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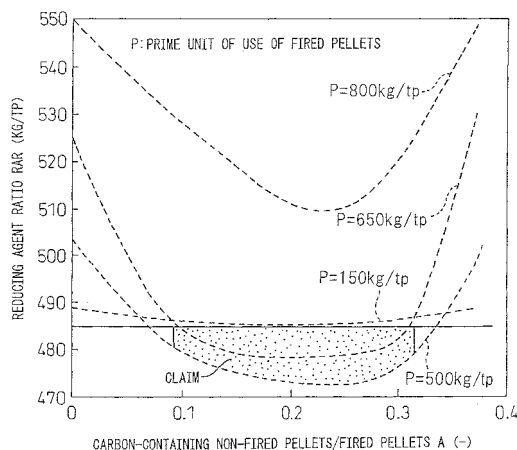
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(54) **BLAST FURNACE OPERATING METHOD USING CARBON-CONTAINING UNFIRED PELLETS**

(57) The present invention provides a method of operating a blast furnace, in blast furnace operation using a large amount of fired pellets as an iron-containing material, which mixes carbon-containing non-fired pellets with the fired pellets to charge them in proximity with the fired pellets with their inferior reducibility so as to eliminate locations of delayed reduction in the vicinity of a melting zone in the furnace and obtain a thin melting zone structure to thereby achieve a large effect of reduction of the specific consumption of fuel during blast furnace operation, that is, a method of operating a blast furnace in blast furnace operation using carbon-containing non-fired pellets which alternately charges an iron-containing material and coke in layers from a top of the blast furnace, comprising (i) mixing in advance carbon-containing non-fired pellets and fired pellets and charging a mixture of the carbon-containing non-fired pellets and the fired pellets so as to replace part of the iron-containing material layer and (ii) adjusting a mixing ratio of the carbon-containing non-fired pellets and the fired pellets so that a ratio R (kg/tp)/ P (kg/tp) of a specific consumption R of the carbon-containing non-fired pellets (kg/tp) and a specific consumption P of the fired pellets (kg/tp) becomes 0.09 to 0.31.

Fig.6



Description

Technical Field

5 **[0001]** The present invention relates to a method of operating a blast furnace comprising producing carbon-containing non-fired pellets which are increased in self-reducibility by the contained carbon and charging them in the blast furnace together with other main materials from the furnace top so as to selectively improve the low reactivity locations in the furnace and decrease the reducing agent ratio of the blast furnace.

10 Background Art

15 **[0002]** In general blast furnace operation, as iron-containing materials, sinter ore, fired pellets, and lumps of ore are being used. In Japan, the ratio of use of sinter ore is the highest - with the ratio being 70 to 90%. On the other hand, fired pellets are also being used in ratios of 5 to 20%. These iron-containing materials are fed out from ore hoppers and charged from the top of the blast furnace to the inside. At that stage, a segregation action occurs due to the differences in particle size, apparent specific gravity, and shape.

20 **[0003]** These iron-containing materials are successively charged from the furnace top so as to be layered with coke lumps inside the blast furnace. Further, at this time, to promote the reduction of the iron-containing materials in the furnace and reduce the gas permeation resistance in the high temperature melting state, the general practice has been to mix small grain or medium grain small coke lumps with the iron-containing materials.

25 **[0004]** In the process of reduction of the iron-containing materials in a blast furnace, the reduction speed is the slowest at the stage of reduction from wustite (FeO) to iron (Fe). This reaction occurs in the 800°C or higher temperature region of the blast furnace shaft. This reaction is governed in speed by the size of the gasification reaction of the coke, where effect of the gas composition is great and which occurs at a temperature near 1000°C (solution loss reaction).

30 **[0005]** Carbon-containing non-fired pellets comprised of fine grains of carbonaceous materials and iron oxide in close proximity are not only superior in reducibility as carbon-containing pellets themselves, but also contain a certain amount or more of carbon content, so it is known that the high coke reactivity enables the iron-containing materials to be strikingly improved in reducibility.

35 **[0006]** Blast furnace-use iron-containing material uses powdered iron ore of about 2 to 3 mm average particle size as the main iron-containing material. To this, limestone, silica, and other secondary materials, powdered coke, anthracite, and other carbonaceous materials are mixed. Furthermore, water is added and the result mixed and granulated to form pseudo particles. After that, a sintering machine is used to heat and sinter the particles, using the carbonaceous material in the raw materials, to obtain sinter ore. This is now the mainstream.

40 **[0007]** The pseudo particles of the sintering materials in this method are mainly granulated matter comprised of coarse particles of a particle size of about 1 mm or more as nuclei and fine particles of a particle size of about 0.5 to less than 1 mm adhered around them. These pseudo particles maintain the gas permeability of the layer charged with sintering materials in the sintering machine and promote a good sintering reaction. For this, enough cold strength is required so as not to be crushed when the sintering materials are charged and, further, while being heated, dried, and sintered.

45 **[0008]** Usually, to form sintering materials into pseudo particles, a drum mixer is used to mix the sintering materials and form them into particles.

50 **[0009]** On the other hand, the iron-containing dust obtained by collecting the sintering dust, blast furnace dust, etc. produced in large amounts in the iron-making process and, furthermore, sludge, scale, and other fine powder dust (these in general called "iron-making dust") and pellet feed or other fine powder materials are also used as iron-containing materials.

55 **[0010]** However, in these fine powder materials, fine powder particles of a particle size of 0.25 mm or less account for 80% or more of the total, so when using these as sintering materials, problems easily arise such as reduction of the gas permeability of the charged material layer due to the fine powder particles and reduction of the productivity.

60 **[0011]** To perform sintering using such fine powder materials as main iron-containing materials, a mixer is used to mix the iron-containing material and secondary materials, with the addition of water, then a disk pelletizer or other granulating machine having a higher granulating strength compared with a drum mixer is used to produce spherical raw pellets mainly comprised of fine powder particles of a particle size of 0.25 mm or less, after that, an external heating type sintering machine using combustion gas etc. as the heat source is used for sintering to produce fired pellets.

65 **[0012]** On the other hand, it has long been known to form a fine powder material into raw pellets, then cure them (by a hydration reaction of quicklime etc. or carbonation treatment) to raise the strength of the granulated matter, then use them as they are as a blast furnace-use iron material, that is, non-fired pellets.

70 **[0013]** As the method of production of non-fired pellets, there is known the method of production of forming blast furnace secondary ash, converter dust, sintering dust, slurry, and other iron-making dust produced in iron-making plants into raw pellets during which adjusting the particle size distribution of the dust to a suitable range, adding quicklime,

cement, or another binder and 5 to 15% of water, using a disk pelletizer etc. to produce raw pellets, curing the pellets by piling in a yard etc. for several days (promotion of a hydration reaction of the CaO-based binder or a carbonation reaction) to cause them to harden and thereby produce cold bond pellets (for example, see PLT 1).

[0014] Further, in recent years, for the purpose of decreasing the reducing agent ratio in blast furnace operation, the method has been proposed of using the above non-fired pellet process to produce high carbon content non-fired pellets (for example, see PLTs 2 to 5).

[0015] For example, carbon-containing non-fired pellets for blast furnace-use which are obtained by mixing iron oxide-bearing materials and carbon-based carbonaceous materials together, adding a binder, then kneading, shaping, and curing the result, which contain 80 to 120% of the theoretical amount of carbon required for reducing the iron oxide of the iron ore to obtain metal iron, and which are selected in binder, shaped, and cured so as to give an ordinary temperature crushing strength of 7850 kN/m² (80 kg/cm²) or more and a method of production of the same have been proposed (for example, see PLT 2).

