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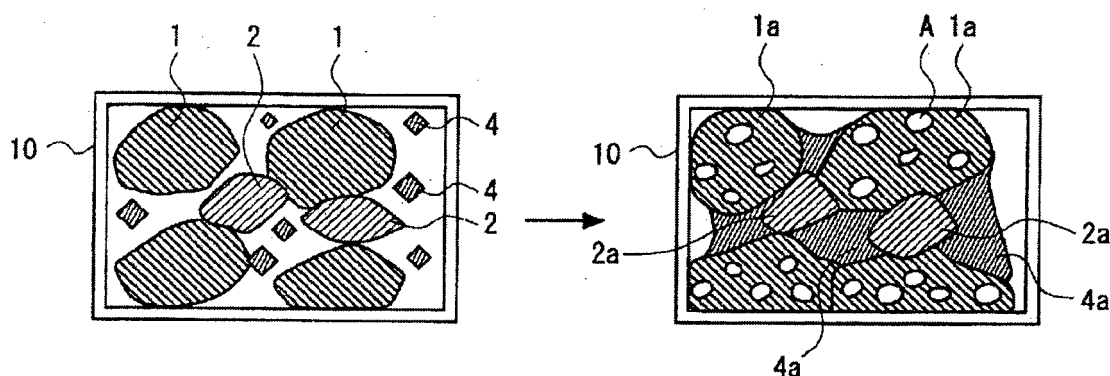
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(54) **METHOD FOR MANUFACTURING BLAST FURNACE COKE, AND BLAST FURNACE COKE**

(57) This method for manufacturing blast furnace coke is provided with a step for blending, with coal, ashless coal obtained by solvent extraction processing of coal, and a step for carbonizing the blended coal, the

blended amount of the ashless coal in the blending step being 3% by mass or greater, and the expansion coefficient of the blended coal being 20% or lower.

FIG. 2



Description

Technical Field

[0001] The present invention relates to a method for producing a blast furnace coke and a blast furnace coke.

Background Art

[0002] For a coke used for ironmaking in a blast furnace, three functions are roughly expected, a function as a reducing material for iron ore (iron oxide), a function as a heat source (fuel) and a function as a filling material for ensuring gas permeability in a blast furnace by withstanding loads of the coke itself and the iron ore. In order to perform these functions, certain levels of strength and reactivity (reducibility and combustibility) are required for the above-mentioned coke.

[0003] In general, a coke is produced by baking (sometimes referred to as "carbonizing") a coal at a high temperature of 1000°C or higher. In the case of obtaining a high-strength coke, so-called a hard coking coal having a high caking property is used. However, such a hard coking coal is relatively expensive. Accordingly, for a purpose of reducing production cost of the coke, a slightly coking coal having a poor caking property or a non-coking coal having almost no caking property (slightly coking coal and non-coking coal are hereinafter sometimes collectively referred to as "non-coking or slightly coking coal") is also blended in a certain amount as a raw material for the coke, in addition to a weakly coking coal having a lower caking property than a hard coking coal. A mechanism of producing the high-strength coke has become clear to some extent, and methods for efficiently obtaining the high-strength coke have been variously proposed (for example, see WO 2010/103828).

[0004] Changes of coal particles in a carbonization process are described herein. FIG. 1A is a view schematically expressing the changes. The left side shows a state in which the coal particles (hard coking coal particles 1 and non-coking or slightly coking coal particles 2) before carbonization are present in an oven body 10, and the right side shows a state in which continuous phases 1a formed by swelling of the hard coking particles 1 and modified components 2a of the non-coking or slightly coking coal particles 2 after carbonization are present. The hard coking coal particles 1 are melted in the carbonization process, include generated gas to swell, and bond with the adjacent the hard coking coal particles 1, thereby forming the continuous phases 1a containing bubbles A. When a ratio of the hard coking coal is equivalent to or more than a certain level and a ratio of the non-coking or slightly coking coal is small, the non-coking or slightly coking coal particles 2 are taken into the hard coking coal in the above-mentioned continuous phase forming process, so that defects are unlikely to occur. However, when the ratio of the non-coking or slightly coking coal is high as shown in FIG. 1A, adhesion between the hard coking coal particles 1 is inhibited, and a low-strength coke having coarse defects B inside is produced.

[0005] In contrast, as one of measures for increasing the strength of the coke, there is (1) a method of increasing a bulk density of a raw material coal higher than usual (see FIG. 1B). In such a manner, the bulk density is increased to decrease a distance between particles, thereby filling spaces with swelling the hard coking coal, and a high-strength coke having a few defects can be produced. Further, the strength of the coke can also be improved by (2) blending a highly swellable hard coking coal (see FIG. 1C). That is, the highly swellable hard coking coal particles 3 having an extremely high swelling rate are blended, whereby pressing force acts between the non-coking or slightly coking coal particles 2 by swelling thereof, and spaces between the particles are effectively filled with continuous phases 3a derived from a highly swellable hard coking coal particles 3. Accordingly, a coke strength is improved.

[0006] However, the above-mentioned production method of the high-strength coke has the following operational problems or difficulties. First, the method of increasing the bulk density of (1) described above requires special operations such as drying of the coal to a high level, densification of the coal by forming a part thereof and mechanical treatment such as stamp charging, all of which require costs. Further, the densification of the raw coal may exert high pressure on a coke oven wall.

[0007] Then, in the method (2) of using the highly swellable hard coking coal, a probability of occurrence of unpredictable operational troubles such as damage or breakage of a coke oven wall and difficulty in discharging the coke from a coke oven may be increased by occurring excess swelling. As countermeasures for improving the problems of such a method of (2), there are proposed (3) a method of suppressing viscosity of the coal in a molten state by using a caking additive such as tar (see JP-A-2001-214171) and (4) a method of controlling the swelling rate of the non-coking or slightly coking coal (see JP-A-2008-156661). However, the method of (3) cannot avoid an increase in production cost of the coke due to addition of the caking additive. Further, in the method of (4), a blending step of the coal is complicated to cause an increase in production cost of the coke.

