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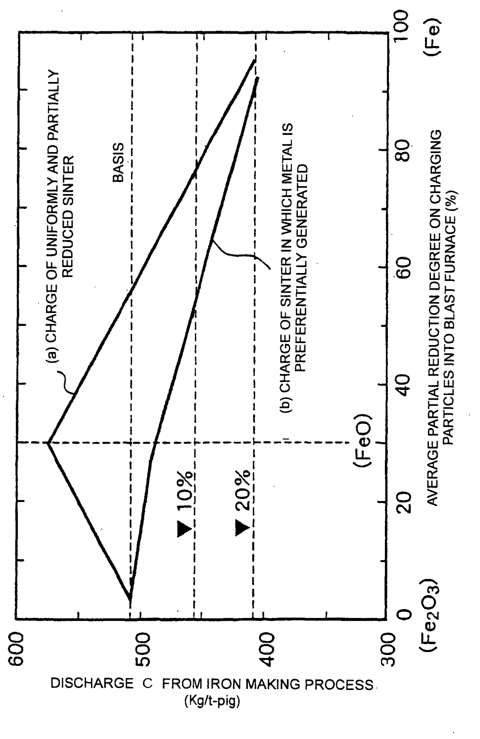
(54) SEMI-REDUCED SINTERED ORE AND METHOD FOR PRODUCTION THEREOF

(57) An iron ore, a carbonaceous material and a CaO-based auxiliary raw material are used as raw materials for sintering. The rawmaterials for sintering are charged into a sinteringmachine to form a raw material layer. A plurality of particles for manufacturing a reduced iron, which are produced by agglomerating at least the iron ore and the carbonaceous material, form a part of the raw material layer. The raw material layer is sintered and a part of the iron ore is reduced by sintering, thereby producing the semi-reduced sinter containing metallic Fe.

FIG. 2



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Description

TECHNICAL FIELD

[0001] The present invention relates to a semi-reduced sinter which is manufactured by sintering raw materials such as iron ore, carbonaceous material, a CaO-based auxiliary raw material, and is used as a raw material for blast furnace and the like, and to a method for manufacturing thereof.

BACKGROUND ART

[0002] Sinter is a major raw material of an iron-making process of blast furnace. The following steps generally manufacture the sinter. To a fine iron ore having sizes of about 8 mm or smaller and having average particle diameters from 2.0 to 3.0 mm, there are added: a CaO-based auxiliary raw material containing CaO such as limestone, burnt lime, and dolomite, (also called the lime-based auxiliary raw material); a raw material containing SiO_2, such as silica rock and nickel slag; recycled fine materials generated and recovered in steel works; a sintered return fines of 3 to 5 mm, need of re-sintering because of small sizes; and a carbonaceous material such as coke fine and anthracite. Further an adequate quantity of water for humidification is added to the mixture. Thus prepared mixture is fully mixed and agglomerated to obtain quasi-particles having average sizes from 3.0 to 5.0 mm. These quasi-particles are then packed on a pallet in an endless mobile sintering machine to thickness of about 400 to 600 mm. The carbonaceous material at surface layer of the packed bed is ignited to combust the carbonaceous material while sucking air downward through the bed, thereby sintering the quasi-particles as the raw material using the combustion heat. The obtained sintered cake is crushed and sized to prepare agglomerates having sizes from 3 to 5 mm or larger, which agglomerates are used as the product sinter.

[0003] That kind of sinter is charged into a blast furnace, where the sinter is reduced by gas mainly of CO to become molten iron.

[0004] Since the blast furnace iron-making process generally utilizes mainly the indirect reduction by CO gas, the process is restricted by the equilibrium of CO/CO_2 gas reaction, and consumes large amount of reducing material. Also from the point of securing permeability in the blast furnace, coke having high strength and high quality is required. In this regard, in recent years, considering the countermeasures to global warming by restricting CO_2 emissions and the life elongation of coke ovens which show significant deterioration, there was developed an iron-making process that mainly utilizes direct reduction of iron oxide by carbon (hereinafter referred to simply as C), and the process has entered the practical application stage. Since the process is not restricted by the gas reduction equilibrium, the unit requirement of reducing material decreases, and the suppression of CO_2 emissions and the reduction in coke oven operating hours can be attained.

[0005] The reduced iron manufacturing process utilizing direct reduction method includes smelting reduction process, rotary hearth furnace process, and rotary kiln process. Since, however, these processes need large investment and have significantly poor productivity, they are adopted only as a supplemental process for the blast furnace process at present.

[0006] On the other hand, there is proposed a method of manufacturing sinter containing a structure reduced to metallic Fe in a part by utilizing an existing sintering machine to conduct simultaneously agglomeration and reduction reaction in the sintering machine.

[0007] Patent Document 1, for example, discloses a method for manufacturing semi-reduced sinter. According to the disclosure, there are formed two-layered quasi-particles composed of the inner layer of mixed and granulated fine iron ore with coke fine and anthracite in amounts from 5 to 20% by weight, and the outer layer of mixed and coated fine iron ore, auxiliary raw material, and coke fine and anthracite in amounts from 2 to 5% by weight, which quasi-particles are mixed and agglomerated as a part of the raw materials for sintering. Thus prepared raw materials are treated by direct reduction during the sintering stage in the melt generated from the outer layer of the raw materials and in the coke fine and anthracite in the inner layer, thereby reducing a part of the sinter. According to the technology, when the coke fine and anthracite are entrapped inside the raw materials, the coke fine and the anthracite do not contact with oxygen in air during the first half period of the temperature-rising step in the sintering stage, thus they do not begin reaction, while beginning the reduction reaction of $FeO + C = Fe + CO$ -36350 kcal/kmol at a point of high temperature of 1100°C to form metallic Fe in a part of the sinter. Since the reaction is endothermic, excess-heat condition can be prevented.

[0008] According to Patent Document 2, the surface part of quasi-particles, which are prepared by mixing iron ore with a carbonaceous material in amounts from 15 to 18%, then by granulating them, is covered with CaO, or the agglomerated quasi-particles are immersed in a solution containing dissolved CaO to add CaO onto the surface of the quasi-particles, thereby preventing re-oxidation after sintering, thus obtaining semi-reduced sinter having high reduction degree.

[0009] That type of process to manufacture semi-reduced sinter utilizing existing sintering machine, conducted by adding a carbonaceous material necessary for reduction to the fine iron ore and by utilizing the direct reduction reaction, is a promised one for practical application without need of large investment and allowing producing large amount of semi-reduced sinter. The semi-reduced sinter thus obtained in an existing sintering machine is used in blast furnace at large quantities even if the content of metallic Fe in the sinter is low. In addition, the carbonaceous material used in the manufacture of reduced ore has very little limitation of quality if only C is existed to some extent. Furthermore, collected dust can be utilized. Therefore, total advantages such as decrease in the blast furnace reducing material ratio and decrease in the coke oven load are significant.

[0010] The technologies of above-given Patent Documents 1 and 2, however, require combustion of carbonaceous material in amounts of approximately two to four times that of ordinary sinter. Accordingly, heat-excess condition likely occurs even the above reduction reaction is endothermic. Consequently, at a point that the fine ore in the raw materials is reduced from Fe_2O or Fe_3O_4 to FeO at elevated temperatures, the FeO reacts with gangue in the ore and with added flux to generate large quantity of melt. The melt is the olivine-based melt generated from the reaction of FeO formed by reduction reaction and gangue SiO_2 in the ore and the calcium ferrite melt generated by the reaction between CaO-based auxiliary raw material added as the auxiliary raw material and the ore. The melt generated in large quantity rapidly fuses surrounding particles, and progresses the fusion of quasi-particles from outer side thereof to inward. The sintering bed as the packed bed of raw materials forms large voids therein by fusion and shrinkage of the quasi-particles, only through which voids the sucked gas in the sintering machine passes. As a result, the sintering reaction in which the combustion zone gradually moves from upper layer to lower layer of the raw material packed bed having normally 400 to 600 mm in height is hindered, thus large quantity of un-burnt portion remains at lower layer zone in the sintering bed, which then raises problems of interfering the progress of reduction reaction and extremely decreasing the productivity.

[0011] Therefore, there is a problem of using existing sintering machine to manufacture a large amount of partially reduced sinter, at a capacity of at least several thousand tons a day as the main raw material for blast furnace.

[0012] Patent Document 1: Japanese Patent Laid-Open No. 4-210432 Patent Document 2: Japanese Patent Laid-Open No. 2000-192154

DISCLOSURE OF THE INVENTION

[0013] The present invention was perfected on the basis of the above-background. It is an object of the present invention to provide a semi-reduced sinter containing iron ore reduced in a part and containing metallic Fe, which semi-reduced sinter is manufactured without deteriorating the operation of existing sintering machine.

[0014] It is another object of the present invention to provide a method for manufacturing semi-reduced sinter, which method progresses direct reduction without deteriorating the operation of existing sintering machine, and allows manufacturing large quantity of semi-reduced sinter containing iron ore reduced in a part, and containing metallic Fe.

[0015] It is a further object of the present invention to provide a method for manufacturing semi-reduced sinter, which method stabilizes the reaction in the sintering stage, and achieves high reduction degree and high metallic Fe content.

[0016] To solve the above problems, the first aspect of the present invention provides a semi-reduced sinter manufactured by a method comprising the steps of:

> providing an iron ore, a carbonaceous material, and a CaO-based auxiliary raw material as raw materials for sintering;
> charging the raw materials into a sintering machine to form a raw material layer therein; and
> sintering the raw material layer to reduce a part of the iron ore, thereby forming the semi-reduced sinter,
> wherein at least the iron ore and the carbonaceous material are agglomerated to form a plurality of particles for manufacturing a reduced iron, the plurality of particles forming a part of the raw material layer, and
> wherein a part of the iron ore is reduced by sintering, thereby producing the semi-reduced sinter containing metallic Fe.