[0016] According to this method, in general, from the relationship between the temperature of the reducing gas and the gas composition ($\eta_{CO} = CO_2 / (CO + CO_2)$), even in the heat storing zone and reduction reaction equilibrium zone of the blast furnace shaft where advance of the reduction reaction of the iron oxide is restricted, in the 900 to 1100°C temperature region, the iron oxide in the non-fired pellets undergoes a reduction reaction due to the carbon contained there. As a result, the reduction rate is improved, so an effect of decrease of the reducing agent ratio at the time of blast furnace operation can be expected.

[0017] However, with these methods, the C content contained in the non-fired pellets is limited to not more than 120% of the theoretical amount of carbon required for reducing the oxide ore to metal iron (below sometimes called the "C equivalent") (by total carbon content (TC), not more than 120% corresponding to not more than 15 mass%). If increasing the C content over this, there was the problem of the cold crushing strength and hot strength of the non-fired pellets being impaired.

[0018] Furthermore, with these methods, to maintain the cold crushing strength of the non-fired pellets containing the carbonaceous material, instead of quicklime, fast hardening Portland cement or other cement-based binder is used, so if increasing the amount of addition of binder, there was the problem that not only did the endothermic reaction of the dehydration reaction of the cement cause a drop in the rate of temperature rise in the shaft in the blast furnace, but also a low temperature slow reduction region (low temperature heat storing zone) was caused and powderization by reduction of the sinter ore charged as a blast furnace-use iron material in the blast furnace ended up being aggravated.

[0019] Further, carbonaceous material-containing non-fired pellets which are comprised of a carbonaceous material and iron ore and which are defined in relationship between the maximum fluidity at the time of softening and melting of the carbonaceous material and the ratio of iron oxide particles of 10 μm or less size in the iron ore so as to obtain superior reducibility and strength after reduction in the carbonaceous material-containing non-fired pellets have been proposed (for example, see PLT 3).

[0020] According to this method, it is possible to utilize the fact that the carbonaceous material in the carbonaceous material-containing non-fired pellets softens and melts in the 260 to 550°C temperature region, then solidifies so as to make the molten carbonaceous material penetrate and solidify in the spaces between the iron oxide particles, increase the contact area of the carbonaceous material and iron oxide, and improve the heat conductivity and raise the reduction efficiency and also so as to strengthen the bonds between iron oxide particles to improve the strength after reduction (hot strength).

[0021] However, with this method, to improve the reducibility and strength after reduction (hot strength) of the carbonaceous material-containing non-fired pellets, it is necessary to use coal with a high maximum fluidity as a carbonaceous material, so this cannot be said to be a preferable method from the viewpoint of the objective of decreasing the reducing agent ratio at the time of a blast furnace operation designed for energy conservation and resource conservation.

[0022] Further, briquettes for producing reduced iron having an apparent density of 2.3 g/cm³ or more obtained by mixing powdered ore and caking coal having 16% or more volatiles and a Gieseler fluidity of 20 DDPM or more (carbonaceous material), hot shaping the mixture in a 260 to 550°C temperature region by shaping pressure of 20 to 150 MPa, then performing degasification in the shaping temperature range for 5 minutes or more have also been proposed (for example, see PLT 4).

[0023] According to this method, the mixture is hot shaped in the 260 to 550°C temperature region at which the carbonaceous material softens and melts, then solidifies, the iron oxide particles are strongly connected by the carbonaceous material to obtain briquettes of an apparent density of 2.3 g/cm³ or more, then these are degasified to drive out the volatiles from the carbonaceous material, whereby the strength of the briquettes is raised and cracking due to swelling of the briquettes during reduction is prevented.

[0024] However, this method requires hot briquetting and degasification treatment, so the energy consumption at the time of production is high and the production costs rise. In this point, it is an economically disadvantageous method. Further, compared with the granulation method, the density of the briquettes becomes higher, so the briquettes easily burst due to gasification of the carbonaceous material in them or CO and CO₂ gas produced in the reduction reaction

of the iron oxide.

[0025] Further, carbonaceous material-containing non-fired pellets of a two-layer structure comprised of a core of a carbonaceous material of a particle size of 3 to 25 mm and an outer circumferential layer surrounding the core of a mixture of an iron material of a particle size of 1 mm or less and a carbonaceous material, wherein the volume percentage of the carbonaceous material of the core is 0.2 to 30 vol% of the pellets as a whole, the content of the carbonaceous material in the outer circumferential layer is 5 to 25 wt%, and the total carbon content in the pellets as a whole is a high 25 to 35 mass%, have been proposed (for example, see PLT 5).

[0026] According to this art, the carbonaceous material of the particle size of 1 mm or less contained in the outer circumferential layer is used to reduce the iron oxide. When the outer circumferential layer melts, the carbonaceous material of the core is made to function as a carburization source. Due to this, it is possible to improve the reducibility in the blast furnace and also improve the drip behavior of the molten pig due to the carburization action and to decrease the fuel ratio at the time of blast furnace operation and reduce the gas permeation resistance at the melting zone.

[0027] However, such pellets which are comprised of a two-layer structure of different particle sizes and compositions of carbonaceous material and oxides and which have a total carbon content of a high 25 mass% or more have the problem of a lower cold wear strength. Further, to produce pellets which have such a special two-layer structure, the production process becomes complicated, a large amount of binder becomes necessary for maintaining strength, etc. This method was disadvantageous from the viewpoint of the productivity and cost at the time of production.

[0028] In the above way, conventional carbon-containing non-fired pellets have had to be limited in carbon content to 15 mass% (by carbon equivalent, corresponding to 1.2) so as to maintain the cold crushing strength of 50 kg/cm² or more demanded as a blast furnace-use material, so even if the direct reduction of the iron oxide in the above carbon-containing non-fired pellets was sufficiently promoted, it was not possible to sufficiently promote the reduction of the sinter ore or other main blast furnace-use iron-containing materials other than the above carbon-containing non-fired pellets.

[0029] Further, by using the conventional method of adding a large amount of Portland cement or other water-hardening binder, carbon-containing non-fired pellets can be improved in cold crushing strength to a certain extent, but in the reduction temperature region of the blast furnace, the above binder undergoes a dehydration reaction, so sufficient hot strength cannot be maintained.

[0030] Therefore, development of a method of production of carbonaceous material-containing non-fired pellets which uses a relatively inexpensive and simple method of production to produce pellets which have a sufficient carbon content and are superior in both cold strength and in hot strength in the reduction temperature region (strength at reduction) has been desired so as to improve the reduction rates of the carbon-containing non-fired pellets and blast furnace-use iron-containing material and greatly decrease the reducing agent ratio at the time of blast furnace operation.

[0031] On the other hand, among the blast furnace-use iron-containing materials, the fired pellets form metal shells (dense layers of iron formed by sintering of reduced iron at surface) due to the strong topochemical reaction during the reduction process where the reducing gas causes reduction from the surface of the pellets, so compared with sinter ore, are harder to reduce in the 1000°C or higher high temperature region. A large amount of melt is discharged at the start of fusing.

[0032] Furthermore, due to the shape (spherical), compared with sinter ore or iron ore, segregation easily occurs at the time of charging into the furnace. In particular, if a large amount segregates in the vicinity of a high reduction load, it is known that a partial delay in reduction occurs, the thickness of the blast furnace melting zone comprised of the sinter ore and fired pellets increases, the gas permeability in the furnace deteriorates, and also unreduced melt drips down, so the reducing agent ratio rises.

[0033] In current general blast furnace operation, sinter ore is mainly used. The ratio is 70 to 90% in range. The ratio of the fired pellets is 5 to 20% or so. However, due to the depletion of ore beds, the quality of iron ore is becoming lower. Due to ore grading, iron ore is increasingly being provided as fine powder. The drop in product yield and productivity due to the lower gas permeability when producing sinter ore using fine powder iron ore is becoming a problem.