Prior Art Literature

Patent Literature

5 **[0008]**

Patent Literature 1: WO 2010/103828

Patent Literature 2: JP-A-2001-214171

Patent Literature 3: JP-A-2008-156661

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Summary of the Invention

Problems That the Invention Is to Solve

15 **[0009]** The present invention has been made in view of circumstances as described above, and an object thereof is to provide a method for producing a blast furnace coke, by which the high-strength coke is obtained at low cost while suppressing an influence on a coke oven due to swelling, and such a blast furnace coke.

Means for Solving the Problems

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[0010] In order to solve the above-mentioned problems, the present inventors have made intensive studies. As a result, it has been found that when the swelling rate of a blended coal is adjusted to 20% or less by blending with the raw coal at least a specified amount of an ashless coal which is an extracted component obtained by solvent extraction treatment of coal and shows high fluidity and swelling property in a molten state, a high-strength blast furnace coke is obtained while suppressing damage and the like of the coke oven due to swelling of the raw coal.

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[0011] That is, the invention made in order to solve the above-mentioned problems is directed to a method for producing a blast furnace coke, including a blending step of blending an ashless coal obtained by solvent extraction treatment of coal with a coal, thereby obtaining a blended coal, and a step of carbonizing the blended coal, wherein a blending amount of the ashless coal in the blending step is 3 mass % or more, and a swelling rate of the blended coal in the blending step is 20% or less

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[0012] The method for producing a blast furnace coke can increase the strength of a resulting coke, by blending the ashless coal with coal in a blending amount within the above-mentioned range, whereby the ashless coal is melted during carbonization and fills spaces of the raw coal. Further, the method for producing a blast furnace coke can suppress the influence on the coke oven due to swelling of the blended coal by adjusting the swelling rate of the blended coal to the above-mentioned range. Furthermore, the adjustment of the swelling rate of the blended coal can be easily achieved by blending of the ashless coal. Therefore, the method for producing a blast furnace coke does not require another caking additive or the like. As a result, according to the method for producing a blast furnace coke, the high-strength blast furnace coke can be obtained at low cost while prolonging the lifetime of an oven body. The "swelling rate" is a value measured in accordance with JIS-M8801:2004.

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[0013] The swelling rate of the blended coal in the above-mentioned blending step is preferably 10% or more. By adjusting the swelling rate of the blended coal to 10% or more as described above, the occurrence of coarse defects during carbonization can be suppressed to further increase the strength of the resulting coke.

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[0014] Coal with which the above-mentioned ashless coal is blended preferably contains the hard coking coal and non-coking or slightly coking coal. A ratio of the hard coking coal in the above-mentioned blended coal is preferably 20 mass % or more and 50 mass % or less. By adjusting the ratio of the hard coking coal to such a range, a high-strength blast furnace coke can be obtained more easily and surely at low cost. "Hard coking coal" generally means a coal having an average maximum reflectance Ro of 1.3% or more and 1.6% or less, and a logarithm of maximum fluidity MF (ddpm) (log MF) of 0.8 or more and 2.5 or less, or an Ro of 1.0% or more and 1.3% or less, and a log MF of 1.5 or more and 4 or less. "Non-coking or slightly coking coal" is generally a general term for slightly coking coal and non-coking coal, and means, for example, a coal having an Ro of less than 0.85 and a log MF of 2.5 or less, or an Ro of 0.85 or more and a log MF of 2 or less. Here, the "average maximum reflectance Ro" is a value measured in accordance with JIS-M8816:1992, and the "maximum fluidity MF" is a value measured in accordance with the Gieseler plastometer method of JIS M8801:2004.

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[0015] Another invention made in order to solve the above-mentioned problems is directed to a blast furnace coke obtained by carbonizing a blended coal prepared by blending an ashless coal obtained by solvent extraction treatment of coal with a coal, wherein a blending amount of the ashless coal in the blended coal is 3 mass % or more, and a swelling rate of the blended coal is 20% or less.

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[0016] For the reasons described above, the blast furnace coke has high strength and can be produced at low cost

while suppressing the influence on the coke oven due to swelling.

Advantageous Effects of the Invention

5 **[0017]** As described above, according to the method for producing a blast furnace coke of the present invention, the high-strength blast furnace coke is obtained at low cost while suppressing the influence on the coke oven due to swelling. Such a blast furnace coke can be suitably used as an ironmaking material.

Brief Description of the Drawings

10 **[0018]**

[FIG. 1A] FIG. 1A is a schematic view for illustrating states before and after carbonization of the coal in a conventional method for producing a coke using no ashless coal.

15 [FIG. 1B] FIG. 1B is a schematic view for illustrating states before and after carbonization of the coal in another conventional method for producing a coke (a method of increasing the bulk density) using no ashless coal.

[FIG. 1C] FIG. 1C is a schematic view for illustrating states before and after carbonization of the coal in still another conventional method for producing a coke (a method of blending hard coking coal) using no ashless coal.

20 [FIG. 2] FIG. 2 is a schematic view for illustrating states before and after carbonization of the coal with which the ashless coal is blended.

Mode for Carrying Out the Invention

25 **[0019]** Embodiments of a method for producing a blast furnace coke and blast furnace coke according to the present invention will be described below.

[Method for producing a blast furnace coke]

30 **[0020]** The method for producing a blast furnace coke is provided with a step of blending the ashless coal obtained by solvent extraction treatment of coal with the coal (blending step) and a step of carbonizing the above-mentioned blended coal (carbonization step).

