

[0026] The results shown in Fig. 7 are used as results obtained by simulating a dropping zone and the relationship between the amount of each carbon iron composite shown in Tables 1 to 3 and the percentage of the carbon iron composite remaining in the dropping zone is entered in Fig. 7, whereby Fig. 1 is obtained.

As is clear from Fig. 1, the pressure drop (relative pressure drop) increases when the percentage of the carbon iron composite remaining in the dropping zone is about 10% by mass or more and the pressure drop increases sharply when the percentage of the carbon iron composite having an iron content of 10% by mass and a particle size of 15 mm is 50% by mass or more, that is, the percentage of the carbon iron composite remaining in the dropping zone is 30% by mass or more. Thus, the pressure drop does not increase even when the percentage of the following carbon iron composite is 50% by mass: a carbon iron composite having an iron content of more than 10% by mass and/or a particle size of more than 15 mm. From the above, the inventors have found that in the case of using a carbon iron composite having an iron content of 10% to 40% by mass and a particle size of 15 mm or more, the upper limit of the percentage of the carbon iron composite used is 50% by mass in order to avoid a sharp increase in pressure drop.

[0027] From the above, the following conclusion is obtained: a conclusion that the pressure drop of the dropping zone is significantly deteriorated when the percentage of the amount of the carbon iron composite in the amount of coke used, that is, the sum of the amount of the carbon iron composite and the amount of the conventional coke exceeds 50% by mass. Thus, a blast furnace needs to be operated in such a manner that the amount of the carbon iron composite charged into the blast furnace is adjusted such that the percentage of the carbon iron composite is 50% by mass or less of the total amount of coke, including conventional coke, charged into the blast furnace. On the other hand, in order to achieve the effect of lowering the reducing agent rate by 20 kg/t or more, the percentage thereof is preferably 25% by mass or more and more preferably 30% by mass or more.

[0028] A carbon iron composite is preferably used in such a manner that the carbon iron composite is mixed with ore (an iron-containing material containing such as sintered ore, pellets, lump ore and the like) (see, for example, Patent Literature 1). In this case, it is operationally important that the gas permeability of a mixed layer of ore and the carbon iron composite is well maintained. Therefore, the inventors have investigated the influence of the size of the carbon iron composite on the gas permeability of the mixed layer of ore and the carbon iron composite (hereinafter referred to as "ore + carbon iron composite-mixed layers"). Fig. 8 shows the particle size distribution of ore used. The inventors have calculated the influence of the particle size of the carbon iron composite mixed in an ore layer on the gas permeability thereof using the following equation (11) on the assumption that the percentage of the carbon iron composite in the ore layer is 21% by volume (which corresponds to a carbon iron composite percentage of 35% by mass):

$$\text{pressure drop index} = (1 / \Phi d_p)^{1.3} \cdot (1 - \varepsilon)^{1.3} / \varepsilon^3 \tag{11}$$

wherein Φ is the shape factor (which is 0.7), d_p is the average particle size of the ore + carbon iron composite-mixed layer, and ε is the voidage of the ore + carbon iron composite-mixed layer. The average particle size of the ore + carbon iron composite-mixed layer was calculated in such a manner that the particle size distribution shown in Fig. 8 was corrected depending on the predicted size of the carbon iron composite. The voidage thereof was estimated from the particle size distribution (see Non-Patent Literature 3). Results are shown in Fig. 9. It is clear that the change in pressure drop is small when the particle size of the carbon iron composite is between 15 mm to 40 mm. When the particle size of the carbon iron composite falls below 15 mm, the average particle size of the ore + carbon iron composite-mixed layer lowers and therefore the pressure drop increases. On the other hand, the pressure drop increases even under such a condition that the size of the carbon iron composite is large. This is due to that the particle size distribution expands and therefore the voidage lowers. From the above, it is clear that the particle size of the carbon iron composite is 15 mm to 40 mm for the purpose of avoiding an increase in pressure drop. A carbon iron composite, produced with a press, having such a shape as shown in Fig. 2 preferably has a particle size (= $(A \times B \times C)^{1/3}$) of 15 mm to 40 mm as defined above. A carbon iron composite, having an irregular shape, produced in a current coke oven is preferably used in such a manner that this carbon iron composite is sieved so as to have a particle size of 15 mm to 40 mm before being charged into a blast furnace.