[0017] Regarding the first aspect of the present invention, it is preferable that the particles for manufacturing reduced iron are 5 to 50% by mass of the raw material layer. Furthermore, it is preferable that the particles for manufacturing reduced iron have 10 cm^3 or smaller volume per single particle.

[0018] The second aspect of the present invention is to provide a method for manufacturing a semi-reduced sinter, comprising the steps of:

> providing an iron ore, a carbonaceous material, and a CaO-based auxiliary raw material as raw materials for sintering;
> charging the raw materials for sintering into a sintering machine to form a raw material layer therein;
> sintering the raw material layer to produce a semi-reduced sinter,
> wherein a plurality of particles for manufacturing a reduced iron is produced by agglomerating the iron ore and the carbonaceous material together in amounts of, (not included in total), 5% by mass or more to the iron ore, the plurality of particles are mixed with the raw material layer as a part of the raw material layer, and the raw material layer is sintered to reduce a part of the iron ore, thereby producing the semi-reduced sinter containing metallic Fe.

[0019] The third aspect of the present invention is to provide a method for manufacturing a semi-reduced sinter, comprising the steps of:

providing an iron ore, a carbonaceous material, and a CaO-based auxiliary raw material as raw materials for sintering;
charging the raw materials for sintering into a sintering machine to form a raw material layer therein; and
sintering the raw material layer to produce the semi-reduced sinter,
wherein a plurality of particles for manufacturing reduced iron is prepared by agglomerating a fine mixture of the iron ore, the CaO-based auxiliary raw material and the carbonaceous material, the carbonaceous material being in amounts of, (not included in total), 10 to 20% by mass or more to the fine mixture, the CaO-based auxiliary raw material being blended so that a mass ratio of CaO to SiO_2 as the components excluding the ignition loss of the particles for manufacturing reduced iron is 1 or more, then the particles for manufacturing reduced iron are mixed with the raw material as a part of the raw material layer, thereby sintering the rawmaterial layer to reduce a part of the iron ore tomanufacture the semi-reduced sinter containing metallic Fe.

[0020] For the second and third aspects of the present invention, the particles for manufacturing reduced iron may be prepared by compressing the raw materials using a roll-molding machine or by pelletizing the raw materials.

[0021] The fourth aspect of the present invention is to provide a method for manufacturing semi-reduced sinter, comprising the steps of:

providing an iron ore, a carbonaceous material, and a CaO-based auxiliary raw material as raw materials for sintering;
charging the raw materials for sintering into a sintering machine to form a raw material layer therein; and
sintering the raw material layer to produce the semi-reduced sinter in which a part of the iron ore is reduced,
wherein the iron ore is mixed with the carbonaceous material in amounts of, (not included in total), 10 to 20% by mass to the iron ore, further with water and, at need, a binder to produce a mixture,
the mixture is compressed into agglomerated particles by using a roll-molding machine;
the raw materials for sintering containing the agglomerated particles in amounts of, (included in total), 5 to 50% by mass are prepared; and
a part of the iron ore is reduced by sintering to produce the semi-reduced sinter containing metallic Fe in amounts of 3% by mass or more as an average of total sinter.

[0022] In the fourth aspect of the present invention, it is preferable that the raw materials for manufacturing the agglomerated particles have 8 mm or smaller size of iron ore and 5 mm or smaller size of carbonaceous material. In that case, it is preferable that the raw materials for manufacturing the agglomerated particles contain particles having 125 μm or smaller sizes in amounts of 40% by mass or more.

[0023] The fifth aspect of the present invention is to provide a method for manufacturing semi-reduced sinter, comprising the steps of:

providing an iron ore, a carbonaceous material, and a CaO-based auxiliary raw material, as raw materials for sintering;
charging the raw materials for sintering into a sintering machine to conduct sintering thereof to produce the semi-reduced sinter,
wherein the iron ore is mixed with the CaO-based auxiliary rawmaterial to prepare a fine mixture, and further the carbonaceous material is added to the fine mixture, and further water and, at need, a binder are added to mix them together, the carbonaceous material being in an amount of, (not included in total), 10 to 20% by mass to the fine mixture, the CaO-based auxiliary raw material being blended so that a mass ratio of CaO to SiO_2 as the components excluding the ignition loss of the particles for manufacturing reduced iron is 1 or more;
the fine mixture is compressed into agglomerated particles by using a roll-molding machine;
the raw materials for sintering containing the agglomerated particles in amounts of, (included in total), 5 to 50% by mass are prepared;
a part of the iron ore is reduced by sintering to produce the semi-reduced sinter containing metallic Fe by in amounts of 3% by mass or more as an average of total sinter.

[0024] In the fifth aspect of the present invention, it is preferable that the raw materials for manufacturing the agglomerated particles have 8 mm or smaller size of iron ore, 5 mm or smaller size of carbonaceous material, and 5 mm or smaller size of CaO-based auxiliary raw material. In that case, it is preferable that the raw materials for manufacturing the agglomerated particles contain 40% by mass or more of particles having 125 μm or smaller size.

[0025] For the fourth and fifth aspects of the present invention, it may be applied that the agglomerated particles prepared by compression-molding using the roll-molding machine are a plurality of briquettes formed into a specified shape by the roll-agglomerating machine, or are particles obtained by pulverizing plate shape, sheet shape, or rod shape form agglomerated by the roll-molding machine into a specified size. In that case, it is preferable that the agglomerated particles have 10 cm^3 or smaller volume per single particle.

[0026] The sixth aspect of the present invention is to provide a method for manufacturing semi-reduced sinter, comprising the steps of:

> charging an iron ore, a carbonaceous material, and an auxiliary raw material, as raw materials for sintering, into a sintering machine;
> sintering thus charged raw materials to reduce a part of the iron ore by using the carbonaceous material,
> wherein a part of the iron ore and a part of the carbonaceous material in the raw materials for sintering, or a part of the iron ore, a part of the carbonaceous material, and a part of the auxiliary raw material in the raw materials for sintering are preliminarily compressed into compression-agglomerated particles, while residual amount of the raw-materials for sintering is formed into agglomerates, then blending them to sinter.

[0027] In the sixth aspect of the present invention, it is preferable that the compression-agglomerated particle has 10 cm^3 or smaller volume. On charging the compression-agglomerated particles into the sintering machine, it is preferable that the compression-molded particles are charged into the sintering machine in the lower three-quarter zone of the raw material layer. Furthermore, it is preferable that the mixing rate of the compression-agglomerated particles is 50% by mass or less.

[0028] The seventh aspect of the present invention is to provide a method for manufacturing semi-reduced sinter, comprising the steps of:

> providing an iron ore, a carbonaceous material, and an auxiliary raw material, as raw materials for sintering;
> uniformly mixing preliminarily a part of the iron ore and a part of the carbonaceous material, or a part of the iron ore, a part of the carbonaceous material, and a part of the auxiliary raw material, to form a mixture;
> compressing the mixture to form compression-agglomerated particles;
> agglomerating residual amount of the raw materials for sintering into agglomerates;
> blending the compression-agglomerated particles and the agglomerates to sinter to reduce a part of the iron ore by the carbonaceous material,
> wherein the iron and the carbonaceous material as the raw materials for structuring the compression-agglomerated particles contain, as the total, 40% by mass or more of particles having 125 μm or less size.

[0029] In the seventh aspect of the present invention, it is preferable that the iron ore and the carbonaceous material as the raw materials for structuring the compression-agglomerated particles contain, as the total, particles having 125 μm or smaller size in amounts of 70% by mass or more.

[0030] The eighth aspect of the present invention is to provide a method for manufacturing semi-reduced sinter, comprising the steps of:

> providing an iron ore, a carbonaceous material, and an auxiliary raw material, as raw materials for sintering;
> uniformly mixing preliminarily a part of the iron ore, a part of the carbonaceous material, and a part of the auxiliary raw material in the raw materials for sintering;
> compressing the mixture to form compression-agglomerated particles;
> forming residual amount of the raw materials for sintering into agglomerates;
> mixing the compression-agglomerated particles and the agglomerates to sinter to reduce a part of the iron ore by the carbonaceous material,
> wherein the auxiliary raw material contains a CaO source, and a part or total of the CaO source is burnt lime, then the compression-agglomerated particle is formed without using binder, while containing burnt lime therein.

[0031] The ninth aspect of the present invention is to provide a method for manufacturing semi-reduced sinter comprising the steps of:

> providing an iron ore, a carbonaceous material, and an auxiliary raw material, as raw materials for sintering;
> uniformly mixing preliminarily a part of the iron ore, a part of the carbonaceous material, and a part of the auxiliary raw material in the raw materials for sintering;
> compressing the mixture to form compression-agglomerated particles;
> forming residual amount of the raw materials for sintering into agglomerates;
> blending the compression-agglomerated particles and the agglomerates to sinter to reduce a part of the iron ore by the carbonaceous material,
> wherein the auxiliary raw material contains a CaO source, and the content of CaO source in the compression-

agglomerated particles is adjusted to 1 or more of the ratio of CaO to SiO_2, existing in the compression-agglomerated particles.

[0032] The term "binder" referred to herein signifies the one having a function of binding iron ore particles with each other. Applicable binder includes starch, tar, and molasses. Nevertheless, the kind of binder is not specifically limited if only it has the above function. Although the CaO-based auxiliary raw materials have the function to bind iron ore particles with each other, they are not included in the "binder" referred to herein from the purport of the present invention.