<Blending step>

35 **[0021]** In the blending step, ashless coal is blended with coal as a raw material for the coke, thereby obtaining the blended coal.

(Coal)

40 **[0022]** A coal used as the raw material for the coke in the method for producing a blast furnace coke is not particularly limited, and the hard coking coal, semi-hard coking coal, weakly coking coal, slightly coking coal, non-coking coal and the like can be used in combination at such an appropriate ratio that fusing of the whole coal becomes possible by carbonization. In particular, it is preferred that the raw coal contains the hard coking coal and non-coking or slightly coking coal.

45 **[0023]** An upper limit of the ratio of the hard coking coal in raw coal is preferably 50 mass % and more preferably 40 mass %, from the viewpoint of more inexpensively producing a high-quality coke. On the other hand, a lower limit of the ratio of the hard coking coal in the raw coal is preferably 20 mass % and more preferably 30 mass %. When the ratio of the hard coking coal exceeds the above-mentioned upper limit, the production cost of the coke may be increased. Conversely, when the ratio of the hard coking coal is less than the above-mentioned lower limit, the strength of the

50 **[0024]** The raw coal is preferably finely pulverized into a granular form. When raw the coal is granulated, an average particle size D20 of the raw coal is preferably 3 mm or less. When the average particle size D20 exceeds 3 mm, miscibility with the ashless coal and the strength of the resulting coke may become insufficient. The "average particle size D20" means a size of an opening of a sieve at the time when an accumulated volume of particles which have remained on the sieve reaches 20% of the volume of all particles, in the case of screening all particles through a metal wire sieve specified in JIS Z 8801-1:2006 from a sieve having a larger opening in order.

55 **[0025]** Although a dried coal obtained by air drying or the like may be used as a raw coal, one in a state of containing moisture may also be used.

(Ashless coal)

[0026] An ashless coal (Hyper-coal, HPC) is a kind of modified coal obtained by modifying a coal, and the modified coal obtained by removing ash and insoluble components as much as possible from the coal using a solvent. However, the ashless coal may contain ash within a range of not significantly impairing fluidity or swelling property of the ashless coal. In general, a coal contains 7 mass % or more and 20 mass % or less of ash. However, an ashless coal used in the method for producing a blast furnace coke may contain ash in an amount of about 2%, and in an amount of about 5% in some cases. "Ash content" means a value measured in accordance with JIS-M8812:2004.

[0027] Such an ashless coal can be obtained by solvent extraction treatment in which a coal is mixed with a solvent having a high affinity for the coal to obtain an extract from which components insoluble in the solvent, such as ash, are separated and the solvent is removed from this extract. As a specific method of the solvent extraction treatment, there can be used, for example, a method disclosed in Japanese Patent No. 4045229. The ashless coal obtained by such solvent extraction treatment does not substantially contain ash, and contains large amounts of organic substances which are soluble in solvent and show softening and melting properties. Structurally, the ashless coal has a wide molecular weight distribution ranging from a component with a relatively low molecular weight having two or three fused aromatic rings to a component with a high molecular weight having about five or six fused aromatic rings. Accordingly, the ashless coal shows high fluidity under heating, and generally melts at 150°C or more and 300°C or less regardless of the grade of the coal used as the raw material. In addition, the ashless coal swells while generating a large amount of volatile matter in an initial stage of carbonization at about 300°C or more and 500°C or less. Further, the ashless coal is obtained through dewatering of a mixture (slurry) of the coal and the solvent. Therefore, the moisture content thereof is from about 0.2 mass % or more and 3 mass % or less, and the ashless coal has a sufficient calorific value.

[0028] As described above, the ashless coal has excellent fluidity and high caking property, so that it can compensate a caking property of the non-coking or slightly coking coal. Specifically, as shown in FIG. 2, by dispersing and blending the ashless coal particles 4 with the raw coal particles (hard coking coal particles 1 and non-coking or slightly coking coal particles 2), the ashless coal particles 4 start to flow at a temperature lower than that of the raw coal particles in the coke oven, and continuous phases 4a derived from the ashless coal particles 4 are almost uniformly formed, including a central portion of the oven in which a temperature rise is slow. Thereby, continuous phases 1a derived from the hard coking coal particles 1 and modified components 2a of the non-coking or slightly coking coal particles 2 are connected to fill spaces between the particles. Further, the ashless coal has a higher swelling property than the hard coking coal, so that the ashless coal particles 4 swell even in a lower part of the coke oven, in which a large load is applied, thereby connecting the coal particles to fill spaces between the particles. As a result, the defects such as occurrence of poor adhesion between the coal particles (macrocracks) and occurrence of excessive swells (coarse pores), which may act as starting points for breakage of the coke, can be reduced, and it is possible to suppress variations in a coke quality depending on a position in the coke oven. On the other hand, the viscosity of the ashless coal in a molten state is low compared to that of the hard coking coal, so that the swelling rate of the blended coal obtained by blending the ashless coal with the raw coal is not excessively increased. Therefore, suppression of an increase in the swelling rate of the blended coal and improvement in the strength of the coke can be made compatible by blending the ashless coal. As described above, by using the ashless coal as a caking additive, the high-strength blast furnace coke can be obtained at low cost while prolonging a lifetime of the coke oven.

[0029] A lower limit of the blending amount of the ashless coal in this blending step is 3 mass %, preferably 4 mass % and more preferably 5 mass %. On the other hand, an upper limit of a blending amount of the ashless coal is preferably 15 mass %, more preferably 12 mass % and still more preferably 10 mass %. When the blending amount of the ashless coal is less than the above-mentioned lower limit, a connecting effect of the coal particles described above is not sufficiently obtained, and the strength of the coke may become insufficient. Conversely, when the blending amount of the ashless coal exceeds the above-mentioned upper limit, the swelling rate of the blended coal is excessively increased, which may have the influence on the oven body and increases the production cost of the coke.