[0029] The amount of a carbon iron composite effective in promoting a reaction was investigated by a gasification reaction test simulating blast furnace conditions. The carbon iron composite and conventional coke were packed into a crucible with an inner diameter of 76 mm at a predetermined ratio and were tested under gas-temperature conditions shown in Fig. 10, whereby the reaction rate of carbon in tested coke was measured. Fig. 11 shows the relative reaction rate of carbon (the relative carbon reaction rate) determined in such a manner that a conventional coke percentage of 100% by mass (a carbon iron composite percentage of 0% by mass) is set to a base and the percentage of the carbon iron composite used is varied. The relative carbon reaction rate is herein the sum of the reaction rate of the carbon iron composite and the reaction rate of conventional coke. There is no clear difference from the base when the percentage of the carbon iron composite used is about 1% by mass, the reaction rate increases from the base when the percentage of the carbon iron composite used is 2% by mass, and the reaction rate increases with an increase in the percentage of the carbon iron composite used when the percentage of the carbon iron composite used is further increased. When the amount of the mixed carbon iron composite is extremely small, the unevenness of a mixed packed layer is significant; hence, a reaction-promoting effect is probably unlikely to occur.

Thus, the percentage of the carbon iron composite used needs to be 2% by mass or more of the amount of coke used, that is, the total amount of coke including conventional coke.

[0030] For the particle size of carbon iron composites, the present invention is preferably applied to a case where a carbon iron composite with a particle size less than the particle size of conventional coke charged into a blast furnace alone without being mixed with ore is used. In the case of using the carbon iron composite with a particle size less than the particle size of conventional coke charged into a blast furnace alone, the gas or liquid permeability of a furnace bottom section may possibly be deteriorated and effects of the present invention are significant. When the particle size of the carbon iron composite is greater than that of conventional coke, the gas or liquid permeability of the furnace bottom section is unlikely to be deteriorated. The term "ore" as used herein refers to an iron source material, such as lump ore or sintered ore, charged into a blast furnace.

EXAMPLE 1

[0031] A carbon iron composite was tested in a blast furnace. The carbon iron composite was produced in such a manner that a mixture of coal and iron ore was briquetted with a briquetting machine, was charged into a vertical shaft furnace, and was then carbonized. The carbon iron composite had a size of 30 mm x 25 mm x 18 mm (a particle size of 24 mm). The rate of reduction of iron ore in carbon iron composite was 80% to 85% and the drum index $DI_{150/15}$ of the carbon iron composite was 82. The carbon iron composite contained 30% by mass iron and 70% by mass coke with a carbon content of 87.5% by mass. Raw materials were charged into the blast furnace in such a manner that mixed layers of the carbon iron composite 10 and ore 20 and layers of conventional coke 30 alone were alternately stacked as shown in Fig. 12. With reference to Fig. 8, the left end is the furnace center and reference numeral 40 represents a furnace wall. The conventional coke 30 had an average particle size of 45 mm. With reference to Fig. 12, the left end is the furnace center and reference numeral 40 represents a furnace wall. Five percent by mass of the conventional coke was small-size coke with a particle size of 10 mm to 25 mm and was mixed with the ore. The layers of conventional coke 30 alone had an average particle size of 45 mm.

[0032] An operation test was performed in such a manner that the percentage of the mixed carbon iron composite was varied when the raw materials were charged into the blast furnace as described above. Table 4 shows variations in the reducing agent rate and pressure drop index (the relative pressure drop index of a furnace bottom section) of the blast furnace. In Table 4, Base is a case where no carbon iron composite is used and Cases 1 to 3 are cases where the percentage of the carbon iron composite used is increased within a range of 50% by mass or less.

[0033]

Table 4

		Base	Case 1	Case 2	Case 3
Carbon iron composite rate	kg/t	0	104	171	180
Carbon in carbon iron composite	kg/t	0	73	120	126
Conventional coke rate	kg/t	379	271	201	183
Percentage of carbon iron composite	mass %	0	28	46	50
Pulverized coal rate	kg/t	126	126	126	120
Reducing agent rate	kg/t	505	470	446	430
Relative pressure drop index of furnace bottom section	-	1	1.01	1.03	1.05

[0034] Although the pressure drop increased with an increase in the percentage of the carbon iron composite used, a stable operation was capable of being continued because the percentage of the carbon iron composite was adjusted to 50% by mass or less. When the percentage of the carbon iron composite used was temporarily increased to 55% by mass, it was difficult to continue a stable operation because of an increase in the pressure drop of a furnace bottom section. Reference Signs List

[0035]

1	pressure drop-measuring unit
2	pressure drop-measuring sample
10	carbon iron composite
20	ore
30	conventional coke
40	furnace wall

Claims

1. A method for operating a blast furnace, comprising charging ore and coke including a carbon iron composite and conventional coke into the blast furnace, wherein the percentage of the carbon iron composite used is 2% to 50% by mass of the coke.

2. The method according to claim 1, wherein the carbon iron composite has a particle size of 15 mm to 40 mm.

3. The method according to claim 2, wherein the carbon iron composite has a particle size of 20 mm to 35 mm.

4. The method according to claim 1, wherein the percentage of the carbon iron composite used is 25% to 50% by mass of the coke.