[0034] Therefore, technology for utilization of non-fired pellets, which can be produced using an iron-containing material including fine powder ore without causing a reduction in the product yield and productivity compared with sinter ore, is growing in importance in blast furnaces. Further, several methods using carbon-containing non-fired pellets in place of part of the fired pellets have been proposed (for example, see PLTs 6 to 7).

[0035] When mixing carbon-containing non-fired pellets in an iron-containing material layer containing a large amount of fired pellets for use in a blast furnace, even if the reduction of the main material of the iron-containing material layer, that is, the sinter ore, could be promoted, it was not possible to selectively promote the reduction reaction at the many locations where the fired pellets segregated in the iron-containing material layer. In the end, a delay in reduction occurred at those locations and a sufficient effect of reduction of the reducing agent ratio could not be enjoyed.

[0036] To sufficiently promote reduction of the locations of concentrated fired pellets in the iron-containing material layer by this method, use of a large amount of carbon-containing non-fired pellets was necessary. If using a large amount of carbon-containing non-fired pellets, however, there were the problems that the dehydration reaction of the binder

contained in the carbon-containing non-fired pellets not only caused a drop in the rate of temperature rise in the shaft in the blast furnace, but also caused the formation of a low temperature slow reduction region (low temperature heat storing zone) and aggravated the powderization by reduction of the sinter ore in the blast furnace-use iron-containing material layer.

[0037] Further, the effect of promotion of reduction of the fired pellets by the carbon-containing non-fired pellets was low and the amount of use of non-fired pellets contained was larger than necessary, so this was liable to lead to powderization by reduction of the sinter ore in the blast furnace (for example, see PLT 7).

[0038] Therefore, in blast furnace operation using a large amount of fired pellets as an iron-containing material, development of a method of use of carbon-containing non-fired pellets in a blast furnace which enables the effect of promotion of reduction of fired pellets by the carbon-containing non-fired pellets to be efficiently exhibited and which promises a large effect of decrease of the reducing agent ratio has been desired.

Citations List

Patent Literature

[0039]

PLT 1 Japanese Patent Publication (A) No. 53-130202

PLT 2 Japanese Patent Publication (A) No. 2003-342646

PLT 3 Japanese Patent Publication (A) No. 2000-160219

PLT 4 Japanese Patent Publication (A) No. 11-92833

PLT 5 Japanese Patent Publication (A) No. 8-199249

PLT 6 Japanese Patent Publication (A) No. 2003-301205

PLT 7 Japanese Patent Publication (A) No. 6-145729

Summary of Invention

Technical Problem

[0040] The present invention, in consideration of the above state of the prior art, has as its object to provide a method of operating a blast furnace, in blast furnace operation using a large amount of fired pellets as an iron-containing material, which mixes carbon-containing non-fired pellets with the fired pellets to charge them in proximity with the fired pellets with their inferior reducibility so as to eliminate locations of delayed reduction in the vicinity of a melting zone in the furnace and obtain a thin melting zone structure, to thereby achieve a large effect of decrease of the specific consumption of fuel during blast furnace operation.

Solution to Problem

[0041] The inventors measured the ingredients forming blast furnace-use iron-containing materials such as sinter ore, fired pellets, and lumps of ore for high temperature behavior and engaged in an intensive study, by experiments etc., on the changes in high temperature behavior when mixing predetermined amounts of carbon-containing non-fired pellets in these.

[0042] As a result, they discovered that when mixing, among the sinter ore, fired pellets, and lumps of ore forming the blast furnace-use iron-containing materials, in particular the fired pellets with carbon-containing non-fired pellets, the effect of improvement of the high temperature reducibility was particularly large.

[0043] Further, they learned from the relationship of the amounts of use of fired pellets and carbon-containing non-fired pellets that by optimizing the amount of use of carbon-containing non-fired pellets, it is possible to draw out the effect of improvement of reduction of the fired pellets by the carbon-containing non-fired pellets to the maximum extent.

[0044] The present invention was made to solve the above problems and has as its gist the following.

(1) A method of operating a blast furnace in blast furnace operation using carbon-containing non-fired pellets which alternately charges an iron-containing material and coke in layers from a top of the blast furnace, the method characterized by

- (i) mixing in advance carbon-containing non-fired pellets and fired pellets and charging a mixture of the carbon-containing non-fired pellets and the fired pellets so as to replace part of the iron-containing material layer and
- (ii) adjusting a mixing ratio of the carbon-containing non-fired pellets and the fired pellets so that a ratio R (kg/tp)

/P(kg/tp) of a specific consumption R (consumed amount for one-ton steel product) of the carbon-containing non-fired pellets (kg/tp) and a specific consumption P (consumed amount for one-ton steel product) of the fired pellets (kg/tp) becomes 0.09 to 0.31.

(2) A method of operating a blast furnace using carbon-containing non-fired pellets as set forth in (1) characterized in that the specific consumption P (consumed amount for one-ton steel product) of the fired pellets is 150 kg/tp to 650 kg/tp.

Advantageous Effects of Invention

[0045] According to the present invention, in operation of a blast furnace which uses iron-containing materials in which a large amount of fired pellets are mixed, it is possible to obtain a major improvement in the reducing agent ratio by use of a smaller amount of carbon-containing non-fired pellets compared with the past.

[0046] Therefore, by application of the present invention, it is possible to use powder iron ore, which is inexpensive but is inferior in quality, as a material to efficiently produce fired pellets and to greatly reduce the reducing agent ratio (coke ratio) at the time of blast furnace operation when using fired pellets. This enables effective utilization of resources, energy conservation, and lower CO₂ output.

Brief Description of Drawings

[0047]

FIG. 1 is a view schematically showing a load softening test apparatus for measuring reduction properties of various types of blast furnace charges.

FIG. 2 is a graph showing changes in the 1200°C reduction rates of sinter ore and fired pellets due to uniform mixing with carbon-containing non-fired pellets.

FIG. 3 is a graph showing consumed C/O for calculating a required amount of close carbon-containing non-fired pellets in a reduction process of fired pellets.

FIG. 4 is a graph showing a relationship among a specific consumption R of carbon-containing non-fired pellets, a C content C of carbon-containing non-fired pellets, and a specific consumption P of fired pellets.

FIG. 5 is a graph showing a relationship among a C content and a strength after reaction of carbon-containing non-fired pellets.

FIG. 6 is a graph showing a relationship of a ratio A (=R/P) of the specific consumption R of the carbon-containing non-fired pellets, the specific consumption P of the fired pellets, and a reducing agent ratio of the blast furnace.

Description of Embodiments

[0048] Details of the present invention will be explained.

[0049] First, the inventors used a load softening test apparatus able to simulate the reaction inside a blast furnace so as to study the changes in the ratio of carbon-containing non-fired pellets with reducibility in various types of iron-containing charges.

[0050] The method of measurement of the reduction rate using a load softening test apparatus will be explained below. FIG. 1 is a cross-sectional view of a load softening test apparatus. A lower electric furnace 6 and an upper electric furnace 5 are connected by a flange to form an integral structure.

[0051] The lower electric furnace 6 is provided for preheating the reducing gas, while the upper electric furnace 5 is used for heating a sample 3. Iron ore or another sample 3 is charged into a crucible, then set inside a reaction tube. The sample 3 is charged between an upper and a lower layer of coke in the crucible.