[0030] Further, 3 mass % of the above-mentioned lower limit can be calculated as described below. First, a porosity at the time of carbonizing the raw coal free from the ashless coal is about 10% by volume. It becomes a problem whether or not the ashless coal can fill the spaces. Here, the ashless coal is extremely high in fluidity in a molten state compared to an ordinary coal, so that measurement of the swelling rate according to the JIS method cannot be applied. Then, the swelling rate of the ashless coal is measured by the following method. First, a quartz test tube having an inner diameter of 15 mm is filled with 1.8 g of an anthracite pulverized into a particle size of 2 mm or less and 0.2 g of the ashless coal pulverized into a particle size of 200 μm or less, followed by heat treatment to 500°C at 3°C/min, and the swelling rate $V_{10\%}$ (%) is determined from a ratio of a height of a sample after heating to a height of the sample before heating. Next, similarly, a quartz test tube having an inner diameter of 15 mm is filled with 1.6 g of an anthracite pulverized into a particle size of 2 mm or less and 0.4 g of the ashless coal pulverized into a particle size of 200 μm or less, followed by heat treatment to 500°C at 3°C/min, and the swelling rate $V_{20\%}$ (%) is determined from the ratio of the height of the sample after heating to the height of the sample before heating. The swelling rate D (%) of the ashless coal is determined from

the following formula (1):

$$D = (V_{20\%} - V_{10\%}) / (20 - 10) \times 100 (\%) \cdots (1)$$

[0031] The swelling rate of the ashless coal measured by this method is about 300% (from 200% or more and 500% or less), although it depends on the raw material or production conditions of the ashless coal. Accordingly, a volume of the ashless coal necessary for filling most of the spaces, for example, 80% of the spaces, is $10 \times 0.8 / 300 \times 100\% = 2.6\%$ by volume. A mass ratio of the ashless coal for filling the above-mentioned spaces is considered to be 3 mass %, because a specific gravity of the ashless coal and the specific gravity of the raw coal are assumed to be substantially equal to each other. A reason for using an anthracite in the above-mentioned measuring method is as follows. Among coals, an anthracite is in a class having the highest degree of coalification, and is often used as a part of raw coal for an ironmaking coke production. However, it has no caking property and no fluidity at all. That is just the reason for using an anthracite in the above-mentioned measuring method. That is, an anthracite is neither melted nor swelled in the carbonization process, and therefore, it is expected that the swelling rate in the course of mixing ashless coal with the coal particles and performing carbonization can be estimated with a higher accuracy.

[0032] Coal acting as a raw material for ashless coal used in the method for producing blast furnace coke is not particularly limited in quality. Further, ashless coal preferably has a granular shape with a small particle size, from a viewpoint of enhancing dispersibility to increase the strength of the coke. An upper limit of a maximum diameter of the ashless coal particles is preferably 1 mm. When the maximum diameter of the ashless coal particles exceeds the above-mentioned range, the connecting effect of the coal particles described above is not sufficiently obtained, and the strength of the coke may become insufficient. The maximum diameter of the ashless coal particles means, for example, a maximum length (maximum distance between two points) of the outer shape of an ashless coal particles photographed under an electron microscope or the like.

(Blended coal)

[0033] A lower limit of the logarithm of the maximum fluidity (log MF) of blended coal obtained by blending ashless coal with raw coal is preferably 1.8, more preferably 2 and still more preferably 2.1. On the other hand, an upper limit of log MF of blended coal is preferably 3, more preferably 2.5 and still more preferably 2.3. When log MF of blended coal is less than the above-mentioned lower limit, the fluidity of blended coal is insufficient, and the strength of the resulting coke may become insufficient. Conversely, when log MF of the blended coal exceeds the above-mentioned upper limit, the fluidity become excessive, and bubbles may become liable to occur in the coke. The maximum fluidity MF mainly indicates a magnitude of heat fluidity, and log MF of the blended coal means a weighted average value of log MF of the whole coal and the ashless coal contained in the raw coal.

[0034] A lower limit of an average maximum reflectance Ro of the blended coal is preferably 0.95 and more preferably 1. On the other hand, an upper limit of the average maximum reflectance Ro of the blended coal is preferably 1.3 and more preferably 1.2. When the average maximum reflectance Ro of the blended coal is less than the above-mentioned lower limit, swelling and fusing of the coal or the ashless coal become insufficient due to the low degree of coalification of the blended coal, and the strength of the resulting coke may become insufficient. Conversely, when the average maximum reflectance Ro of the blended coal exceeds the above-mentioned upper limit, the swelling rate of the blended coal is excessively increased, which may have the influence on the oven body. The average maximum reflectance Ro mainly indicates the degree of coalification, and Ro of blended coal means a weighted average value of Ro of the whole coal and the ashless coal contained in raw the coal.

[0035] An upper limit of the swelling rate of the blended coal is 20%, preferably 19% and more preferably 18%. On the other hand, a lower limit of the swelling rate of the blended coal is preferably 10%, more preferably 12% and still more preferably 14%. When the swelling rate of the blended coal exceeds the above-mentioned upper limit, damage of the coke oven due to swelling of the blended coal may occur. Conversely, when the swelling rate of the blended coal is less than the above-mentioned lower limit, swelling and fusing of the coal or ashless coal become insufficient due to the low degree of coalification of the blended coal, and the strength of the resulting coke may become insufficient. A swelling phenomenon of coal is affected by an interaction between the coal particles. Therefore, the swelling rate of the blended coal is not a weighted average of the swelling rate of the coal and ashless coal contained in the blended coal, and accurate prediction thereof is said to be difficult.