5. The method according to claim 3, wherein the percentage of the carbon iron composite used is 30% to 50% by mass of the coke.

6. The method according to claim 1, wherein the carbon iron composite has an iron content of 10% to 40% by mass.

FIG. 1

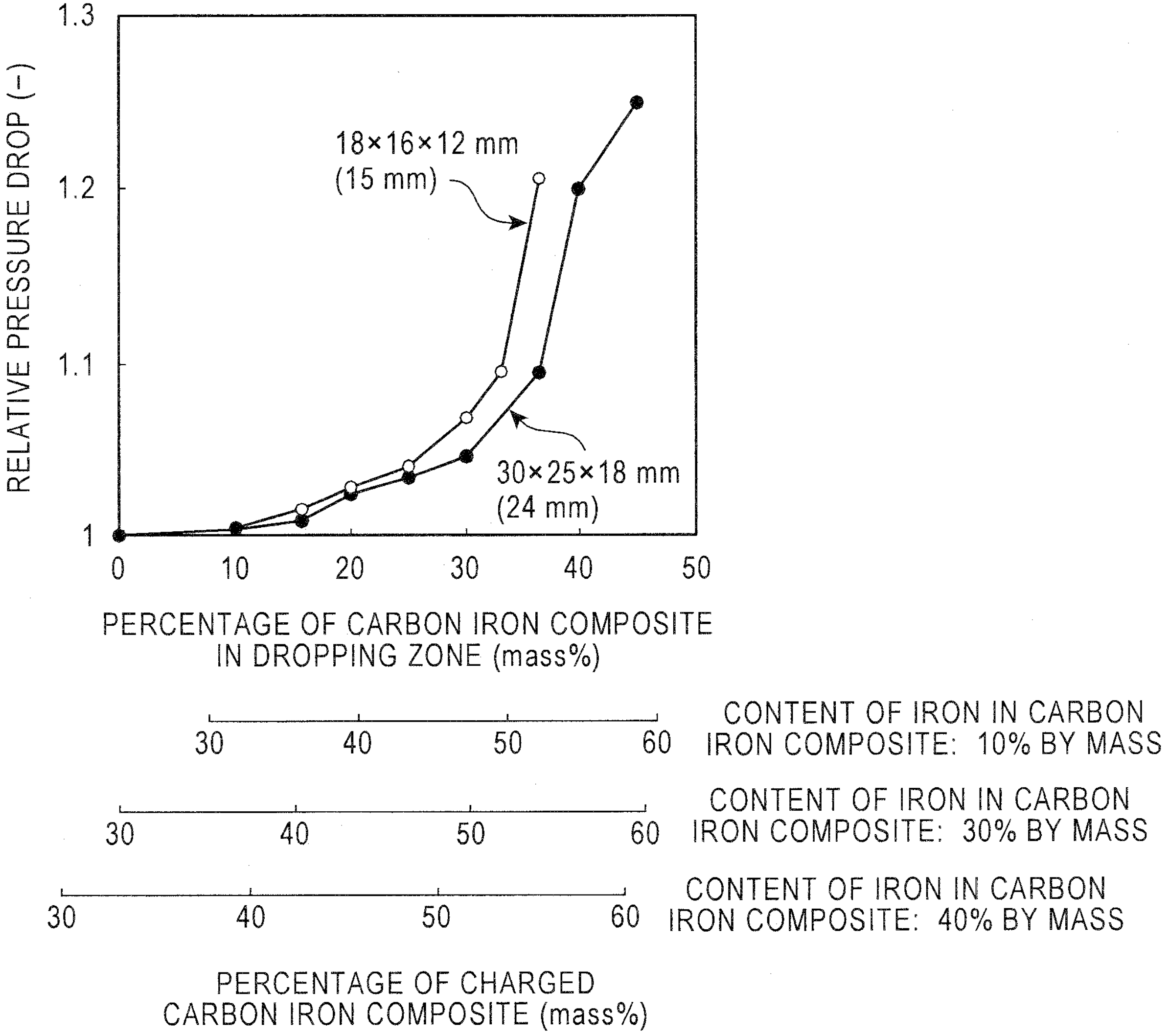

RELATIVE PRESSURE DROP (–)
1.3
1.2
1.1
1
0
10
20
30
40
50
18×16×12 mm
(15 mm)
30×25×18 mm
(24 mm)
PERCENTAGE OF CARBON IRON COMPOSITE IN DROPPING ZONE (mass%)
30
40
50
60
CONTENT OF IRON IN CARBON IRON COMPOSITE: 10% BY MASS
30
40
50
60
CONTENT OF IRON IN CARBON IRON COMPOSITE: 30% BY MASS
30
40
50
60
CONTENT OF IRON IN CARBON IRON COMPOSITE: 40% BY MASS
PERCENTAGE OF CHARGED CARBON IRON COMPOSITE (mass%)