[0052] Reducing gas which has been adjusted in advance to a predetermined composition and flow rate is introduced from a reducing gas inlet 7 into the reaction tube, is preheated in the lower electric furnace 6, then is introduced into the sample 3 in the crucible. The gas after the reaction is exhausted from a reaction gas outlet 2. Part of this exhaust gas is sampled and analyzed for ingredients by a gas analyzer. The reduction rate is calculated from the analysis values of this exhaust gas.

[0053] At the same time, a thermocouple 4 is used to measure the temperature of the part right above the sample 3. The gas pressures at the reducing gas inlet 7 and the reaction gas outlet 2 are also measured. From the pressure difference, the gas permeation resistance of the sample 3 is measured. Further, in the process of the sample 3 being raised in temperature and reduced, the load applying device 1 is used to apply any load to the sample 3 to simulate the load conditions in an actual furnace. The shrinkage behavior of the sample 3 obtained as a result is measured. Note that, in the figure, 8 indicates a liquid drop container, while 9 indicates a liquid drop detector.

[0054] FIG. 2 shows the measurement results. The sinter ore and fired pellets used in an actual furnace were screened to an average particle size of 10 to 15 mm, then were respectively uniformly mixed with carbon-containing non-fired pellets for use as samples.

[0055] The carbon-containing non-fired pellets were produced by mixing iron-containing dust, carbon-containing dust, and fast hardening Portland cement in predetermined amounts, then granulating the mixture by a pan pelletizer, after that, curing for two weeks out in the open. The carbon-containing non-fired pellets were comprised of carbon 25% and T.Fe 45% and had a carbon equivalent of 2.0.

[0056] By mixing in the carbon-containing non-fired pellets, the peak reduction rates of the sinter ore and the fired pellets at 1200°C were improved. If comparing the two, first, the fired pellets are lower in reduction rate.

[0057] This is due to the following reason. In the case of fired pellets, the pore size distribution is uniform, so the reduction proceeds by a topochemical reaction, a strong metal shell is formed in the low temperature region, and diffusion of gas to the inside is suppressed. As a result, inside of the fired pellets, melt containing a large amount of unreduced FeO is contained. This flows outside and is lost all at once in the high temperature region, so the reduction becomes remarkably slow due to pore clogging in the high temperature region.

[0058] On the other hand, sinter ore has an uneven pore structure, so reduction proceeds quickly and uniformly to the inside resulting in metallization. Therefore, there is relatively little melt containing a large amount of unreduced FeO and reduction is promoted in the high temperature region as well.

[0059] If comparing the effects of the carbon-containing non-fired pellets, it is learned that uniform mixing of carbon-containing non-fired pellets with the fired pellets has a larger effect of improvement of the reduction rate. This is because carbon-containing non-fired pellets themselves are extremely high in reduction rate and, before the formation of the above metal shell, reduction by the CO gas formed by gasification of the carbon-containing non-fired pellets is promoted, so the amount of melt remaining inside is reduced and the slowdown of reduction in the high temperature region is mitigated.

[0060] From the above results, the inventors thought that if mixing the carbon-containing non-fired pellets with the fired pellets rather than near the sinter ore and thereby making the carbon-containing non-fired pellets close to the fired pellets, the effect could be greatly exhibited.

[0061] Furthermore, the inventors engaged in an in-depth study of the mixing ratio of carbon-containing non-fired pellets to fired pellets for reducing the specific consumption of fuel at the time blast furnace operation.

[0062] Before this, they calculated the carbon equivalent (mol) derived from the nearby carbon-containing non-fired pellets required for reduction of the fired pellets. The reduction stage of fired pellets and carbon-containing non-fired pellets charged as part of the iron-containing material layer into a blast furnace is generally divided into the following three stages ((1) to (3)). The consumed C/O at the different stages are calculated.

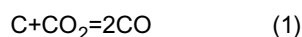
[0063] Here, O is the total (mol) of the amount of reduced oxygen of the fired pellets and carbon-containing non-fired pellets, C is the amount of C (mol) derived from the carbon-containing non-fired pellets, and C/O expresses the amount of carbon derived from the carbon-containing non-fired pellets required for reduction of the amount of oxygen derived from the fired pellets to be reduced.

(1) Reduction rate of fired pellets < 30% (low temperature region)

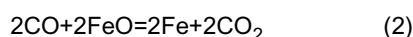
[0064] The fired pellets are reduced by the reducing gas derived from ordinary coke without the involvement of the carbon-containing non-fired pellets.

(2) Reduction rate of fired pellets: 30 to 50% (indirect reduction region)

[0065] The fired pellets are reduced by the reducing gas derived from the carbon-containing non-fired pellets.

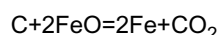


(start of gasification of C derived from carbon-containing non-fired pellets)



(indirect region of fired pellets)

[0066] From the above formula (1) and formula (2),



Molar ratio: C/O=0.5

(3) Reduction rate of fired pellets: 50 to 100% (melting (direct) reduction region)

[0067] The fired pellets start to soften and melt and are reduced by melt (direct) reduction.



Molar ratio: C/O=1.0

[0068] The above results are as shown in FIG. 3. The effect of promotion of reduction by the carbon-containing non-fired pellets is exhibited in the region of (2). Around the fired pellets, it is sufficient to give a molar ratio C/O of $0.2 \times 0.5 = 0.1$.

[0069] On the other hand, the oxygen to be reduced in the carbon-containing non-fired pellets is reduced in the regions of (2) and (3) by the carbon in the carbon-containing non-fired pellets, so around the carbon-containing non-fired pellets, the molar ratio C/O has to be 0.6.

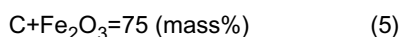
[0070] Based on the results of the above study, the inventors found specific consumption R of the carbon-containing non-fired pellets (kg/tp) in accordance with the specific consumption P of the fired pellets (kg/tp).

[0071] For example, when using the specific consumption P of fired pellets (kg/tp) to mix fired pellets of O: 28.1% (T.Fe = 65.7%, FeO=0.9%) and carbon-containing non-fired pellets with an amount of oxygen to be reduced of 0% and charging the mixture into a blast furnace, the specific consumption R of the carbon-containing non-fired pellets for reducing the fired pellets and carbon-containing non-fired pellets (kg/tp) is expressed by the following formula where C: carbon content in the carbon-containing non-fired pellets (%) and O: amount of oxygen to be reduced in the carbon-containing non-fired pellets,

$$\begin{aligned} R \\ (\text{kg/tp}) = 12 \times 100 / C \times (0.1 \times 28.1 / 100 / 16 \times P + 0.6 \times O / 100 / 16 \times R) \quad (\text{kg/tp}) \\ \dots (4) \end{aligned}$$

[0072] Here, the relationship between the carbon content and the amount of oxygen to be reduced in the carbon-containing non-fired pellets will be explained. The carbon-containing non-fired pellets are mainly comprised of carbon C and iron oxide Fe_2O_3 , but contains ash content derived from the iron-containing dust and carbon-containing dust, gangue ingredients derived from cement, and water of crystallization due to the cement hydration reaction to a total of an extent of 20 to 30%. Here, the ingredients of the carbon-containing non-fired pellets are expressed by [C/O] (molar ratio).

[0073] Now, if making the ganque ingredient of the carbon-containing non-fired pellets 25%,



so the relationship of oxygen to be reduced O (mol%) and carbon content C (mass%) becomes

$$O \text{ (mol\%)} = 3 \times 16 / (2 \times 55.85 + 3 \times 16) \times (75 - C) / 16 = 0.3 \times (75 - C) / 16 \dots (6)$$

[0074] If applying this relationship to formula (4), then

$$R(\text{kg/tp}) = 12 / C \times 100 \times (0.1 \times 28.1 / 100 / 16 \times P + 0.6 \times 0.3 \times (75 - C) / 16 / 100 \times R) \\ = 2.1075 \times P / (1.135 \times C - 10.125) \dots (7)$$

[0075] Therefore, by setting the specific consumption R of the carbon-containing non-fired pellets (kg/tp) in accordance with the specific consumption P of the fired pellets (kg/tp) and C content of the carbon-containing non-fired pellets based on the relationship of the above formula (7), it is possible to reduce the close fired pellets.