[0033] According to the first to fifth aspects of the present invention, the iron ore, the carbonaceous material, and other materials are agglomerated to particles for manufacturing reduced iron or to agglomerated particles before charging them into blast furnace as a part of the raw material layer. Consequently, the iron ore and the carbonaceous material strongly contact with each other, and give a large contact area. In addition, since the direct reduction reaction occurs only locally, there is no possibility of generating large quantity of melt. Furthermore, since the particles for manufacturing reduced iron have strong adhesion between iron ore and carbonaceous material, the oxidation of metallic Fe is suppressed, thus attaining high metallic Fe content. As a result, the direct reduction is progressed without deteriorating the operation of existing sintering machine, while reducing a part of the iron ore, thereby manufacturing a large quantity of semi-reduced sinter containing metallic Fe. Therefore, with the use of the semi-reduced sinter inblast furnace, the use amount of reducing material can be decreased as the total iron-making process, which then leads the decrease in the CO_2 emissions from the iron-making process.

[0034] In particular, as in the fourth and fifth aspects of the present invention, by compressing the iron ore, the carbonaceous material, and other materials in a roll-molding machine to prepare agglomerated particles, and by charging the agglomerated particles into the sintering machine as a part of the raw materials for sintering, and further by limiting the operating conditions, the contact between the iron ore and the carbonaceous material becomes further strong, the contact area between them becomes further large, and the sintering proceeds further adequately, thus the above effects are further enhanced.

[0035] According to the sixth to ninth aspects of the present invention, a part of the iron ore and a part of the carbonaceous material in the raw materials for sintering, or a part of the iron ore, a part of the carbonaceous material, and a part of the auxiliary raw material in the raw materials for sintering are preliminarily compression-agglomerated to prepare compression-agglomerated particles before charging them to the sintering machine. As a result, the contact area between the iron ore and the carbonaceous material increases to stabilize the reaction in the sintering stage, and the reduction degree increases. In addition, the compression-agglomerated particles are in a dense state so that the ingredients of the compression-agglomerated particles are shielded from outer atmosphere, thus suppressing the oxidation of metallic Fe, which provides high metallic Fe content.

[0036] As in the case of seventh aspect of the present invention, further high reduction degree is attained by refining the particle size of the iron ore and the carbonaceous material to 125 μm or smaller size in amounts of 40% by mass or more, as the total. Furthermore, as in the case of eighth aspect of the present invention, use of burnt lime as the CaO source being existed in the compression-agglomerated particles provides both functions of CaO source and binder. Therefore, the agglomerating is available without using binder for manufacturing the compression-agglomerated particles, which decreases cost. In addition, as in the case of ninth aspect of the present invention, by applying the content of CaO source in the compression-agglomerated particles adjusted to 1 or more of the ratio of CaO to SiO_2 as the components excluding the ignition loss of the compressed particles, the CaO-based auxiliary raw material performs effectively the function of aggregate to keep the strength of the compression-agglomerated particles or the function of preventing the generation of slightly-reducing $FeO\text{-}SiO_2$-based slag as a fusion structure of the sinter. Furthermore, by combining adequately these conditions, synergy effects can be attained.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037]

Figure 1 is a graph showing the relation between the reduction degree of sinter and the blast furnace reducing material ratio.

Figure 2 is a graph showing the relation between the average reduction degree at the point of charging sinter into blast furnace and the quantity of C discharge from iron-making process, comparing the sinter which was uniformly and partially reduced with the sinter which preferentially generated metallic Fe.

Figure 3 is a graph showing the relation between the reduction degree on sintering and the content of metallic Fe after sintering, comparing the case of quasi-particles prepared by tumbling-granulation with the case of briquettes.

Figure 4 shows a schematic flowchart of an example of facilities for the method of manufacturing semi-reduced sinter according to the first embodiment of the present invention.

Figure 5 illustrates the structure of raw material layer according to the method of manufacturing semi-reduced sinter of the first embodiment of the present invention.

Figure 6 illustrates the agglomerated particle in sintering stage according to the method of manufacturing semi-reduced sinter of the second embodiment of the present invention.

Figure 7 is a graph showing the relation between the compression pressure for the briquettes and the defect rate of +5 mm briquettes after drop test.

Figure 8 shows a schematic flowchart of an example of facilities for the method of manufacturing semi-reduced sinter according to the second embodiment of the present invention.

Figure 9 illustrates the structure of raw material layer according to the method of manufacturing semi-reduced sinter of the second embodiment of the present invention.

Figure 10 illustrates an example of charging method for the raw materials for sintering in the method for manufacturing semi-reduced sinter according to the third embodiment of the present invention.

EMBODIMENTS OF THE INVENTION

[0038] The present invention is described in detail in the following.

First Embodiment

[0039] According to the first embodiment of the present invention, basically the raw materials for sintering adopt an iron ore, a carbonaceous material, and a CaO-based auxiliary raw material. By charging these materials into a sintering machine, a raw material layer is formed therein, which layer is then sintered to manufacture a semi-reduced sinter.

[0040] As a part of the raw material layer, preferably a plurality of particles for manufacturing reduced iron is charged, which particles are prepared by agglomerating the iron ore and the carbonaceous material in amounts of, (not included in total), normally 5% by mass or more, preferably 10 to 20% by mass or more to the iron ore. By sintering the raw material layer in that state in the sintering machine, a part of the iron ore is reduced mainly by direct reduction, thus providing the semi-reduced sinter containing metallic Fe.

[0041] That type of structure is attained on the basis of the findings derived by the inventors of the present invention as given below.

(1) The contact condition between the carbonaceous material as the C-source and the iron ore as the substance being reduced plays a main role to effectively progress the direct reduction reaction of iron ore by C. The important things are the strong contact between them and the large contact area between them.

(2) Those agglomerated particles may be excessively fused because the carbonaceous material for progressing the reduction reaction exists in large quantities. Even if the particles are excessively fused, however, there is little possibility of generating large quantity of melt because the agglomerated particles are a part of the raw materials for sintering. Therefore, the phenomenon does not affect substantially on the permeability of total sintering bed, thus the productivity of sinter decreases very little.

(3) The reduced particles may be re-oxidized by oxygen in the sucked gas. Since, however, the particles prepared by agglomerating iron ore, carbonaceous material, and other materials have strong adhesion among these individual particles, the particle shape sustains after reducing, and sustains favorable reduced condition because, even if the surface is oxidized, the inner part of the particle is difficult to be oxidized.

[0042] Detail description about the phenomena is given below.

[0043] The reduction reaction of iron ore proceeds, similar to the internal state of blast furnace, following the reaction with carbon in the carbonaceous material such as coke, (direct reduction), represented by the formula (1), and the reaction with CO gas, (indirect reduction), represented by the formula (2). The CO_2 gas generated by the indirect reduction becomes CO gas by the reaction called the solution-loss reaction, represented by the formula (3).

$$Fe_2O_3 + (3/2)C = 2Fe + (3/2)CO_2 \qquad (1)$$

$$Fe_2O_3 + 3CO = 2Fe + 3CO_2 \qquad (2)$$

$$CO_2 + C = 2CO \qquad (3)$$

[0044] In these reduction reactions, the indirect reduction is predominant in a temperature range from 900°C to 1100°C, and the direct reduction is predominant in a temperature range of 1200°C or above. On manufacturing the semi-reduced sinter, the present invention intends to bring the temperature of raw material layer to a level of about 1400°C, and to extend the retention time at 1200°C or higher temperature, thus progressing the direct reduction.

[0045] In that case, the particles for manufacturing reduced iron have strong contact between the iron ore as the substance being reduced and the carbonaceous material as the reducing material, and have a large contact area between them. Therefore, the direct reduction reaction of iron ore is allowed to effectively proceed in the particles for manufacturing reduced iron. In addition, since the particles for manufacturing reduced iron are charged as a part of the raw material layer, the above reactions occur locally, and the excessive fusing occurs only a portion of the particles for manufacturing reduced iron, thus there is little possibility of generating large amount of melt. Furthermore, since the particles for manufacturing reduced iron have strong adhesion between the iron ore and the carbonaceous material, and since the condition sustains after the reduction, the re-oxidation in inner portion of the particle is prevented even by the oxygen in the sucked gas, thus keeping the favorable reduced condition. As a result, direct reduction can be progressed without deteriorating the operation of existing sintering machine, allowing reducing a part of the iron ore, thus manufacturing large quantity of semi-reduced sinter containing metallic Fe.

[0046] By using that kind of semi-reduced sinter, containing metallic Fe with reduced iron ore in a part, for a blast furnace, the use amount of reducing material (reducing material ratio) as total of iron-making process decreases, which further decreases the CO_2 emissions from the iron-making process. In particular, preferential precipitation of metallic Fe increases the effect of decreasing the CO_2 emissions from the iron-making process.

[0047] The above effect is described in more detail.

[0048] Figure 1 is a graph showing the relation of reduction degree of sinter, as horizontal axis, and the reducing material ratio in the blast furnace, as vertical axis. The graph is drawn under the condition of 131 kg/thm of pulverized coal charge (131 kg per ton of molten iron). The figure shows that the increase in the reduction degree of sinter decreases the reducing material ratio in the blast furnace, and that the decreasing rate of the reducing material ratio becomes rapid at higher than 30% of reduction degree. Since ordinary sinter has about 2% of reduction degree, the reducing material ratio in the blast furnace can be significantly decreased by attaining the semi-reduced sinter having 30% or higher reduction degree according to the first embodiment.