FIG. 2

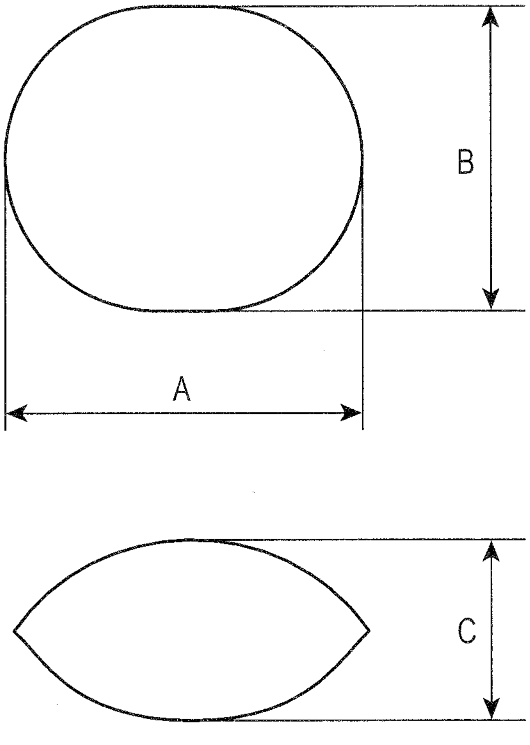


FIG. 3

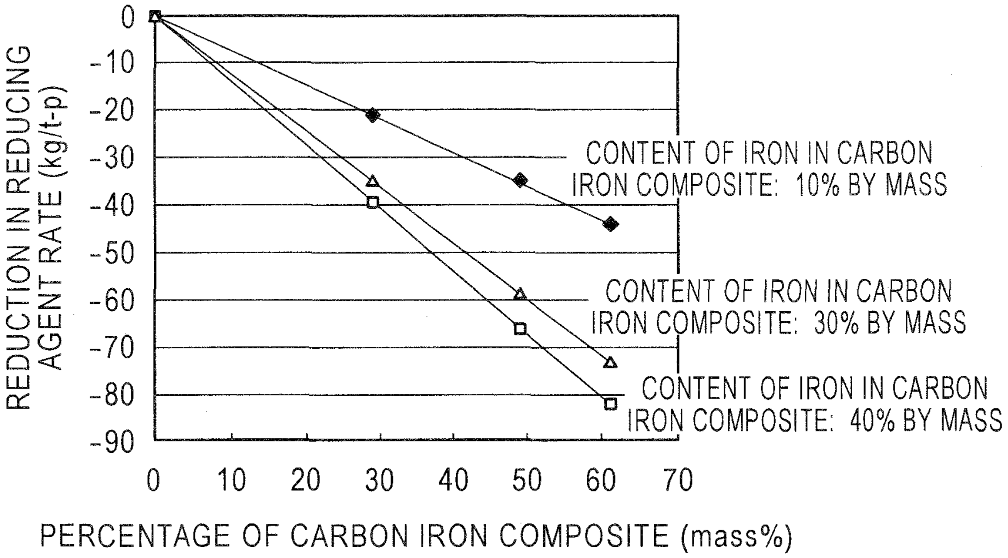

REDUCTION IN REDUCING AGENT RATE (kg/t-p)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
10
20
30
40
50
60
70
PERCENTAGE OF CARBON IRON COMPOSITE (mass%)
CONTENT OF IRON IN CARBON IRON COMPOSITE: 10% BY MASS
CONTENT OF IRON IN CARBON IRON COMPOSITE: 30% BY MASS
CONTENT OF IRON IN CARBON IRON COMPOSITE: 40% BY MASS