[0076] The relationship between the specific consumption R of the carbon-containing non-fired pellets (kg/tp) and the

specific consumption P of the fired pellets (kg/tp) is shown in FIG. 4.

[0077] Further, if expressing the ingredients of the carbon-containing non-fired pellets by C/O (molar ratio), from formula (6),

$$[C/O] = C / 12 \times 16 / 0.3 / (75 - C) = 4.44 \times C / (75 - C) \dots (7)$$

and

$$C = 75 \times [C/O] / (4.44 + [C/O]) \dots (8)$$

[0078] From this relationship, for example, [C/O]=1.0, 2.0, 3.0 respectively correspond to C (mass%) = 14%, 23%, and 30%.

[0079] If the C content increases, the cold and hot strength of the carbon-containing non-fired pellets falls, so there is an upper limit. Therefore, the inventors investigated the effects of the C content on the strength after reaction of the carbon-containing non-fired pellets.

[0080] The inventors investigated the crushing strength after heating carbon-containing non-fired pellets having various C contents under conditions of 900°C and CO/CO₂=7/3 for 1 hour. As shown in FIG. 5, along with the rise in the C content C, the strength after the reaction fell. From the NPLT "Tetsu to Hagane 72 (1986), S98", in the blast furnace, the carbon-containing pellets have to be maintained at 10 kg/piece or more, but the inventors learned that if the C content C is larger than 30%, 10 kg/piece cannot be maintained. Accordingly, the upper limit of the C content C in the present invention is made 30%.

[0081] The inventors next intensively studied the optimal range of the specific consumption R of carbon-containing non-fired pellets (kg/tp) for decreasing the reducing agent ratio. If the carbon content Y of the carbon-containing non-fired pellets is less than 15% (C/O corresponds to 1.0), the effect of improvement of the reaction efficiency of the indirect reduction and melt (direct) reduction of the above formula (2) becomes lower. As a result, compared with use of ordinary coke, it becomes difficult to sufficiently decrease the reducing agent ratio.

[0082] Further, if the carbon content C of the carbon-containing non-fired pellets exceeds 30% (C/O corresponding to 3.0), the crushing strength falls and the gas permeability in the blast furnace is inhibited, so progression of the indirect reduction reaction of the above formula (1) to formula (2) is inhibited. As a result, compared with use of ordinary coke, it becomes difficult to sufficiently decrease the reducing agent ratio.

[0083] For this reason, the C content C of the carbon-containing non-fired pellets is preferably made 15 to 30%. If based on this preferable C amount C of carbon-containing non-fired pellets of 15 to 30% and the above formula (7), the upper and lower limits of the specific consumption R of carbon-containing non-fired pellets (kg/tp) for decreasing the reducing agent ratio become as follows.

$$R \text{ (kg/tp)} = (0.09 \text{ to } 0.31) \times P \text{ (kg/tp)} \dots (9)$$

[0084] Therefore, in the present invention, to decrease the reducing agent ratio at the time of blast furnace operation, the mixing ratio of carbon-containing non-fired pellets and fired pellets is adjusted so that the ratio R (kg/tp)/P (kg/tp) of the specific consumption R of the carbon-containing non-fired pellets (kg/tp) and the specific consumption P of the fired pellets (kg/tp) satisfies the above formula (9).

[0085] Next, the inventors studied in depth the range of the specific consumption P of the fired pellets. If the specific consumption P of the fired pellets is less than 150 kg/tp, the blast furnace charge becomes mainly sinter ore and ore lumps. Their reaction characteristics end up governing the results of the blast furnace operation. Even if the reducibility of the charged fired pellets is improved by the nearly charged carbon-containing non-fired pellets, the contribution to the overall operation ends up becoming relatively small.

[0086] Further, if the specific consumption P of the fired pellets is over 650 kg/tp, the degree of segregation of fired pellets at the time of charging becomes greater and even the carbon-containing non-fired pellets are not enough to cover for the detrimental effects.

[0087] From the above, in the present invention, the specific consumption P of the fired pellets (kg/tp) is made 150 to 650 kg/tp. This corresponds to a ratio of fired pellets of 10 to 40%. The range of the specific consumption R of the carbon-containing non-fired pellets corresponds to 14 to 202 kg/tp.

[0088] FIG. 6 shows the relationship of the ratio A (=R/P) between the specific consumption R of the carbon-containing

non-fired pellets (kg/tp) and the specific consumption R of the fired pellets (kg/tp) with the reducing agent ratio.

[0089] The inventors investigated the change in the reducing agent ratio due to the amounts of use of fired pellets and carbon-containing non-fired pellets in a blast furnace of an effective volume of 5500 m³. During the survey period, the quality of the sinter ore was substantially constant. Operation was performed to give a tapping ratio of 2.1 to 2.2 (t/d/m³). When no carbon-containing non-fired pellets were mixed in, the reducing agent ratio rose along with an increase in the specific consumption P of the fired pellets.

[0090] On the other hand, if mixing the carbon-containing non-fired pellets and fired pellets so that the ratio A (=R/P) of the specific consumption R of the carbon-containing non-fired pellets (kg/tp) and the specific consumption P of the fired pellets (kg/tp) became 0.09 to 0.31, the reducing agent ratio was kept to 485 (kg/tp) or less.

[0091] However, if the specific consumption P of the fired pellets exceeded 650 kg/tp, even if using carbon-containing non-fired pellets, operation by a reducing agent ratio 485 (kg/tp) or less was difficult. Further, even if the specific consumption P of the fired pellets was lower than 150 kg/tp, even if using carbon-containing non-fired pellets, operation by a reducing agent ratio 485 (kg/tp) or less was difficult.

[0092] If the ratio A (=R/P) of the specific consumption R of the carbon-containing non-fired pellets and the specific consumption P of the fired pellets exceeded 0.31, along with the rise of the specific consumption P of the fired pellets, the amount of use of carbon-containing non-fired pellets became insufficient and the reducing agent ratio rose.

[0093] On the other hand, even if the ratio A (=R/P) of the specific consumption R of the carbon-containing non-fired pellets and the specific consumption P of the fired pellets became lower than 0.09, along with the rise of the specific consumption P of the fired pellets, the reducing agent ratio rose.

[0094] This was because, as explained above, an amount of carbon-containing non-fired pellets more than necessary for reducing the fired pellets was blended in - resulting in an increase in carbon-containing non-fired pellets with a lower crushing strength than fired pellets and an accompanying remarkable drop in gas permeability and, further, the CO gas produced by the fast gasification of the carbon-containing non-fired pellets was not effectively utilized but ended up escaping to the furnace top.

[0095] Note that, the same thing does not stand even if applied to ordinary coke (small lumps of coke). Ordinary coke is slow in speed of gasification reaction ($C+CO_2=2CO$), so a larger amount of coke becomes required.

[0096] Further, the particle size of the carbon-containing non-fired pellets used is not particularly limited in the present invention, but to promote uniform mixing with the fired pellets and to suppress a drop in the gas permeability of the carbon-containing non-fired pellets due to crushing, the average particle size is preferably made 20 mm or less.

[0097] Further, the method of charging the carbon-containing non-fired pellets into the blast furnace preferably comprises alternately charging iron-containing material and coke in layers from the top of the blast furnace during which mixing the fired pellets and the carbon-containing non-fired pellets in advance before charging and charging the mixture of the above carbon-containing non-fired pellets and the above fired pellets so as to replace part of the above iron-containing material layer.