[0049] The reducing material ratio in the blast furnace can be decreased by increasing the reduction degree of sinter. As described above, however, from the point of more effectively decreasing the CO_2 emissions, it is preferable to precipitate the metallic Fe rather than uniformly increasing the reduction degree over the total sinter. The matter is described referring to Fig. 2. Figure 2 compares the quantity of C-discharge between the sinter which was uniformly and partially reduced and the sinter which preferentially generated metallic Fe. The horizontal axis is the average reduction degree at the point of charging the sinter into the blast furnace, and the vertical axis is the quantity of C-discharge from iron-making process. The line (a) is for the case of sinter being uniformly and partially reduced, and the line (b) is for the case of sinter generated metal preferentially. Actual semi-reduced sinter positions between the line (a) and the line (b). The "basis" in the graph signifies the quantity of C-discharge for the case of sinter without partially reduced. As seen in the graph, the case of containing large amount of metallic Fe further decreases the quantity of C-discharge, or CO_2 emissions, more than the case of uniformly and partially reduced. For the case of uniformly and partially reduced sinter, the quantity of C-discharge rather increases up to 30% of reduction degree. Similar tendency presumably occurs even if the metallic Fe exists to some extent. Consequently, it was found that 30% or more of reduction degree is preferable to decrease the CO_2 emissions.

[0050] Preferred quantities of metallic Fe in the semi-reduced sinter are 3% by mass or more as total average value. That level of metallic Fe allows effectively performing the decrease in the reducing material ratio in blast furnace, decrease in the CO_2 emissions of total iron-making process, and decrease in the load to coke oven.

[0051] To obtain the semi-reduced sinter of the first embodiment, the content of carbonaceous material in the particles for manufacturing reduced iron is preferably 5% by mass or more. If the content is less than 5% by mass, the direct reduction reaction may not effectively begin. The content of carbonaceous material of 10% by mass or more is further preferable to enhance the direct reduction reaction. If, however, the carbonaceous material content exceeds 20% by mass, excess fusion likely occurs. Accordingly, the content of carbonaceous material is preferably in a range from 10 to 20% by mass. Coke fine is suitable for the carbonaceous material. Other carbonaceous material such as anthracite and powder collected in a coke-cooling facility may be applied.

[0052] The particles for manufacturing reduced iron after sintered may contain a CaO-based auxiliary raw material in amounts of 1 or more of the mass ratio of CaO to SiO_2 as the components excluding the ignition loss. The CaO-based auxiliary raw material performs the function of aggregate to keep the strength of the particles for manufacturing reduced iron or the function of preventing the generation of irreducibe $FeO-SiO_2$-based slag as a fusion structure of sinter. If the mass ratio of CaO to SiO_2 is smaller than 1, the $FeO-SiO_2$-based melt of low melting point and irreducible likely appears. On the other hand, if the quantity of CaO becomes excessively large, a $CaO-Fe_2O_3$-based low melting point melt likely appears. When the melt is generated in a large quantity, the particles may be excessively fused to lose their shape. Ordinary iron ore contains SiO_2 in amounts from 0.6 to 5.5% by mass. Since current sintering operation adds plurality of grades (normally 5 to 10 grades) of iron ores, the resulting SiO_2 content in the iron ore raw material becomes 3.7 to 4.8% by mass. For functioning as the aggregate, the content of CaO-based auxiliary raw material is preferably 2% by mass or more as CaO. To prevent the generation of less sintering SiO_2-CaO-based melt, and to prevent the generation of large quantity of CaO-Fe_2O_3-baed low melting point melt, the content of CaO-based auxiliary rawmaterial is preferably 8% by mass or less as CaO. The CaO-based raw material, (also referred to as lime-based auxiliary raw material), is not specifically limited if only it contains CaO component. Typical examples of the CaO-based raw material are limestone, burnt lime, and dolomite.

[0053] As of the raw materials structuring the particles for manufacturing reduced iron, preferable particle sizes thereof are 8 mm or smaller for iron ore, 5 mm or smaller for carbonaceous material, and 5 mm or smaller for CaO-based auxiliary raw material. With that small size of raw materials, the contact area between the iron ore and the carbonaceous material increases to effectively induce the reduction reactions, thereby attaining highly dense reduced particles.

[0054] For the particles for manufacturing reduced iron, it is preferable that at least the iron ore and the carbonaceous material contain particles of 125 μm or smaller size in amounts of 40% by mass or more. By refining the iron ore and the carbonaceous material as above, the reactivity of reduction reaction between them increases to further increase the reduction degree of iron ore. A more preferable content of the particles having 125 μm or smaller size is 70% by mass ormore. When the CaO-based auxiliary raw material is added to the particles for manufacturing reduced iron, it is preferable that the particles having 125 μm or smaller size is 40% by mass or more to the total of particles for manufacturing reduced iron, including the CaO-based auxiliary raw material, and more preferably 70% by mass or more.

[0055] The size of particles for manufacturing reduced iron is preferably 10 cm^3 or smaller per single particle. Since the reduction reaction is endothermic, the reaction heat is supplied by the coke combustion heat during the manufacture of sinter. If, however, the size of the particles for manufacturing reduced iron is excessively large, the heat cannot be supplied to inner portion of the particle, which likely leaves unreacted zone behind. By refining the size of particles to 10 cm^3 or smaller, the reduction reaction sufficiently proceeds, and an effect of improving permeability of the raw material layer is attained. If, however, the size of particles for manufacturing reduced iron becomes smaller than 0. 065 cm^3, (equivalent to sphere of 5 mm in diameter), the particles become smaller than surrounding granules, and the particles assimilate and fuse with the granules during sintering. Excessively small particles fail to effectively attain the improving effect of permeation. Therefore, the size thereof is preferably in a range from 0.065 to 10 cm^3. When the effect of improving the permeation is further emphasized, the size thereof is preferably 0.3 cm^3 or more.

[0056] The particles for manufacturing reduced iron preferably occupy the total raw material layer in amounts from 5 to 50% by mass, and more preferably from 10 to 50% by mass. The particles for manufacturing reduced iron after agglomerating have relatively high strength, and show not much collapse at the point of charging them into the sintering machine, thus functioning as the coarse particles in the raw material layer to secure the permeation. Accordingly, an adequate quantity of the particles functions to improve the productivity of sinter. If, however, the content of the particles exceeds 50% by mass of the total raw material layer, a layer with segregated particles for manufacturing reduced iron appears, which makes the permeation excessive, thus resulting likely forming un-sintered portion. If the size of the particles for manufacturing sintered iron is less than 5% by mass, the quantity of metallic Fe in the obtained semi-reduced sinter becomes small, which tends to failing in attaining sufficiently the effects to decrease the reducing material ratio in the blast furnace and to decrease the CO_2 emissions.

[0057] The particles for manufacturing reduced iron are prepared by agglomerating iron ore and carbonaceous material, or iron ore, carbonaceous material, and CaO-based auxiliary raw material by an adequate method. The applicable method includes known methods of tumbling granulation for manufacturing quasi-particles as the raw material for sintering, such as drummixer and disk pelletizer, and of compression-agglomerating (also called the pressure-agglomerating) to form briquettes using roll-agglomerating machine represented by briquetting by briquetting machine. As of these methods, compression-agglomerating is preferred.

[0058] Compared with the method for forming quasi-particles by tumbling granulation, the method for compression-agglomerating of iron ore and carbonaceous material, or iron ore, carbonaceous material, and CaO-based auxiliary raw material makes the contact between the iron ore and the carbonaceous material stronger to widen the contact area there between, thus the compression-agglomerating method allows more easily progressing the reduction reaction of iron ore, thereby further increasing the reduction degree and the content of metallic Fe.

[0059] The above matter is described referring to Fig. 3. Figure 3 is a graph showing the relation between the reduction degree of sinter, given on the horizontal axis, and the content of metallic Fe after sintering, given on the vertical axis, comparing the case of quasi-particles prepared by tumbling granulation with the case of briquettes. As shown in the graph, the briquettes gave higher reduction degree after sintered than that of quasi-particles, and gave higher content of metallic Fe after sintering.

[0060] By using the compression-agglomerated particles such as briquettes, the void fraction in the raw material packed bed becomes large, thereby improving the permeation of the sintered bed.

[0061] For manufacturing the particles for manufacturing reduced iron by compression-agglomerating represented by briquetting, it is preferable that the above-described raw materials are mixed with an adequate amount of water and/or binder, and that the mixed material is compression-agglomerated. Also for agglomerating by tumbling-granulation, it is preferable that the tumbling-granulation is given after adding and mixing adequate amount of water and/or binder to the above raw materials.

[0062] As for the residual portion of the raw material layer, quasi-particles used in ordinary sinter are adopted. That is, the raw materials for sintering composed mainly of iron ore, carbonaceous material, and CaO-based auxiliary raw material are agglomerated by tumbling-granulation using drum mixer, disk pelletizer, or the like. In that case, the iron ore adopts ordinary fine iron ore, the carbonaceous material adopts coke fines, and the CaO-based auxiliary raw material adopts limestone or burnt lime. Preferred blending ratios of them are, for 100% by mass of iron ore and CaO- based auxiliary raw material, 2 to 6% by mass of, (not included in total) , carbonaceous material. A preferable content of the CaO-based auxiliary raw material is in a range from 4 to 10% by mass, (included in the total of iron ore and CaO-based auxiliary raw material).

[0063] The sintering machine generally adopts a bottom-suction type endless mobile sintering machine. That type of sintering machine has an endless traveling grate, on which grate the particles for manufacturing reduced iron and the ordinary quasi-particles are supplied to form the raw material layer. The raw material layer is continuously sintered to manufacture the semi-reduced sinter of the first embodiment.