FIG. 4

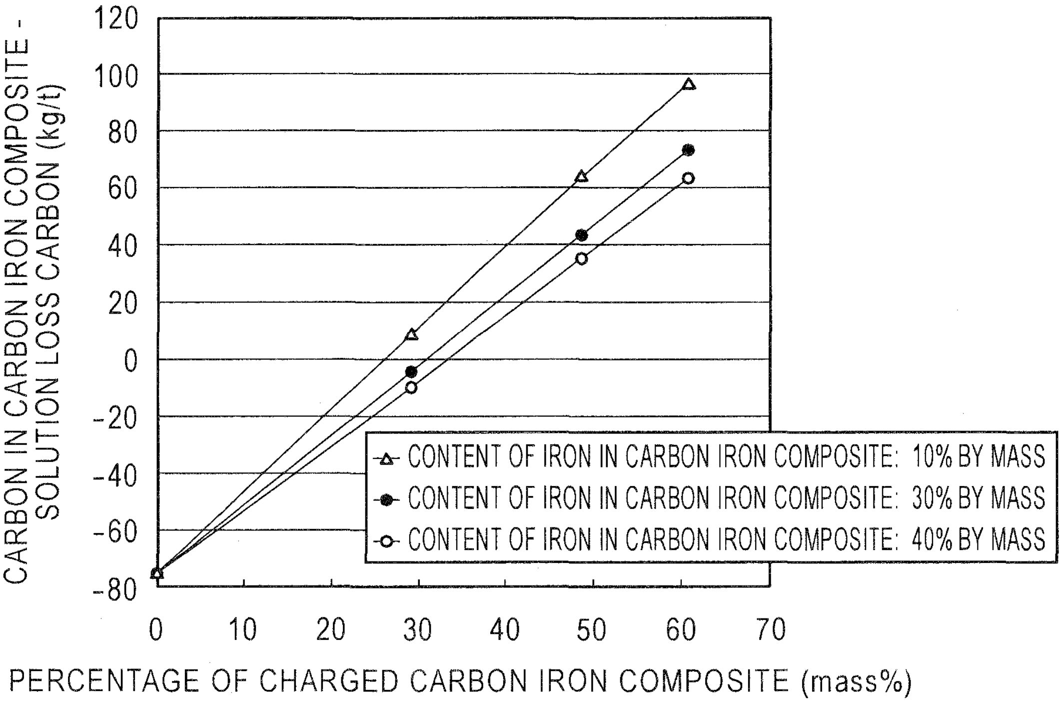

CARBON IN CARBON IRON COMPOSITE - SOLUTION LOSS CARBON (kg/t)
120
100
80
60
40
20
0
-20
-40
-60
-80
0
10
20
30
40
50
60
70
PERCENTAGE OF CHARGED CARBON IRON COMPOSITE (mass%)
CONTENT OF IRON IN CARBON IRON COMPOSITE: 10% BY MASS
CONTENT OF IRON IN CARBON IRON COMPOSITE: 30% BY MASS
CONTENT OF IRON IN CARBON IRON COMPOSITE: 40% BY MASS

FIG. 5

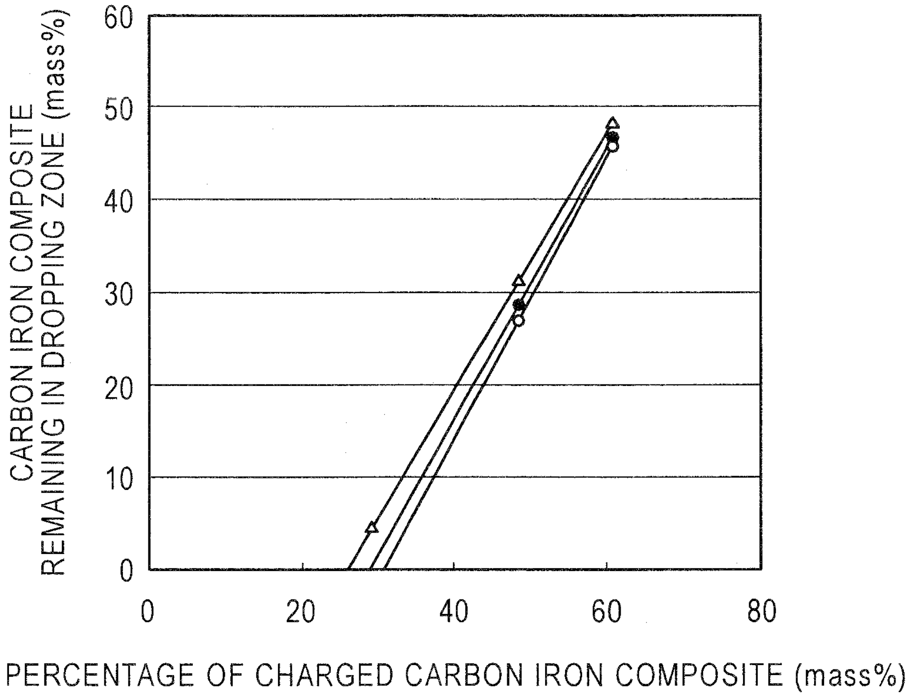

CARBON IRON COMPOSITE REMAINING IN DROPPING ZONE (mass%)
60
50
40
30
20
10
0
0
20
40
60
80
PERCENTAGE OF CHARGED CARBON IRON COMPOSITE (mass%)