[0036] A blending method of an ashless coal with the raw coal is not particularly limited. For example, there can be used a method of feeding the raw coal and ashless coal from each hopper into a known mixer, followed by stirring while pulverizing by an ordinary method. By using this method, not only secondary particles formed by coagulation of the ashless coal are pulverized, but also the raw coal can be pulverized into a granular shape. Further, the coal and ashless

coal which are pulverized in advance may be mixed.

[0037] Furthermore, a caking additive other than the ashless coal may be added to the raw coal. However, in the method for producing a blast furnace coke, the coal particles are connected with the ashless coal as described above. It is therefore unnecessary to add the caking additive. For this reason, the blended coal preferably contains no caking additive other than the ashless coal, from a viewpoint of cost reduction.

<Carbonization step>

[0038] In the carbonization step, the above-mentioned blended coal is charged into the coke oven, and carbonized, thereby obtaining the coke. As this coke oven, there can be used, for example, one having an oven body which can be charged with 30 tons per oven.

[0039] A lower limit of the bulk density of the blended coal at the time of charging into the coke oven is preferably 720 kg/m³ and more preferably 730 kg/m³. On the other hand, an upper limit of the above-mentioned bulk density is preferably 850 kg/m³ and more preferably 800 kg/m³. When the above-mentioned bulk density is less than the above-mentioned lower limit, the strength of the coke may become insufficient. Conversely, when the above-mentioned bulk density exceeds the above-mentioned upper limit, a pressure applied to the oven body is increased, which may cause damage of the oven body, or operations for improving the bulk density of the blended coal may increase the production cost of the coke. The "bulk density" means the bulk density measured in accordance with JIS-K2151:2004.

[0040] A lower limit of a carbonization temperature of the blended coal is preferably 950°C and more preferably 1000°C. On the other hand, an upper limit of the carbonization temperature is preferably 1200°C and more preferably 1050°C. When the carbonization temperature is less than the above-mentioned lower limit, melting of the coal becomes insufficient, and the strength of the coke may be decreased. Conversely, when the carbonization temperature exceeds the above-mentioned upper limit, the production cost may be increased, from a viewpoint of heat resistance of the oven body or fuel consumption.

[0041] A lower limit of the carbonization time of the blended coal is preferably 8 hours and more preferably 10 hours. On the other hand, an upper limit of the carbonization time is preferably 24 hours and more preferably 20 hours. When the carbonization time is less than the above-mentioned lower limit, melting of the coal becomes insufficient, and the strength of the coke may be decreased. Conversely, when the carbonization time exceeds the above-mentioned upper limit, the production cost may be increased, from a viewpoint of fuel consumption.

<Advantages>

[0042] The method for producing a blast furnace coke can increase the strength of the resulting coke, by blending the ashless coal with coal so that the blending amount is within the above-mentioned range, whereby the ashless coal is melted during carbonization and fills spaces of the raw coal. Further, the method for producing a blast furnace coke can suppress the influence on the coke oven due to swelling of the blended coal by adjusting the swelling rate of blended coal to the above-mentioned range. Furthermore, the adjustment of the swelling rate of the blended coal can be easily achieved by blending of the ashless coal. Therefore, the method for producing a blast furnace coke does not require another caking additive or the like. As a result, according to the method for producing a blast furnace coke, the high-strength blast furnace coke can be obtained at low cost while prolonging the lifetime of the oven body.

[Blast furnace coke]

[0043] The blast furnace coke of the present invention is produced by carbonizing the blended coal prepared by blending the ashless coal obtained by solvent extraction treatment of coal with the coal. In the blast furnace coke, the blending amount of the above-mentioned ashless coal and the swelling rate of the blended coal in the above-mentioned blended coal are within the above-mentioned respective ranges. Therefore, the blast furnace coke has high strength despite low cost.

Examples

[0044] The present invention will be described in more detail below with reference to examples, but the present invention should not be construed as being limited thereto.

<Production of ashless coal>

[0045] Using a Hyper-coal continuous production facility (Bench Scale Unit), an ashless coal was produced by a following method. First, a bituminous coal produced in Australia was used as a raw coal for the ashless coal, and 5 kg

of the raw coal (in terms of dried coal) and 1-methylnaphthalene (manufactured by Nippon Steel Chemical Co., Ltd.) as a solvent in four times the volume (20 kg) of the raw coal were mixed to prepare a slurry. This slurry was placed in a batch-type autoclave with an inner volume of 30 L, and nitrogen was introduced therein to increase the pressure to 1.2 MPa, followed by heating at 370°C for one hour. This slurry was separated into a supernatant and a solid-content concentrated liquid in a gravity settling tank maintaining the temperature and the pressure described above, and the solvent was separated and recovered from the supernatant by distillation to obtain 2.7 kg of the ashless coal F. The ash content of the resulting ashless coal F was 0.9 mass %, and the logarithm of the maximum fluidity (log MF) and the average maximum reflectance Ro were as shown in Table 1. The ashless coal F was pulverized so that all (100% by mass) thereof had a maximum diameter of 3 mm or less.

<Examples 1 to 4 and Comparative Example 8>

[0046] Using the ashless coal F produced as described above, the blast furnace coke of Examples 1 to 4 and Comparative Example 8 was produced by a following procedure.

(Blending step)

[0047] The above-mentioned ashless coal F and various kinds of the raw coal having properties shown in Table 1 were each adjusted to a moisture content of 7.5 mass %, and mixed at the blending ratios shown in Table 2, on the dry coal basis, to obtain the blended coal. At this time, there was used the raw coal all (100 mass %) of which was pulverized so as to have a maximum diameter of 3 mm or less. The maximum fluidity MF (dppm) of the coal and ashless coal shown in Table 1 was measured by the Gieseler plastometer method in accordance with JIS-M8801:2004. Further, the average maximum reflectance Ro (%) was measured in accordance with JIS-M8816:1992, and the swelling rate (%) was measured in accordance with JIS-M8801:2004.