[0064] The following is the description about the examples of method for manufacturing the semi-reduced sinter according to the first embodiment.

[0065] Figure 4 shows a schematic flowchart of an example of facilities for the method of manufacturing semi-reduced sinter according to the first embodiment. The facilities have a raw material manufacturing apparatus 40 and a bottom-suction type endless mobile sintering machine 50.

[0066] The raw material manufacturing apparatus 40 has a raw material source for ordinary quasi-particles 1 which can supply iron ore, carbonaceous material, CaO-based auxiliary raw material, and the like, which are the raw materials of ordinary quasi-particles. The raw materials coming from the raw material source for the ordinary quasi-particles 1 are granulated in a tumbling-granulation apparatus 2 composed of drum mixer, disk pelletizer, and the like, to become the ordinary quasi-particles. The raw material manufacturing apparatus 40 has a raw material source 3 for particles for manufacturing reduced iron, which source 3 can supply iron ore and carbonaceous material, or iron ore, carbonaceous material, and CaO-based auxiliary raw material, as the raw materials of particles for manufacturing reduced iron. The raw materials coming from the raw material source 3 for particles for manufacturing reduced iron are agglomerated in an agglomerating machine 4 such as above-described roll-agglomerating machine or tumbling-granulation apparatus, thus providing particles for manufacturing reduced iron. Those ordinary quasi-particles and the particles for manufacturing reduced iron are, for example, mixed in a mixer 5 at an adequate ratio, and stored in a hopper 6.

[0067] The bottom-suction type sintering machine 50 has an endless traveling grate 11, on which a mixture of the ordinary quasi-particles and the particles for manufacturing reduced iron are supplied by a roll feeder 10 as the charging system, thus forming a raw material layer 13. Alternatively, the ordinary quasi-particles and the particles for manufacturing reduced iron may be separately supplied onto the traveling grate 11 without using the mixer 5.

[0068] An ignition furnace 12 is located in the moving course of the traveling grate 11. The quasi-particles on the traveling grate 11 is ignited when they pass under the ignition furnace 12 to begin the sintering of the raw material layer 13 to form a sintered cake 13a. At exit of the traveling grate 11, a crusher (not shown) is positioned. The sinter cake dropped from the traveling grate 11 is crushed by the crusher, and is fed to a conveyer 14, and then is finally charged to the blast furnace.

[0069] At directly beneath the traveling grate 11, plurality of blast boxes 15 are arranged along the traveling direction of the traveling grate 11. To each of the blast boxes 15, a vertical duct 16 is connected. Through the blast boxes 15 and the vertical ducts 16, the gas above the raw material layer 13 is sucked via the raw material layer 13.

[0070] The vertical ducts 16 are connected to a horizontally positioned main flue gas duct 17, and the flue gas is discharged there through. The main flue gas duct 17 is connected to an electric precipitator 20 and a main blower 21. The main blower 21 sucks the gas above the raw material layer 13 to discharge the gas from a stack 22 via the blast boxes 15, the vertical ducts 16, the main flue gas duct 17, and the electric precipitator 20, and the like.

[0071] There may be installed a gas supply hood at downstream side of the ignition furnace 12 above the raw material layer 13, and may be installed a flue gas circulation duct branched from the vertical ducts 16 and connected to the hood for circulating the flue gas. That type of flue gas circulation method allows easy and adequate control of atmosphere (oxygen concentration) in the raw material layer 13, which provides further effective prevention of metallic Fe generation and of re-oxidation.

[0072] With the facilities having that configuration, the raw materials coming from the raw material source for ordinary quasi-particles 1 are granulated by the tumbling-granulation apparatus 2 to prepare the ordinary quasi-particles, while the raw materials coming from the raw material source 3 for particles for manufacturing reduced iron are agglomerated in the agglomerating machine 4 to manufacture the particles for manufacturing reduced iron, then both the ordinary quasi-particles and the particles for manufacturing reduced iron are mixed in the mixer 5, which mixture is then supplied onto the traveling grate 11 of the bottom-suction type endless mobile sintering machine 50 via the hopper 6 and the roll feeder 10, thereby forming the raw material layer 13. In that case, the raw material layer 13 is, as illustrated in Fig. 5, in a state that particles 32 for manufacturing reduced iron are dispersed in a matrix 31 of the ordinary quasi-particles.

[0073] By igniting the surface of the raw material layer 13 using the ignition furnace 12, the raw material layer 13 is sintered while sucking the gas downward via the blast boxes 15 to sinter the quasi-particles structuring the rawmaterial layer 13 to obtain the sinter. Thus obtained sinter cake from the traveling grate 11, and the dropped sinter is crushed by the crusher located at exit of the grate, which is then fed to the conveyer 14 and further to the blast furnace. In this case, as described above, inside the particle 32 for manufacturing reduced iron in the raw material layer 13, direct reduction occurs by the iron ore and the carbonaceous material, thus manufacturing the semi-reduced sinter in which the iron ore is partially reduced to become metallic Fe in a part.

Second embodiment

[0074] According to the second embodiment of the present invention, the raw materials for sintering adopt at least iron ore, carbonaceous material, and CaO-based auxiliary raw material, and these raw materials are charged into the sintering machine to form the raw material layer, which layer is then sintered to manufacture the semi-reduced sinter. The second embodiment specifies more detailed ranges than those in the first embodiment.

[0075] In the second embodiment, the carbonaceous material is mixed with the fine iron ore in amounts of, (not included in total), 10 to 20% by mass to the fine iron ore, and further adding water and, at need, binder to mix them together. The mixture is compression-agglomerated to form agglomerated particles by a roll-agglomerating machine. The raw materials for sintering containing the agglomerated particles in amounts of, (included in total), 5 to 30% by mass are charged to the sintering machine. The raw materials for sintering containing the agglomerated particles in amounts of 5 to 50% by mass, preferably 5 to 30% by mass, are sintered to partially reduce the iron ore, thus obtaining the semi-reduced sinter containing metallic Fe in amounts of 3% by mass or more as an average of total sinter.

[0076] In the second embodiment, similar to the first embodiment, the manufacture of sinter is conducted by raising the temperature of raw material layer to about 1400°C, and by extending the retention time at 1200°C or higher temperatures to make the direct reduction predominant.

[0077] In the second embodiment, agglomerated particles prepared by compression-agglomerating in the roll agglomerating machine are adopted corresponding to the particles for manufacturing reduced iron used in the first embodiment. Those kind of compression-agglomerated particles have higher density compared with that of the granulated quasi-particles as the ordinary raw material for sintering, and, as described in the first embodiment, have higher reduction degree after sintering and higher content of metallic Fe after sintering than those of quasi-particles.

[0078] That is, the agglomerated particles prepared by compression-agglomerating in the roll-agglomerating machine have, on the surface thereof, strong contact of the iron ore as the substance being reduced and the carbonaceous material as the reducing material, and have a large contact area there between, thus the direct reduction proceeds to rapidly reduce to metallic Fe. On the other hand, the inner portion of the agglomerated particle gives slow diffusion rate of oxygen owing to the high density, thus no C-combustion occurs, and the direct reduction reaction proceeds when the temperature increases by heat transfer. As shown in Fig. 6, on the surface of the agglomerated particles 63 which disperse in the ordinary quasi-particles 62 in the sintered packed bed (raw material layer) 61, there is formed a film 64 having a fused structure by the FeO-SiO_2-based or FeO-CaO-based melt. The film 64 prevents burst caused by CO gas or CO_2 gas generated by the direct reduction inside the particle. As a result, even after the reduction (after the sintering), the film 64 remains to keep the shape of the particle, then the remained film 64 effectively functions to prevent re-oxidation of reduced Fe or FeO. In this manner, the agglomerated particles allow the direct reduction reaction of iron ore to effectively proceed. Since the agglomerated particles are a part of the raw materials for sintering, and since the agglomerated particles become in a dispersed state in the raw material layer in the sintering machine, the above reactions occur locally, thus the excessive fusion occurs only in the portion of particles for manufacturing reduced iron, and there is little possibility to generate large quantity of melt. Furthermore, since the agglomerated particles keep their shape even after reduction, as described above, the inner re-oxidation by the oxygen in the suction gas is prevented to keep favorable reducing state. Therefore, the direct reduction can proceed without deteriorating the operation of existing sintering machine, thereby allowing manufacturing a large quantity of semi-reduced sinter containing metallic Fe in amounts of 3% or more. Owing to the advantages, similar to the first embodiment, the use amount of reducing material (reducing material ratio) can be decreased in total manufacturing process, and further the CO_2 emissions from the manufacturing process can be decreased. In particular, preferential precipitation of metallic Fe increases the effect to decrease the CO_2 emissions from the manufacturing process.

[0079] The agglomerated particles effectively reduce the iron ore as described above, and have high strength so that they collapse not significantly at the point of charging into the sintering machine, and that they function as coarse particles to keep the permeation in the raw material layer. Consequently, by adding the agglomerated particles in an adequate amount, they function to improve the productivity of the sinter. If, however, the adding quantity of the agglomerated particles exceeds 30% by mass to the total of raw materials for sintering, there is formed a layer concentrated by the particles for manufacturing reduced iron, which then leads to excess permeation, thus likely generating un-sintered portion. On the other hand, if the content of the particles for manufacturing reduced iron is less than 5% by mass, the metallic Fe in the obtained sinter becomes difficult to attain 3% by mass or more. Therefore, the second embodiment specifies the content of the agglomerated particles in the raw materials for sintering to a range from 5 to 30% by mass.