FIG. 6

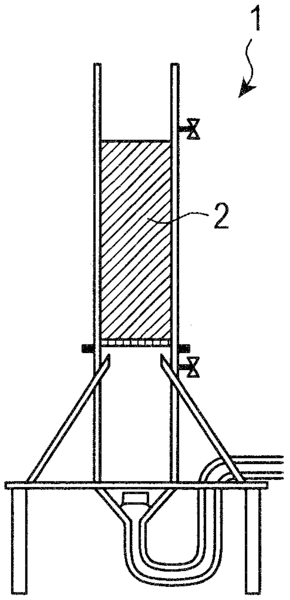

1
2

FIG. 7

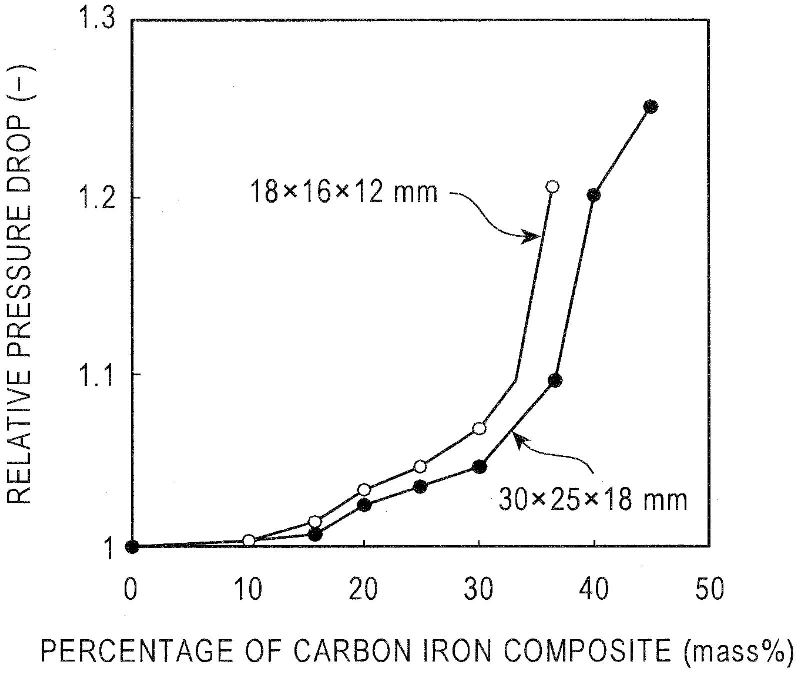

1.3
1.2
1.1
1
RELATIVE PRESSURE DROP (−)
18×16×12 mm
30×25×18 mm
0
10
20
30
40
50
PERCENTAGE OF CARBON IRON COMPOSITE (mass%)

FIG. 8

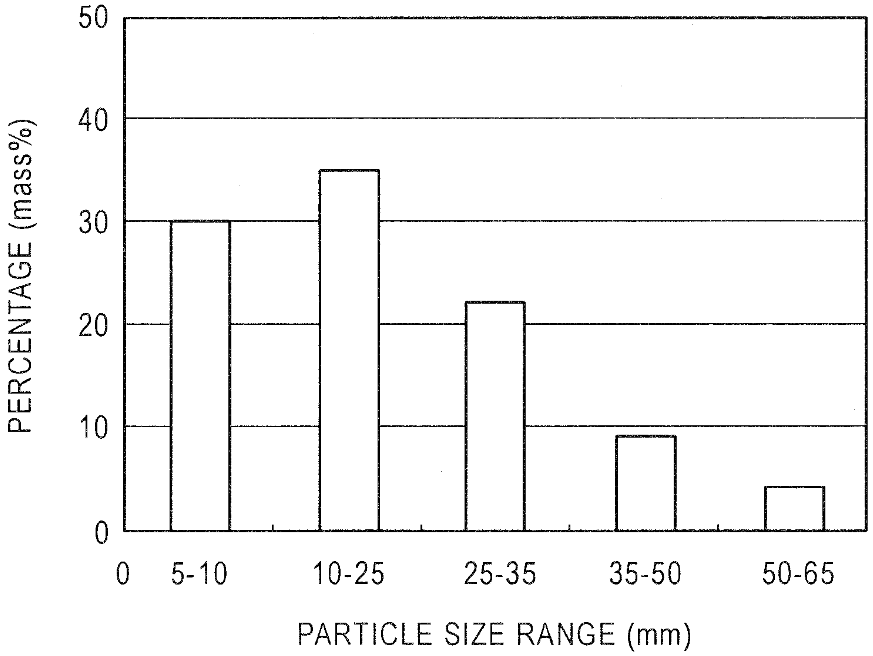

50
40
30
20
10
0
PERCENTAGE (mass%)
0
5-10
10-25
25-35
35-50
50-65
PARTICLE SIZE RANGE (mm)