[0048] For the above-mentioned blended coal, the maximum fluidity MF was calculated from the respective blending ratios of various kinds of the coal and ashless coal. Furthermore, the swelling rate of the blended coal was measured in accordance with JIS-M8801:2004. These values are shown in Table 2.

(Carbonization step)

[0049] The above-mentioned blended coal was arranged in a retort made of steel, and vibration was applied to the retort, thereby adjusting the bulk density as shown in Table 2. Then, the retort was placed in an electric furnace of a both-side heating type, and carbonization was performed under a nitrogen stream. The carbonization conditions were heating at 1,000°C for 20 minutes after the temperature was raised at 3°C/min. After the carbonization, the retort was taken out of the electric furnace and left to cool naturally. Thus, the blast furnace coke was obtained.

<Comparative Examples 1 to 7>

[0050] The raw coal was blended at the blending ratios shown in Table 2 by the same procedure as in Examples 1 to 4 and Comparative Example 8 described above, except that no ashless coal was added, and the blended coal was carbonized to obtain the blast furnace coke of Comparative Examples 1 to 7.

<Comparative Examples 9 to 11 >

[0051] The raw coal was blended at the blending ratios shown in Table 2 by the same procedure as in Examples 1 to 4 and Comparative Example 8 described above, except for that the ashless coal M obtained by the same procedure as in the case of the above-mentioned ashless coal F and having properties shown in Table 1 was used, and that the raw coal shown in Table 1 and different from one used in Examples 1 to 4 and Comparative Examples 1 to 8 described above was used, and the blended coal was carbonized to obtain the blast furnace coke of Comparative Examples 9 to 11. These Comparative Examples 9 to 11 are some parts of Examples described in JP-A-2014-015502.

<Evaluation>

[0052] For the blast furnace coke of Examples 1 to 4 and Comparative Examples 1 to 11 described above, a drum strength index DI was measured. Specifically, in accordance with JISK2151:2004, the blast furnace coke was rotated in a drum for 150 revolutions, and thereafter, screened using a metal plate sieve with an opening of 15 mm, which is specified in JIS-Z8801-2:2006, and a mass ratio (DI 15015) of the blast furnace coke remaining on the sieve was determined. The acceptability criterion for strength is set to DI>84.5%. The blast furnace coke satisfying this was ac-

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ceptable and evaluated as A, and the blast furnace coke not satisfying this was unacceptable and evaluated as B. These results are shown in Table 2.

[Table 1]

	Log MF	Ro	Swelling Rate
	-	%	%
Hard coking coal A	1.70	1.41	65
Hard coking coal B	2.80	1.19	36
Semi-hard coking coal C	3.50	0.86	51
Non-coking or slightly coking coal D	1.60	0.82	-15
Non-coking or slightly coking coal E	0.60	0.75	-20
Ashless coal F	6.00	0.97	-
Hard coking coal G	0.81	1.60	102
Hard coking coal H	2.20	1.35	42
Semi-hard coking coal I	3.10	0.78	53
Non-coking or slightly coking coal J	0.99	1.05	5
Non-coking or slightly coking coal K	2.58	0.75	-11
Non-coking or slightly coking coal L	0.02	1.22	-18
Ashless coal M	4.78	0.95	-

[Table 2]

		Example 1	Example 2	Example 3	Example 4	Comparative Example 1
Blended coal	Hard coking coal A [mass%]	20	20	20	20	20
	Hard coking coal B [mass%]	17	15	13	5	30
	Semi-hard coking coal C [mass%]	20	20	20	20	20
	Non-coking or slightly coking coal D [mass%]	25	25	25	25	25
	Non-coking or slightly coking coal E [mass%]	15	15	15	20	5
	Ashless coal F [mass%]	3	5	7	10	0
	Total [mass%]	100	100	100	100	100
	Log MF	2.19	2.25	2.31	2.30	2.31
	Swelling rate [%]	16.0	17.0	19.0	13.5	34.0
	Bulk density [kg/m ³]	740	740	740	740	740
Coke	DI [%]	84.6	85.3	85.8	84.7	85.3
	Strength evaluation	A	A	A	A	A

[Table 2 continued]

		Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6
5 10	Blended coal	Hard coking coal A [mass%]	20	25	20	20
		Hard coking coal B [mass%]	20	15	20	20
		Semi-hard coking coal C [mass%]	20	20	20	20
		Non-coking or slightly coking coal D [mass%]	25	25	25	25
		Non-coking or slightly coking coal E [mass%]	15	15	15	15
		Ashless coal F [mass%]	0	0	0	0
		Total [mass%]	100	100	100	100
		Log MF	2.09	2.04	2.09	2.06
		Swelling rate [%]	13.0	26.0	15.0	19.0
15	Coke	Bulk density [kg/m ³]	740	740	800	770
		DI [%]	83.2	85.1	85.0	84.1
		Strength evaluation	B	A	A	B

[Table 2 continued]

		Comparative Example 7	Comparative Example 8	Comparative Example 9	Comparative Example 10	Comparative Example 11
20 25	Blended coal	Hard coking coal A [mass%]	20	20	5	5
		Hard coking coal B [mass%]	15	13	21	19
		Semi-hard coking coal C [mass%]	20	20	30	30
		Non-coking or slightly coking coal D [mass%]	25	25	15	15
		Non-coking or slightly coking coal E [mass%]	20	20	10	10
		Ashless coal F [mass%]	0	2	15	15
		Total [mass%]	100	100	4	6
		Log MF	1.98	2.04	100	100
		Swelling rate [%]	6.0	9.0	2.03	2.08
30	Coke	Bulk density [kg/m ³]	740	740	29.0	35.0
		DI [%]	82.2	82.6	740	740
		Strength evaluation	B	B	86.0	85.4

[0053] As shown in Table 1, the blast furnace coke of Examples 1 to 4 in which 3 mass % or more of the ashless coal is blended has a drum strength index DI of 84.5% or more and has high strength, and the swelling rate of the blended coal is 20% or less. Therefore, damage to the coke oven can be prevented. Further, Examples 1 to 4 are excellent in production cost, because the bulk density is as relatively low as 740 kg/m³.