[0080] The content of metallic Fe in the sinter is specified to 3% by mass or more as an average of total because that range allows effective functioning of the effects of decreasing the reducing material ratio in the blast furnace and of decreasing the load to coke oven.

[0081] The reason to specify the content of carbonaceous material in the agglomerated particles in the second embodiment to a range from 10 to 20% by mass is the following. The total Fe in the iron ore is in a range from 56 to 65% by mass, and the amount of Fe per ton of iron ore is in a range from 560 to 650 kg. Since the Fe in the iron ore is presumably mostly Fe^{3+}, the quantity of C necessary for completely (100%) reducing Fe_2O_3 by the direct reduction reaction of formula (1) is 180 to 210 kg. If the fixed C in the coke fines, which is a typical carbonaceous material, is 88% by mass, the quantity of coke fines necessary for completely reducing Fe_2O_3 becomes 205 to 239 kg/t-iron ore. Since the actual agglomerated particles require the reduction degree of about 50% or more, the necessary quantity of coke fines is about 100 kg/t-iron ore or more, or 10% by mass or more. A preferable content of metallic Fe in the agglomerated particles is 30% by mass. Since the reduction degree at that content is about 60%, the necessary quantity of carbonaceous material (coke fines) is 123 to 143 kg/t-iron ore. If 1.2 to 1.3 times the theoretical quantity is required, a preferable range of carbonaceous material content becomes about 15 to 19% by mass. If the carbonaceous material content exceeds 20% by mass, excessive fusion likely occurs, thus the upper limit of the content of carbonaceous material is specified to 20% by mass. Although coke fines are suitable for the carbonaceous material, other carbonaceous materials such as anthracite or powder collected in the coke-cooling apparatus may be applied.

[0082] Iron ores normally contain SiO_2 as gangue in amounts approximately from 1 to 5% by mass, and contain Al_2O_3 by amount approximately from 1 to 2.5% bymass, while the CaO-based auxiliary raw material contains very little gangue. The main components of ash in the coke fines as the carbonaceous material are SiO_2 and Al_2O_3. Consequently, when the sinter is manufactured by sintering solely iron ore and carbonaceous material, the slag becomes a FeO-SiO_2-based slag composed of FeO produced by reducing Fe_2O_3 and of SiO_2, or what is called the fayalite. The fayalite is extremely poor in reducing performance. Nevertheless, by the addition of CaO-based auxiliary raw material, a calcium-ferrite-based slag is formed to improve the reducing performance. Furthermore, fayalite has a function of aggregate or binder to maintain the strength of the agglomerated particles of CaO-based auxiliary raw material. Therefore, it is preferable for the agglomerated particles to contain a CaO-based auxiliary raw material so as the ratio of CaO to SiO_2 to become 1 or more, more preferably larger than 1.5, excluding the ignition loss of the agglomerated particles. On the other hand, since the CaO-based auxiliary raw material likely induces generation of low melting point melt, when the melt is generated in a large quantity, the particles may be excessively fused not to remain their shape. Accordingly, to prevent the excessive fusion of particles, the content of CaO-based auxiliary raw material is preferably 8% by mass or less as CaO. The CaO-based auxiliary raw material is not specifically limited if only it contains CaO component. Typical CaO-based auxiliary raw material includes limestone, burnt lime, and dolomite.

[0083] The size of raw materials structuring the agglomerated particles is preferably 8 mm or smaller for iron ore, 5 mm or smaller for carbonaceous material, and 5 mm or smaller for CaO-based auxiliary raw material. With that small size of raw material, the contact area between the iron ore and the carbonaceous material increases to effectively induce the reduction reactions, thereby attaining high density reduced particles.

[0084] For the agglomerated particles, it is preferable that at least the iron ore and carbonaceous material contain particles of 125 μm or smaller in size in amounts of 40% by mass or more as the total. By refining the iron ore and the carbonaceous material as above, the reactivity of reduction reaction between them increases to further increase the reduction degree of iron ore. The phrase "iron ore and carbonaceous material contain particles of 125 μm or smaller in size in amounts of 40% by mass or more as the total" means that the sum of the particles of iron ore and of carbonaceous material having 125 μm or smaller size becomes 40% by mass or more, on the total basis, not the separate amount of iron ore and carbonaceous material. A more preferred range is 70% by mass or more. It is preferred that not only the iron ore and the carbonaceous material, but also the CaO-based auxiliary raw material is included to specify the 40% by mass or more for 125 μm or smaller particles as the total particle, and 70% by mass or more is further preferable.

[0085] The size of agglomerated particles is preferably 10 cm^3 or smaller. Since the reduction reaction is endothermic, the reaction heat is supplied by the coke combustion heat during the manufacture of sinter. If, however, the size of the particles for manufacturing reduced iron is excessively large, the heat cannot be supplied to inner portion of the particle, which likely leaves unreacted zone behind. For a particle having 10 cm^3 of volume, the diameter thereof is 26.8 mm, which diameter is a limit from the point of heat transfer. By refining the size of particles to 10 cm^3 or smaller, the reduction reaction sufficiently proceeds, and the effect of improving permeation of raw material layer is attained. If, however, the size of particles for manufacturing reduced iron becomes smaller than 0.065 cm^3, (equivalent to a sphere of 5 mm in diameter), the particles become difficult to function the permeation effect. Therefore, the size thereof is preferably in a range from 0.065 to 10 cm^3. When the effect of improving the permeation is further emphasized, the size thereof is preferably 0.3 cm^3 or more. From the point of heat transfer, 6 cm^3 ore smaller is preferred.

[0086] The agglomerated particles are prepared by compression-agglomerating of iron ore and carbonaceous material, or iron ore, carbonaceous material, and CaO-based auxiliary raw material in a roll-agglomerating machine or the like.

The agglomerating by roll-agglomerating machine is classified to briquetting and compacting. As for the briquetting, two rolls, each having plurality of concavities on the surface as the mother mold for agglomerated particles, are arranged so as to mating with each other while rotating at an equal speed. The raw materials are charged between the rotating rolls to continuously obtain the briquettes having a specified shape of agglomerated particles. For the compacting, two rolls having no concavities thereon are rotated at equal speed with each other to obtain a plate-shaped form, and then the plate is pulverized to obtain the agglomerated particles. In the latter case, the above-raw materials are further mixed with water and, at need, a binder at an adequate quantity to mix them together, which mixture is then subjected to compression-agglomerating.

[0087] The compression pressure for making the agglomerated particles is preferably 980 kN/m or more. That level of compression pressure gives sufficient strength to the agglomerated particles. An experiment to prove that level of strength was given, which is described below. To iron ore having 8 mm or smaller size, coke fines (-5 mm) was added in amounts of, (not included in total), 20% by mass, and further added water in amounts of, (not included in total), 3% and binder (aqueous solution of 40% by mass of alpha-starch) in amounts of, (not included in total), 1.4% by mass. Almond-shaped briquettes having 35 mm in length, 25 mm in width, and 16 mm in thickness were prepared by varying the agglomerating pressure in a range from 245 to 1470 kN/m. With each 20 kg of briquettes prepared under the respective agglomerating pressures, drop test was conducted at 2 meter height and 25 times of repetition. The defect rate of +5 mm size briquettes was determined. The result is given in Fig. 7. As seen in the figure, favorable result is obtained at 980 kN/m or larger compression pressure. The defect rate saturates at or larger than 980 kN/m. The [2 m x 25 times = 50 m] is equivalent to the drop distance at relay point of conveyers in the transfer line.

[0088] The residual portion of the raw material layer adopts, similar to the first embodiment, the quasi-particles used for ordinary sinter. That is, the raw materials for sintering composed mainly of iron ore, carbonaceous material, and CaO-based auxiliary raw material are agglomerated by tumbling-granulation using drum mixer, disk pelletizer, and the like. In this case, the iron ore adopts ordinary fine iron ore, and the carbonaceous material adopts coke fines, and the CaO-based auxiliary raw material adopts limestone or burnt lime. A preferable mixing ratio is, for 100% by mass of iron ore and CaO-based auxiliary raw material, 4 to 6% by mass of carbonaceous material, (not including in total). A preferable range of CaO-based auxiliary raw material content is about 4 to about 10% by mass, (including in total), to the sum of iron ore and CaO-based auxiliary raw material.

[0089] Generally the sintering machine adopts, similar to the first embodiment,bottom-suctiontype endlessmobile sinteringmachine. That type of sintering machine has an endless traveling grate, on which grate the particles for manufacturing reduced iron and the ordinary quasi-particles are supplied to form the raw material layer. The raw material layer is continuously sintered to manufacture the semi-reduced sinter of the second embodiment.

[0090] Examples of method for manufacturing the semi-reduced sinter according to the second embodiment are described below.

[0091] Figure 8 shows a schematic flowchart of an example of facilities for the method of manufacturing semi-reduced sinter according to the second embodiment. The facilities have a agglomerated particle manufacturing apparatus 100, a quasi-particlesmanufacturing apparatus 200, and a bottom-suction type endless mobile sintering machine 300.

[0092] The agglomerated particle manufacturing apparatus 100 has a group of raw material hoppers 101 which can supply iron ore, carbonaceous material, CaO-based auxiliary raw material, and the like, an agitator 102 which mixes raw materials and a binder (such as starch, tar, and molasses), and a roll-agglomerating machine 103 which forms agglomerated particles from the mixture. The raw materials come from the group of raw material hoppers 101 are fed to the agitator 102 via the respective conveyers 104 and 105. The mixture after agitated by the agitator 102 is supplied to the roll-agglomerating machine 103 via a conveyer 106. The agglomerated particles manufactured by the roll-agglomerating machine 103 are transferred by a conveyer 107 to a conveyer 401 which transfers the agglomerated particles to the sintering machine 300.