FIG. 9

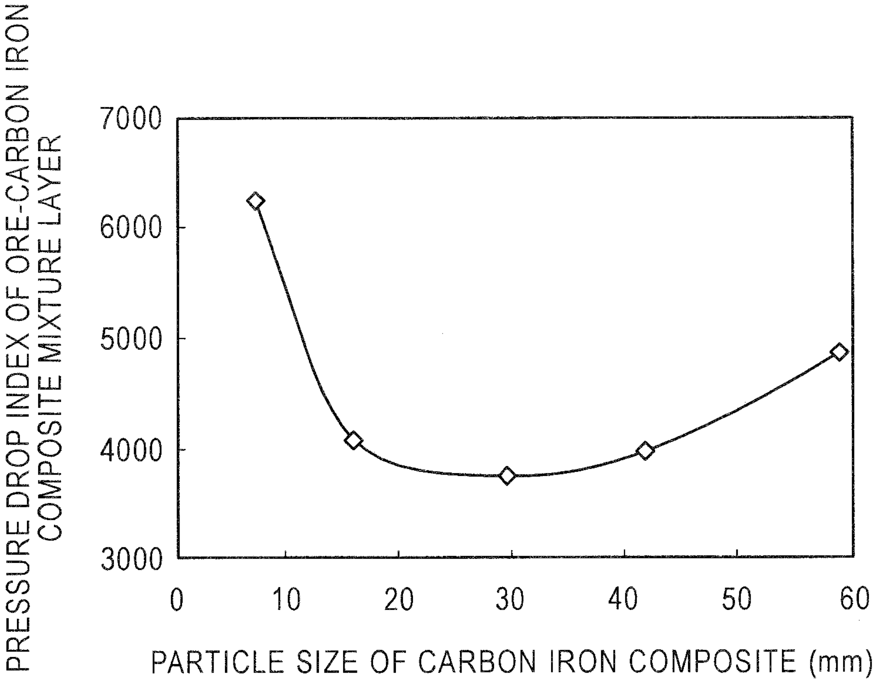

PRESSURE DROP INDEX OF ORE-CARBON IRON COMPOSITE MIXTURE LAYER
7000
6000
5000
4000
3000
0
10
20
30
40
50
60
PARTICLE SIZE OF CARBON IRON COMPOSITE (mm)

FIG. 10

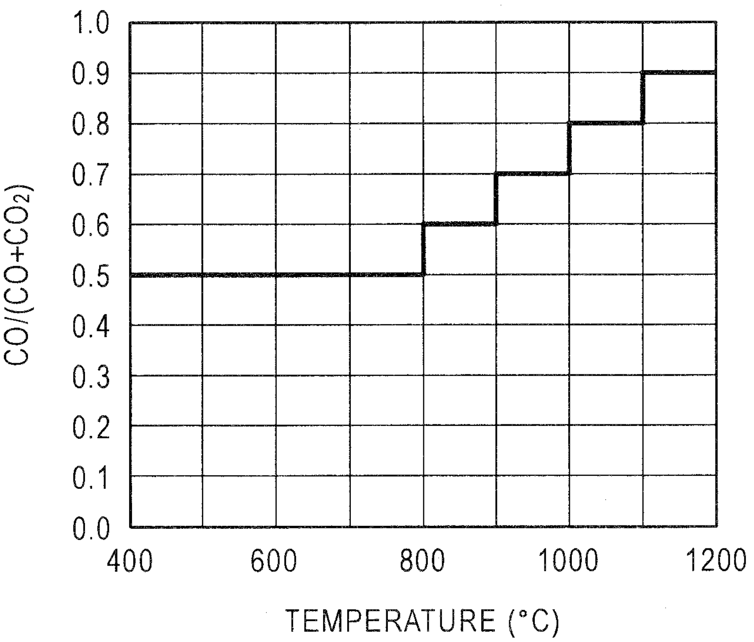

$CO/(CO+CO_2)$
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
400
600
800
1000
1200
TEMPERATURE (°C)