[0054] On the other hand, the blast furnace coke of Comparative Example 1 in which the ratio of the hard coking coal is high has excellent strength, but the swelling rate of the blended coal is as high as 34%. Therefore, the coke oven may be damaged. The blast furnace coke of Comparative Examples 2, 6 and 7 in which the ratios of the non-coking or slightly coking coal are increased has insufficient strength, although the swelling rate of the blended coal is small. The blast furnace coke of Comparative Example 3 in which the ratio of the highly swellable hard coking coal A is increased provides high strength, but the swelling rate of the blended coal is as high as 26%. Therefore, the coke oven may be damaged. In addition, the cost is high, because the hard coking coal A is much used. The blast furnace coke of Comparative Example 4 in which the bulk density is increased has sufficient strength and a small probability of damaging the coke oven. However, cost increase cannot be avoided, because filling treatment is needed. The blast furnace coke of Comparative Example 5 in which the bulk density is similarly increased is insufficient in strength, and cost increase cannot be avoided, similarly to Comparative Example 4. In the blast furnace coke of Comparative Example 8, the ashless coal is blended. However, the blending amount thereof is less than 3 mass %, so that sufficient strength cannot be secured. Also in the blast furnace coke of Comparative Examples 9 to 11, the ashless coal is blended. However, the swelling rate of the hard coking coal G is extremely high, so that the swelling rate of the blended coal is also high. From a long-term view, therefore, the probability of damaging the coke oven is increased.

[0055] The results of Table 2 reveal that there is no direct correlation between log MF and the swelling rate, and between log MF and the drum strength index. It is therefore difficult to obtain the blast furnace coke having high strength and a small influence on the coke oven at low cost, using log MF as an index.

[0056] While the present invention has been described in detail with reference to the specific embodiments thereof, it is apparent to one skilled in the art that various changes and modifications can be made without departing from the

spirit and scope of the present invention.

[0057] The present application is based on Japanese Patent Application No. 2014-110159 filed on May 28, 2014, the contents of which are incorporated herein by reference.

5 Industrial Applicability

[0058] As described above, according to the method for producing a blast furnace coke of the present invention, the high-strength blast furnace coke is obtained at low cost while suppressing the influence on the coke oven due to swelling. Such a blast furnace coke can be suitably used as an ironmaking material.

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Description of Reference Numerals and Signs

[0059]

- 15 1: Hard coking coal particle
 1a: Continuous phase
 2: Non-coking or slightly coking coal particle
 2a: Modified component
 3: Highly swellable hard coking coal particle
 20 3a: Continuous phase
 4: Ashless coal particle
 4a: Continuous phase
 10: Oven body
 A: Bubble
 25 B: Coarse defect

Claims

- 30 1. A method for producing a blast furnace coke, comprising:
 a blending step of blending an ashless coal obtained by solvent extraction treatment of coal with a coal, thereby obtaining a blended coal, and
 a step of carbonizing the blended coal,
 35 wherein a blending amount of the ashless coal in the blending step is 3 mass % or more, and a swelling rate of the blended coal in the blending step is 20% or less.
 2. The method for producing a blast furnace coke according to claim 1, wherein the swelling rate of the blended coal in the blending step is 10% or more.
 40 3. The method for producing a blast furnace coke according to claim 1 or claim 2, wherein the coal with which the ashless coal is blended contains a hard coking coal and a non-coking or slightly coking coal, and a ratio of the hard coking coal in the blended coal is 20 mass % or more and 50 mass % or less.
 45 4. A blast furnace coke obtained by carbonizing a blended coal prepared by blending an ashless coal obtained by solvent extraction treatment of coal with a coal, wherein a blending amount of the ashless coal in the blended coal is 3 mass % or more, and a swelling rate of the blended coal is 20% or less.