[0093] The quasi-particles manufacturing apparatus 200 has a group of rawmaterials hoppers 201 which can supply iron ore, carbonaceous material, CaO-based auxiliary raw material, and the like, a mixing and humidifying apparatus (drum) 202 which mixes these raw materials and humidify them by adding water thereto, and a granulating machine (drum) 203 which granulates the raw materials. The raw materials coming from the group of raw materials hoppers 201 are transferred to the mixing and humidifying apparatus (drum) 202 via the respective conveyers 204 and 205. The mixture discharged from the mixing and humidifying apparatus (drum) 202 is fed to the granulating machine (drum) 203 by a conveyer 206. The quasi-particles manufactured in the granulating machine (drum) 203 are transferred by a conveyer 207 to a conveyer 401 to transport them to the sintering machine 300.

[0094] By the above handling, the agglomerated particles and the quasi-particles are mixed together on a conveyer 401. The mixture on the conveyer 401 is transferred onto a conveyer 402 to send to the sintering machine 300.

[0095] The bottom-suction type endless mobile sintering machine 300 has an endless traveling grate 311, on which grate a mixture of the ordinary quasi-particles and the agglomerated particles are supplied by an adequate charging system, thus forming a raw material layer 313.

[0096] An ignition furnace 312 is located in the moving course of the traveling grate 311. The quasi-particles on the traveling grate 311 are ignited when they passes under the ignition furnace 312 to begin the sintering of the raw material layer 313 to form a sintered cake 313a. At exit of the traveling grate 311, a crusher (not shown) is positioned. The sinter cake from the traveling grate 311 is crushed by the crusher, and is fed to a conveyer 314, and is finally charged to the blast furnace.

[0097] At directly beneath the traveling grate 311, pluralities of blast boxes 315 are arranged along the traveling direction of the traveling grate 311. To each of the blast boxes 315, a vertical duct 316 is connected. Through the blast boxes 315 and the vertical ducts 316, the gas above the raw material layer 313 is sucked via the raw material layer 313.

[0098] The vertical ducts 316 are connected to a horizontally positioned main flue gas duct 317, and the flue gas is discharged there through. The main flue gas duct 317 is connected to an electric precipitator 320 and a main blower 321. The main blower 321 sucks the gas above the raw material layer 313 to discharge the gas from a stack 322 via the blast boxes 315, the vertical ducts 316, the main flue gas duct 317, and the electric precipitator 320, and the like.

[0099] There may be installed a gas supply hood at downstream side of the ignition furnace 312 above the raw material layer 313, and may be installed a flue gas circulation duct branched from the vertical ducts 316 and connecting to the hood for circulating the flue gas. That type of flue gas circulation method allows easy and adequate control of atmosphere (oxygen concentration) in the raw material layer 313, which provides further effective generation of metallic Fe and prevention of re-oxidation.

[0100] With the facilities having that configuration, the agglomerated particles are manufactured by the agglomerated particle manufacturing apparatus 100, and the quasi-particles are manufactured by the pseudo-particle manufacturing apparatus 200, and then both of these particles are mixed together on the conveyer 401 by an adequate means. The mixture is fed onto the traveling grate 311 of the bottom-suction type endless mobile sintering machine 300 via the conveyer 402, thereby forming the raw material layer 313. In that case, the raw material layer 313 is, as illustrated in Fig. 9, in a state that the agglomerated particles 332 are dispersed in a matrix 331 of the ordinary quasi-particles.

[0101] By igniting the surface of the raw material layer 313 using the ignition furnace 312, the raw material layer 313 is sintered while sucking the gas downward via the blast boxes 315 to sinter the quasi-particles structuring the raw material layer 313 to obtain the sinter. Thus obtained sinter cake from the traveling grate 311, and the dropped sinter is crushed by the crusher located at exit of the grate, which is then fed to the conveyer 314 and further to the blast furnace. In this case, as described above, inside the particle for manufacturing reduced iron 332 in the raw material layer 313, direct reduction occurs by the iron ore and the carbonaceous material, thus providing the semi-reduced sinter in which the iron ore is partially reduced to metallic Fe in a part.

Third embodiment

[0102] In the third embodiment, similar to the first and second embodiments, the manufacture of sinter is conducted by raising the temperature of raw material layer to about 1400°C, and by extending the retention time at 1200°C or higher temperatures to make the direct reduction predominant. To do this, on manufacturing the semi-reduced sinter by charging iron ore, carbonaceous material, and auxiliary raw material as the raw materials for sintering into the sintering machine, thus sintering to reduce a part of the iron ore by the carbonaceous material, a part of iron ore and a part of carbonaceous material in the raw materials for sintering, or a part of iron ore, a part of carbonaceous material, and a part of auxiliary raw material in the raw materials for sintering are preliminarily compression-agglomerated (also called as pressure-agglomerating) to prepare compression-agglomerated particles, while the residual amount of the raw materials for sintering is formed into granules, and then mixing them together to sinter.

[0103] As described above, a part of iron ore and a part of carbonaceous material in the raw materials for sintering, or a part of iron ore, a part of carbonaceous material, and a part of auxiliary raw material in the raw materials for sintering are compression-agglomerated to consolidate the iron ore and the carbonaceous material, thus to increase the contact area there between. By charging thus prepared compression-agglomerated particles as a part of the raw materials into the sintering machine, the reduction of sinter is enhanced, and the reduction degree and the content of metallic Fe in the sinter can be increased. As a result, use of that kind of sinter in the blast furnace decreases the use amount of reducing material (reducing material ratio) as the total of manufacturing process, and further decreases the CO_2 emissions from the manufacturing process, similar to the first embodiment.

[0104] Within the compression-agglomerated particle, the raw materials become dense resulting from the compression. Accordingly, after the compression-agglomerated particle becomes the sinter, the raw materials in the sinter are in dense state compared with the granule. In this state, a portion which becomes to a dense state by the compression-agglomerating is shielded from outer atmosphere, thus the oxidation of metallic Fe generated by the direct reduction is suppressed.

[0105] That is, by manufacturing the semi-reduced sinter by charging a compression-agglomerated particles, prepared by compression-agglomerating of, a part of iron ore and a part of carbonaceous material in the raw materials for sintering, or a part of iron ore, a part of carbonaceous material, and a part of auxiliary raw material in the raw materials for sintering, together with the granules of raw materials for sintering into the sintering machine, high reduction degree and high metallic Fe content are attained.

[0106] According to the third embodiment, the iron ore is preferably a fine iron ore having 8 mm or smaller particle size in view of maintaining favorable reactivity. The carbonaceous material is preferably a coke fines having 5 mm or smaller particle size, and more preferably a coke fines having 3 mm or smaller particle size. The auxiliary raw material is a CaO-based auxiliary raw material such as limestone and burnt lime.

[0107] The composition of core part (part excluding the setting material described later) of the granule and the composition of compression-agglomerated particle are preferably the ones containing 10 to 20% by mass of carbonaceous material as the reducing material to 100% by mass of iron ore and auxiliary raw material. The content of auxiliary raw material is preferably adjusted so as the basicity (CaO/SiO_2) in the core part to become 1 or more, and specifically 4 to 10% by mass is preferred. The core part of the granule may be a single layer or a two-layer structure which is prepared by, for example, forming an outer layer of iron ore on the inner layer of iron ore, auxiliary raw material, and carbonaceous material. The granule is composed of the core part coated by carbonaceous material as the fuel (setting material) thereon. A compression-agglomerated particle which is coated by carbonaceous material thereon may be applied. The coating carbonaceous material is preferably in amounts of 1 to 4% by mass to 100% by mass of total of iron ore and auxiliary raw material.

[0108] The specification of carbonaceous material quantity in the core part as 10 to 20% by mass to 100% by mass of iron ore and auxiliary raw material is given because that range allows effectively reducing the iron ore in the quasi-particles while leaving very little unreacted coke behind. By selecting the quantity of carbonaceous material to coat the core part to 1 to 4% by mass to 100% by mass of total of iron ore and auxiliary raw material, the sintering of iron ore is adequately progressed.

[0109] In the third embodiment, the compression-agglomerated particles are prepared by compression-agglomerating of the raw materials using a roll-agglomerating machine into briquettes having a specified size, or by agglomerating of the raw materials by a roll-agglomerating machine into plate shape, sheet shape, or rod shape, followed by pulverizing to a specified size, which prepared compression-agglomerated particles have 39. 2 N or higher crushing strength for a single particle.

[0110] The compression-agglomerated particle preferably has a volume of 10 cm^3 or smaller. With that range of volume, optimum permeability is attained. If the size of the compression-agglomerated particle exceeds the volume of 10 cm^3, the permeability likely becomes excessive, and the non-sintered part likely appears. If, however, the size of the compression-agglomerated particle is smaller than 0.065 cm^3, the particle becomes smaller than surrounding granules, the particle assimilates and fuses with granules during sintering stage, thus failing to sufficiently increase the reduction degree. Therefore, the volume of the compression-agglomerated particle is more preferably in a range from 0.065 to 10 cm^3. Better permeation is available by adjusting the width of thinnest part of the compression-agglomerated particle to a range from 8 mm to 20 mm.