FIG. 11

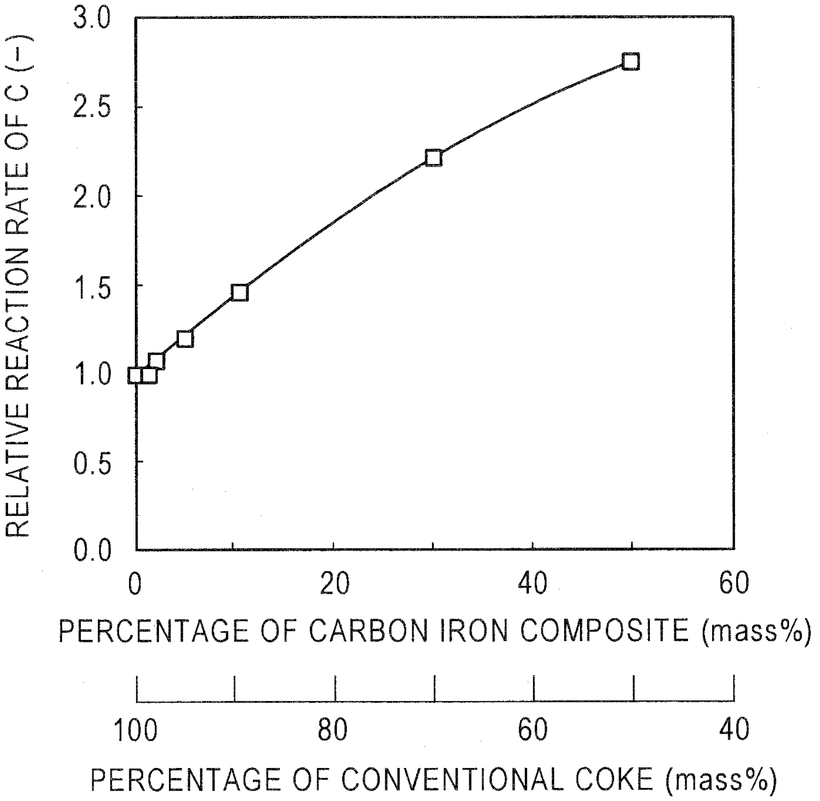
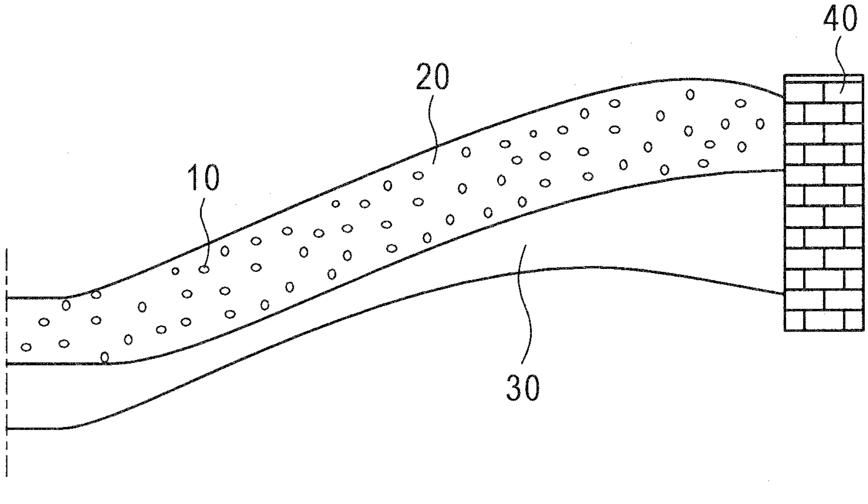

RELATIVE REACTION RATE OF C (−)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
20
40
60
PERCENTAGE OF CARBON IRON COMPOSITE (mass%)
100
80
60
40
PERCENTAGE OF CONVENTIONAL COKE (mass%)

FIG. 12


40
20
10
30

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/069645

A. CLASSIFICATION OF SUBJECT MATTER
C21B5/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C21B5/00-5/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2007-231326 A (JFE Steel Corp.), 13 September 2007 (13.09.2007), claims 1, 2; example 1; fig. 6 (Family: none)	1-6 2,3
X Y	JP 2008-106320 A (JFE Steel Corp.), 08 May 2008 (08.05.2008), example 1; tables 1, 2 (Family: none)	1,4 2,3,6
Y	Seiji NOMURA, et al., "Kakushinteki Shinkaiseibutsu ni yoru Koro Netsu Hozontai Ondo Teigen Koka", Current advances in materials and processes, vol.22, no.2, 01 September 2009 (01.09.2009), pages 746 to 749	6

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"&" document member of the same patent family

Date of the actual completion of the international search 05 January, 2011 (05.01.11)	Date of mailing of the international search report 18 January, 2011 (18.01.11)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/069645

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2008-56985 A (JFE Steel Corp.), 13 March 2008 (13.03.2008), example 1; table 1 (Family: none)	1-6

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2006028594 A **[0008]**

Non-patent literature cited in the description

- Tetsu-to-Hagane. The Iron and Steel Institute of Japan, 2001, vol. 87, 357 **[0009]**
- Tetsu-to-Hagane. The Iron and Steel Institute of Japan, 1993, vol. 79, 618 **[0009]**
- *KAWASAKI STEEL GIHO,* 1974, vol. 6, 16 **[0009]**