[0098] As the method of mixing the fired pellets and the carbon-containing non-fired pellets before charging, similar effects can be obtained even if setting the fired pellet hopper and carbon-containing non-fired pellet hopper in close proximity and feeding out the pellets from them.

[0099] Furthermore, the carbon-containing non-fired pellets of the present invention are not particularly limited in shape or method of production. In general, a method of forming raw pellets using a pan pelletizer is used, but similar effects can be obtained even if using the method of forming briquettes enabling press-forming.

[0100] Further, the carbon-containing non-fired pellets of the present invention are not particularly limited in material conditions either. In general, iron-containing dust, coke-containing dust, etc. are mainly used, but even if blending in iron ore, scale, etc., so long as the range of ingredients is within the scope of the present invention, substantially similar effects can be obtained.

Examples

[0101] Below, examples of the present invention will be explained, but the conditions of the examples are one illustration of conditions employed for confirming the workability and advantageous effect of the present invention. The present invention is not limited to this illustration of conditions. The present invention can use various conditions so long as not departing from the gist of the present invention and achieving the object of the present invention.

[Example 1]

[0102] Iron-containing dust, carbon-containing dust, and quick curing Portland cement were used as materials to produce two types of carbon-containing non-fired pellets P1 and P2. P1 had a C content of 23%, a C/O of 2.0, and a gangue ingredient of 25%. P2 had a C content of 28%, a C/O of 2.8, and a gangue ingredient of 25%.

[0103] These carbon-containing non-fired pellets were charged into an effective volume 5500 m³ blast furnace together

with the fired pellets from the furnace top for use. During the usage period, the quality of the sinter ore was substantially constant, and operation was performed to give a tapping ratio of 2.1 to 2.2 (t/d/m³).

[0104] Table 1 shows the conditions of use of the carbon-containing non-fired pellets and fired pellets and the results of evaluation of blast furnace operation. As will be understood from Table 1, when using carbon-containing non-fired pellets P1, with Comparative Example 1 with an amount of use of carbon-containing non-fired pellets smaller than the amount of use of fired pellets, operation with a reducing agent ratio of 485 (kg/tp) or less was not possible.

[0105] Comparative Example 2 conversely had an amount of use of carbon-containing non-fired pellets too much greater than the amount of use of fired pellets so the reducing agent ratio ended up rising. Again, operation with a reducing agent ratio of 485 (kg/tp) or less was not possible.

[0106] The inventors conducted a study of the case of using the carbon-containing non-fired pellets P2 under conditions of a large amount of use of fired pellets. Comparative Example 3 had an amount of use of carbon-containing non-fired pellets of 45 (kg/tp) or an amount of use the same as the Invention Example 1, yet was insufficient in amount of fired pellets and could not decrease the reducing agent ratio. Comparative Example 4 conversely had an excessively large ratio of carbon-containing non-fired pellets, so again the reducing agent ratio trended high.

Table 1						
	Invention Example 1	Invention Example 2	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4
Carbon-containing non-fired pellets used	P1	P2	P1	P1	P2	P2
C content mass%	23	28	23	23	28	28
C/O -	2.0	2.8	2.0	2.0	2.8	2.8
Specific consumption R of Carbon-containing non-fired pellets kg/tp	45	190	14	55	45	210
Specific consumption P of Fired pellets kg/tp	170	640	170	170	640	640
Coefficient A (R=A×P) -	0.26	0.30	0.08	0.32	0.07	0.33
Tapping ratio t/d/m ³	2.19	2.12	2.19	2.19	2.12	2.12
Reducing agent ratio kg/tp	484	485	487	490	492	492

Industrial Applicability

[0107] As explained above, according to the present invention, in operation of a blast furnace which uses an iron-containing material in which a large amount of fired pellets are mixed, it is possible to obtain a major improvement in the reducing agent ratio by use of a smaller amount of carbon-containing non-fired pellets compared with the past.

[0108] Therefore, by application of the present invention, it is possible to use powder iron ore, which is inexpensive but is inferior in quality, as a material to efficiently produce fired pellets and to greatly reduce the reducing agent ratio (coke ratio) at the time of blast furnace operation when using fired pellets. This enables effective utilization of resources, energy conservation, and lower CO₂ output. Accordingly, the present invention greatly contributes to industry and society.

Reference Signs List

[0109]

- 1 load applying device
- 2 reaction gas outlet
- 3 sample
- 4 thermocouple
- 5 upper electric furnace
- 6 lower electric furnace
- 7 reducing gas inlet
- 8 liquid drop container
- 9 liquid drop detector

Claims

1. A method of operating a blast furnace using carbon-containing non-fired pellets wherein an iron-containing material and coke are alternately charged in layers from a top of the blast furnace, said method **characterized by**
 - (i) mixing in advance carbon-containing non-fired pellets and fired pellets and charging a mixture of said carbon-containing non-fired pellets and said fired pellets so as to replace part of said iron-containing material layer and
 - (ii) adjusting a mixing ratio of said carbon-containing non-fired pellets and said fired pellets so that a ratio R (kg/tp)/ P (kg/tp) of a specific consumption R of said carbon-containing non-fired pellets (kg/tp) and a specific consumption P of said fired pellets (kg/tp) becomes 0.09 to 0.31.
2. A method of operating a blast furnace using carbon-containing non-fired pellets as set forth in claim 1 **characterized in that** said specific consumption P of the fired pellets is 150 kg/tp to 650 kg/tp.