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FIG. 1A

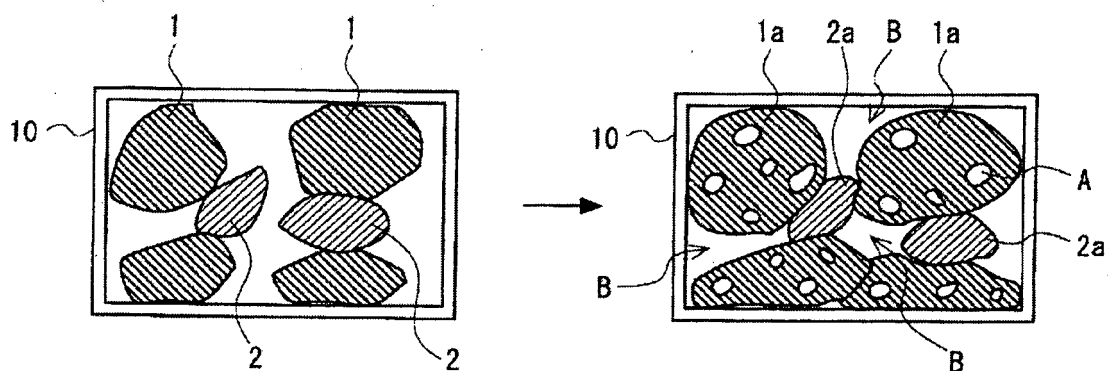


FIG. 1B

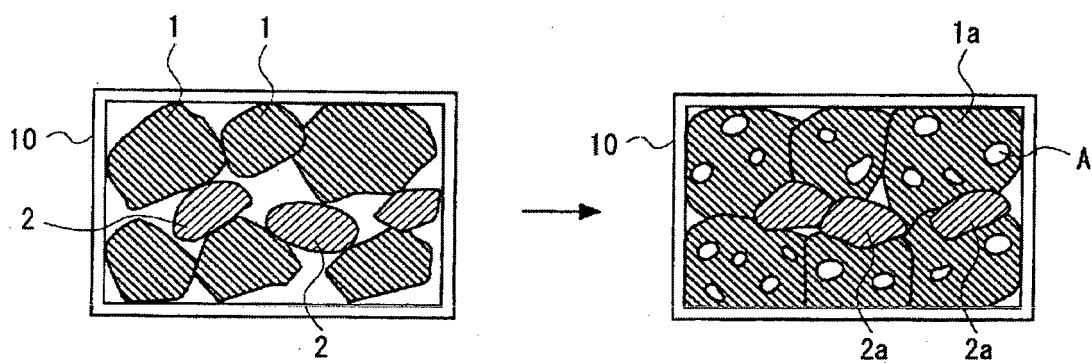


FIG. 1C

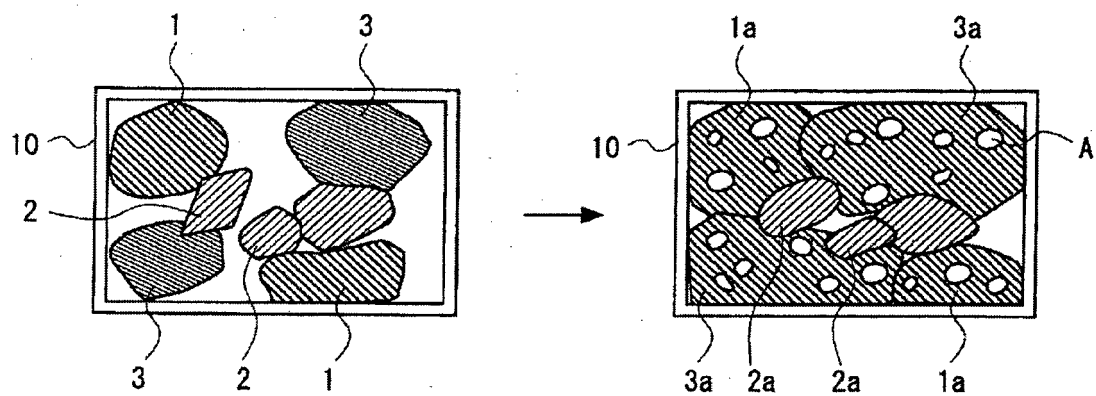
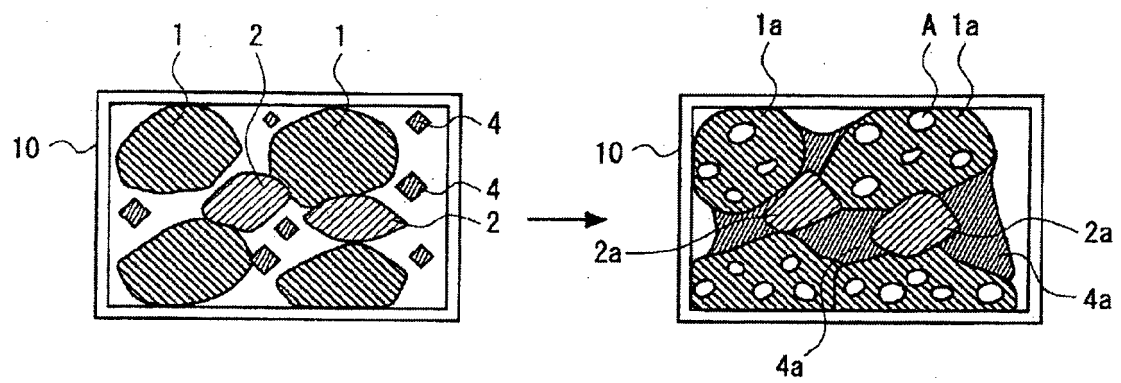


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/064824

A. CLASSIFICATION OF SUBJECT MATTER

C10B57/04(2006.01)i, C10B57/08(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)

C10B57/04, C10B57/08

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 1996-2015

Kokai Jitsuyo Shinan Koho 1971-2015 Toroku Jitsuyo Shinan Koho 1994-2015

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

JSTPlus/JST7580/JSTChina(JDreamIII)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	"Hyper-coal Tenka ni yoru Bochoatsu eno Eikyo", Current advances in materials and processes, vol.19(2006), no.4, page 757	1-4
A	JP 2008-174592 A (Kobe Steel, Ltd.), 31 July 2008 (31.07.2008), (Family: none)	1-4
A	JP 2012-031235 A (Kobe Steel, Ltd.), 16 February 2012 (16.02.2012), (Family: none)	1-4
A	JP 2014-015502 A (Kobe Steel, Ltd.), 30 January 2014 (30.01.2014), & WO 2014/007184 A1 & EP 2871226 A1 & CN 104428398 A & KR 10-2015-0021543 A	1-4

☒ Further documents are listed in the continuation of Box C.
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Date of the actual completion of the international search
13 July 2015 (13.07.15)Date of mailing of the international search report
21 July 2015 (21.07.15)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/064824

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 2009/0229463 A1 (RADER FISHMAN & GRAUER PLLC), 17 September 2009 (17.09.2009), & WO 2009/102959 A1	1-4

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REFERENCES CITED IN THE DESCRIPTION

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