Fig.1

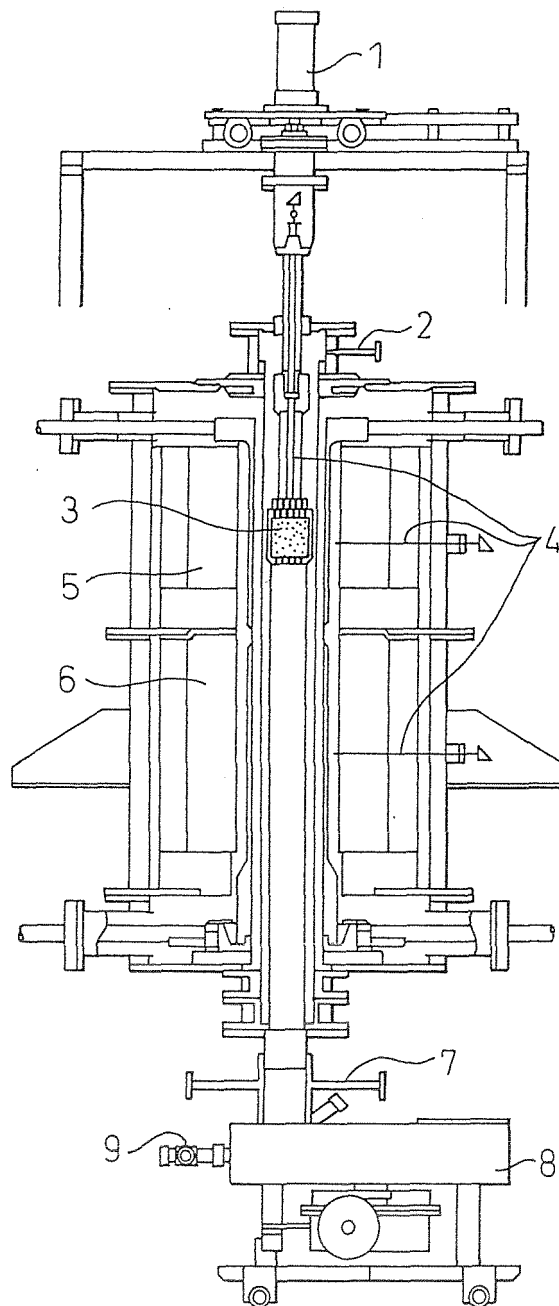


Fig.2

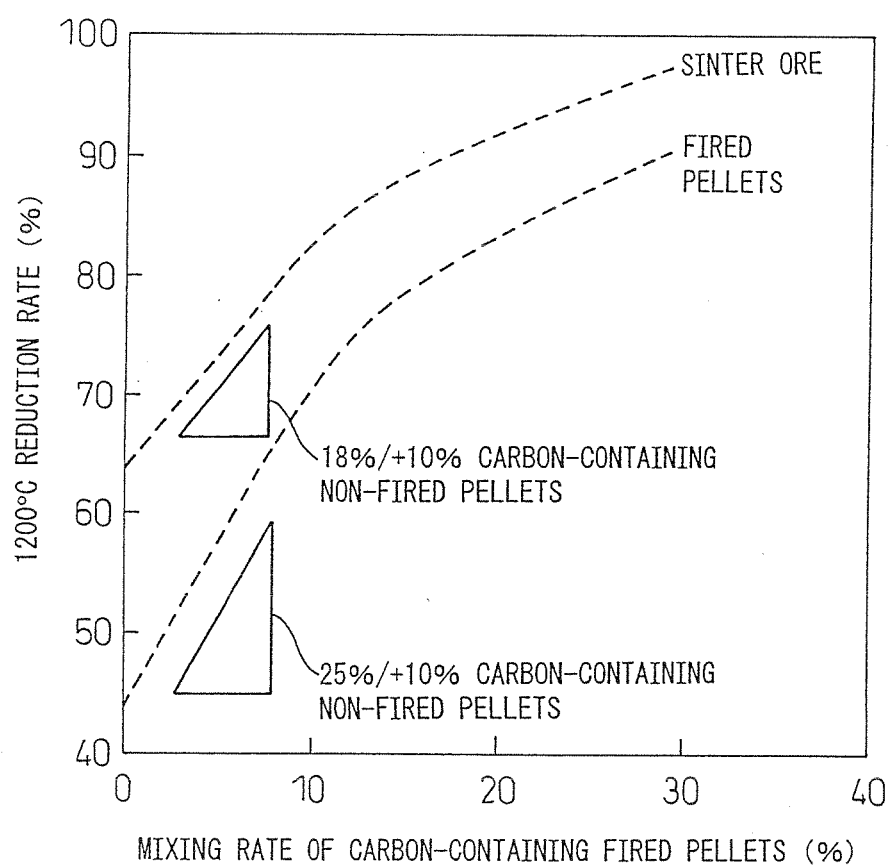


Fig.3

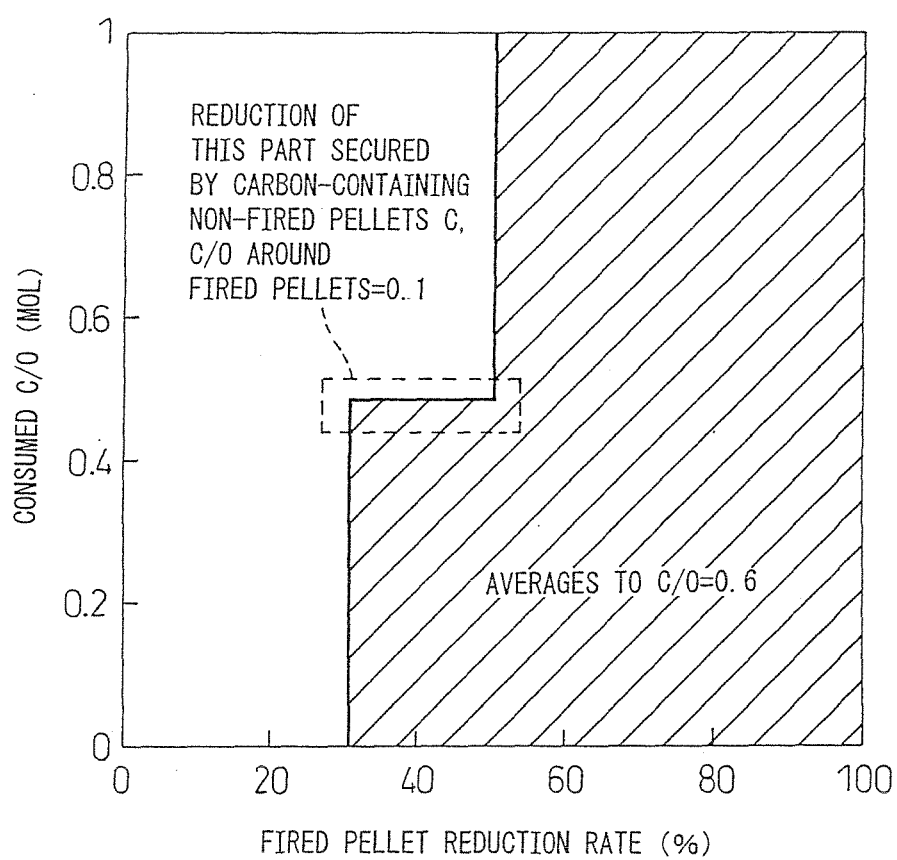


Fig. 4

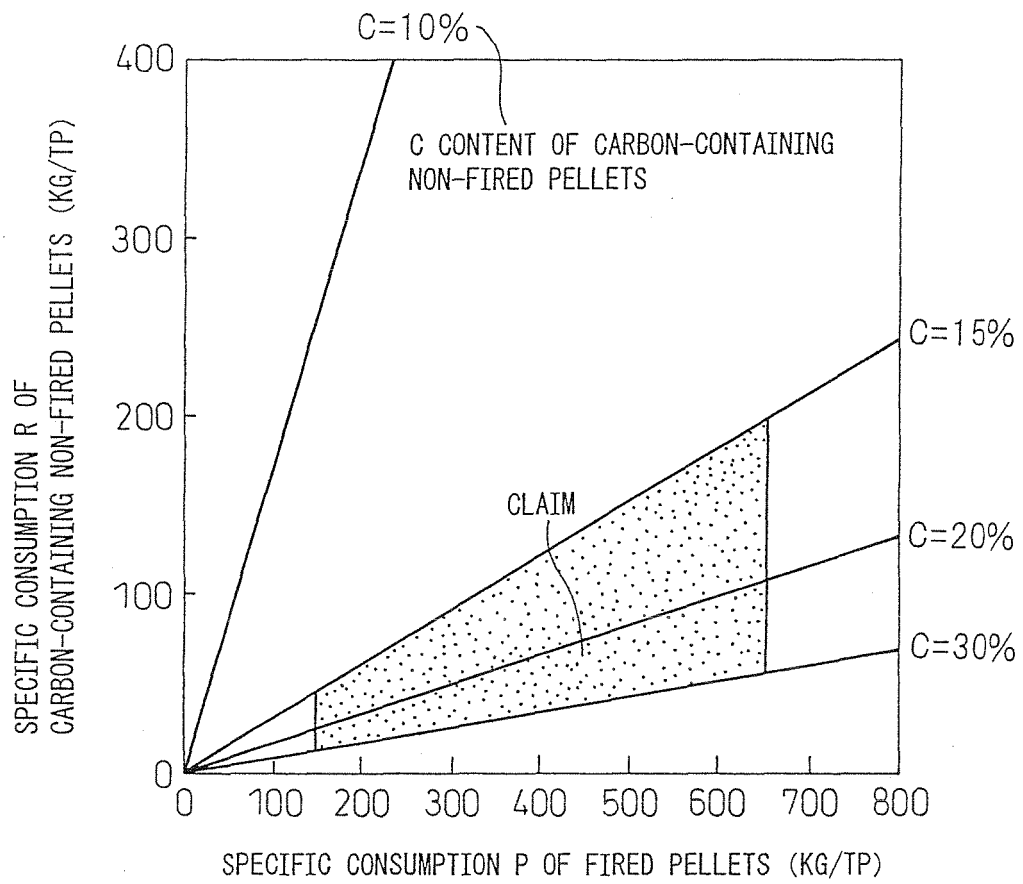


Fig.5

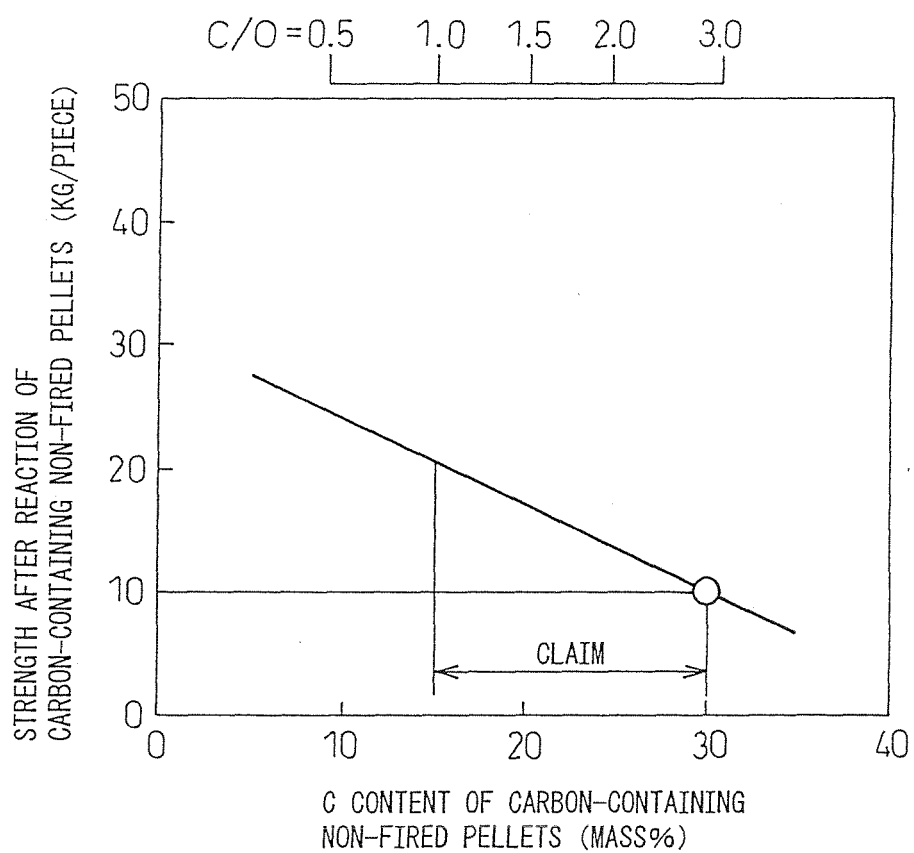
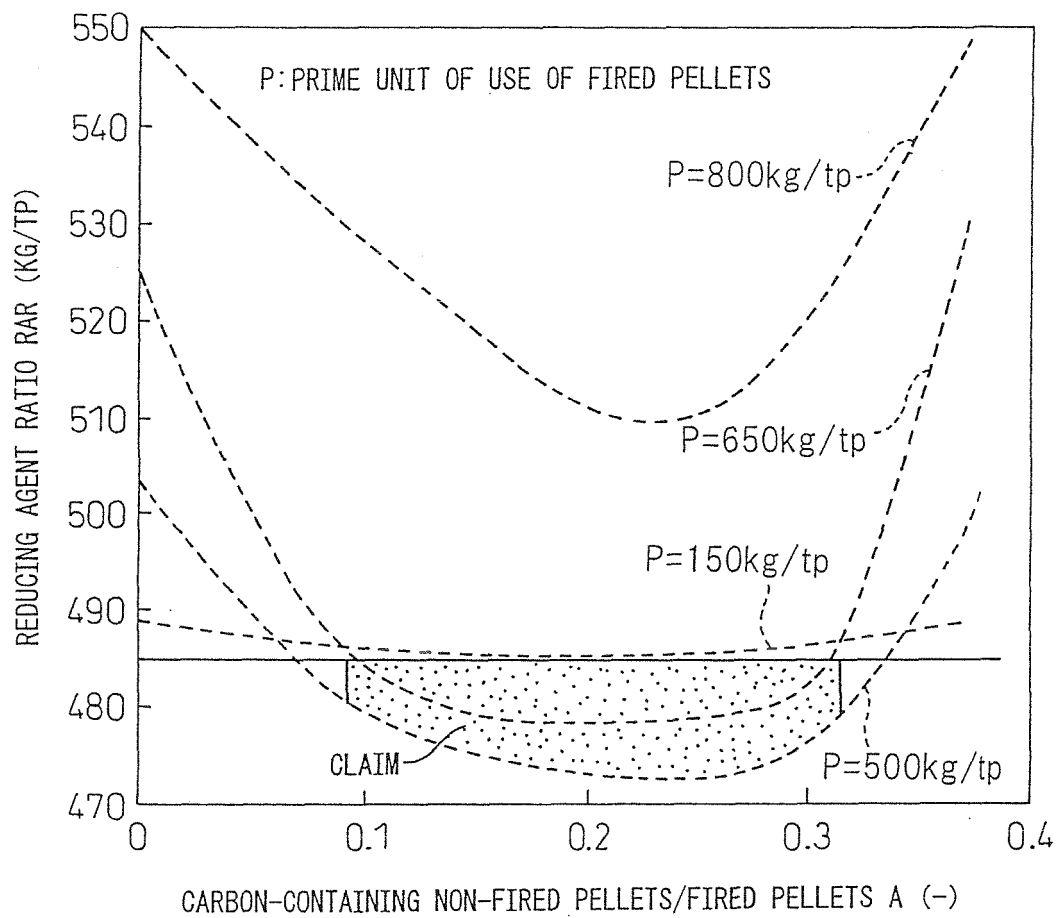


Fig.6



INTERNATIONAL SEARCH REPORT

 International application No.
PCT/JP2009/067948

A. CLASSIFICATION OF SUBJECT MATTER C21B5/00(2006.01)i, C22B1/24(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, C22B1/24		
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 1996-2010 Kokai Jitsuyo Shinan Koho 1971-2010 Toroku Jitsuyo Shinan Koho 1994-2010		
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.
A	Shunsuke TAKASHIRO et al., "Cokes Naiso Cold Pellet no Ko Haigo Koro Sogyo", Journal of the Iron & Steel Institute of Japan, 09 September 1986 (09.09.1986), vol.72, no.12, page S886	1,2
A	JP 2008-95177 A (Nippon Steel Corp.), 24 April 2008 (24.04.2008), claims 1 to 6; paragraphs [0151] to [0153] (Family: none)	1,2
A	JP 58-164710 A (Sumitomo Metal Industries, Ltd.), 29 September 1983 (29.09.1983), claims (Family: none)	1,2
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "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 "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 13 January, 2010 (13.01.10)		Date of mailing of the international search report 26 January, 2010 (26.01.10)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/067948

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 53-58416 A (Nippon Steel Corp.), 26 May 1978 (26.05.1978), claims (Family: none)	1, 2

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REFERENCES CITED IN THE DESCRIPTION

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- *Tetsu to Hagane*, 1986, vol. 72, S98 [0080]