[0111] It is preferable for the iron ore and the carbonaceous material, as the raw materials structuring the compression-agglomerated particle, to contain the particles having 125 μm or smaller size in amounts of 40% by mass or more, as the total. By refining the iron ore and the carbonaceous material as above, the reactivity of reduction reaction between them increases to further increase the reduction degree of iron ore. The phrase "iron ore and carbonaceous material of 125 μm or smaller in size in amounts of 40% by mass or more as the total" means that the sum of the particles of iron ore and of carbonaceous material having 125 μm or smaller size becomes 40% by mass or more, on the total basis, not the separate amount of iron ore and carbonaceous material. More preferred range is 70% by mass or more. It is preferred that not only the iron ore and the carbonaceous material, but also the CaO-based auxiliary raw material are included to specify the 40% by mass or more for 125 μm or smaller particles as the total, and 70% by mass or more is further preferable.

[0112] Similar to the first and second embodiments, the sintering machine is preferably a bottom-suction type endless mobile sintering machine. In that case, quasi-particles which are the granules of raw materials for sintering and compression-agglomerated particles are supplied onto the endless traveling grate to form the raw material layer thereon. The raw material layer is ignited by the ignition furnace located in the moving route of the traveling grate, thus conducting the sintering of raw material layer. At directly beneath the traveling grate, pluralities of blast boxes are arranged to suck gas above the raw material layer downward through the individual blast boxes during sintering stage.

[0113] On charging the compression-agglomerated particles into the sintering machine, it is preferable to charge them to the lower three-quarter zone of the raw material layer in the sintering machine. In a zone close to the surface of raw material layer, the temperature during sintering is relatively low, and the holding time at high temperatures is short. Since the charge of compression-agglomerated particles into the surface zone improves the permeation, the tendency further increases, thereby ending the reduction reaction of agglomerated particles insufficiently compared with the condition of lower three-quarter zone. Charging he agglomerated particles to the lower three-quarter zone may be done as illustrated in Fig. 10, for example. That is, the quasi-particles 71 as the granules are supplied from above the raw material layer using a transfer means such as belt conveyer 79, while the compression-agglomerated particles 74 are supplied to an adequate position on the raw material layer 72 from a hopper 77 for compression-agglomerated particles via a chute 73 adjustable in the charging position. Figure 10 shows a bed ore 75, a sintering pallet 76, a metering feeder 78 for the compression-agglomerated particles, and a segregation feed unit 80.

[0114] The mixing ratio of the compression-agglomerated particles to the granules being charged to the sintering machine, or the mixing ratio of compression-agglomerated particles in the raw material layer, is preferably in a range from 5 to 50% by mass. If the mixing ratio exceeds 50% by mass, or if the quantity of the compression-agglomerated particles becomes equal or larger than the quantity of the granules, the permeability likely become excessive, which likely induces un-sintered portion. If the mixing ratio is less than 5% by mass, the effect of mixed charge of compression-agglomerated particles becomes small. A preferable range of the mixing ratio is from 10 to 50% by mass.

Fourth embodiment

[0115] In the fourth embodiment, similar to the first to third embodiments, the manufacture of sinter is conducted by raising the temperature of raw material layer to about 1400°C, and by extending the retention time at 1200°C or higher temperatures to make the direct reduction predominant. To do this, on manufacturing the semi-reduced sinter by charging iron ore, carbonaceous material, and auxiliary raw material as the raw materials for sintering into the sintering machine to sinter them, thus reducing a part of the iron ore by the carbonaceous material, a part of iron ore, a part of carbonaceous material, and a part of auxiliary raw material, in the raw materials for sintering are uniformly mixed preliminarily together, then the mixture is compression-agglomerated to prepare compression-agglomerated particles, while the residual amount of the raw materials for sintering is formed into granules, and then mixing them together to sinter.

[0116] As described above, a part of iron ore, a part of carbonaceous material, and a part of auxiliary raw material in the raw materials for sintering are compression-agglomerated to consolidate the iron ore and the carbonaceous material, thus to increase the contact area therebetween. By charging thus prepared compression-agglomerated particles as a part of the raw materials to the sintering machine, the reduction of sinter is enhanced.

[0117] Within the compression-agglomerated particle, the raw materials become dense resulting by compression. Accordingly, after the compression-agglomerated particles become the sinter, the raw materials in the sinter are in dense state compared with the granules. In this state, a portion in a dense state by the compression-agglomerating is shielded from outer atmosphere, thus the oxidation of metallic Fe generated by the direct reduction is suppressed.

[0118] As described above, a part of iron ore, a part of carbonaceous material, and a part of auxiliary raw material in the raw materials for sintering are compression-agglomerated to prepare the compression-agglomerated particles, which agglomerated particles are then charged into the sintering machine together with the granules as the raw material for sintering to manufacture the semi-reduced sinter. Thus, the high reduction degree and the large content of metallic Fe are attained. As a result, use of that kind of sinter in the blast furnace decreases the use amount of reducing material (reducing material ratio) as the total of manufacturing process, and further decreases the CO_2 emissions from the manufacturing process, similar to the first embodiment.

[0119] According to the fourth embodiment, similar to the third embodiment, the iron ore is preferably a fine iron ore containing particles having 8 mm or smaller sizes in amounts of 80% or more in view of maintaining favorable reactivity. The carbonaceous material is preferably a coke fines containing particles having 5 mm or smaller size in amounts of 80% or more, and more preferably a coke fines containing particles having sizes of 3 mm or smaller size in amounts of 80% or more. The auxiliary raw material preferably contains a CaO source. The CaO source includes limestone and burnt lime.

[0120] In the fourth embodiment, similar to the third embodiment, the compression-agglomerated particles are prepared by compression-agglomerating the raw materials using a roll-agglomerating machine into briquettes having a specified shape, or by agglomerating of the raw materials by a roll-agglomerating machine into plate shape, sheet shape, or rod shape, followed by pulverizing to a specified size similar to the third embodiment, which prepared particles have 39.2 N or higher crushing strength for a single particle.

[0121] In the fourth embodiment, similar to the third embodiment, the compression-agglomerated particle preferably has a volume of 10 cm^3 or smaller in view of attaining optimum permeability and of reactivity. If, however, the size of the compression-agglomerated particle is smaller than 0.065 cm^3, the particle assimilates and fuses with granules during sintering stage, thus failing to sufficiently increase the reduction degree. Therefore, the volume of the compression-agglomerated particle is more preferably in a range from 0.065 to 10 cm^3. Better permeation is available by adjusting the width of thinnest part of the compression-agglomerated particle to a range from 8 to 20 mm.

[0122] Similar to the third embodiment, it is preferable for the iron ore and the carbonaceous material, as the raw materials structuring the compression-agglomerated particles, to contain the particles having 125 μm or smaller size in amounts of 40% by mass or more, as the total. By refining the iron ore and the carbonaceous material as above, the reactivity of reduction reaction between them increases to further increase the reduction degree of iron ore. The phrase "iron ore and carbonaceous material contains particles having 125 μm or smaller sizes in amounts of 40% by mass or more as the total" means that the sum of the particles of iron ore and of carbonaceous material having 125 μm or smaller size becomes 40% by mass or more, on the total basis, not the separate amount of iron ore and carbonaceous material. More preferred range is 70% by mass or more. It is preferred that not only the iron ore and the carbonaceous material, but also the CaO-based auxiliary raw material are included to specify the 40% by mass or more for 125 μm or smaller particles as the total agglomerated particles, and 70% by mass or more is further preferable.

[0123] When a part or total of CaO source as the auxiliary raw material adopts burnt lime, and when the compression-agglomerated particle contains burnt lime as the auxiliary raw material, the compression-agglomerated particle is preferably prepared without using binder. With the use of burnt lime as the CaO source in the compression-agglomerated particle, the burnt lime functions as both the CaO source and the binder. Therefore, on manufacturing the compression-agglomerated particles, agglomerating is conducted without using organic binder which is applied in general preparation process. As a result, cost is decreased by eliminating the binder which is normally used in forming the compression-agglomerated particles.

[0124] The CaO source used as the auxiliary raw material is preferably mixed in larger quantity in the granule than in the compression-agglomerated particle. Specifically, it is preferable that the quantity of CaO source in the compression-agglomerated particle is 40 to 70% by mass to the quantity of CaO source in the granule. Since the CaO source is added generally to generate melt necessary for sintering. Since, however, the compression-agglomerated particle according to the present invention is compressed so as the reduction reaction to effectively occur between the iron ore and the carbonaceous material, the quantity of CaO source is not required so large quantity as the quantity of CaO source in the residual granules, and 40 to 70% by mass to the quantity of CaO source in the residual granules is sufficient. Even with that decreased amount of CaO source in the compression-agglomerated particles, the quality of sinter can be adequately maintained, the reduction degree of the compression-agglomerated particles rather increases, and the cost decreases by the decrease in the quantity of CaO source.

[0125] The mixing ratio of the CaO-based auxiliary raw material in the compression-agglomerated particle is preferably to have the ratio of CaO to SiO_2 to 1 or more in the compression-agglomerated particle excluding the ignition loss. With that range of mixing ratio, the CaO-based auxiliary raw material performs effectively the function of aggregate to keep the strength of the compression-agglomerated particle or the function of preventing the generation of irreducible FeO-SiO_2 slag as the fusion structure of sinter.

[0126] The composition of core part of granule and the composition of compression-agglomerated particle are preferably the ones containing 10 to 20% by mass of carbonaceous material as the reducing material to 100% by mass of iron ore and auxiliary raw material. The content of auxiliary raw material is preferably adjusted so as the basicity (CaO/SiO_2) in the core part to become 1 or more, and specifically 4 to 10% by mass is preferred. The core part of the granule may be a single layer or a two-layer structure, for example, which is prepared by forming an outer layer of iron ore on the inner layer of iron ore, auxiliary raw material, and carbonaceous material. The granule is composed of the core part coated by carbonaceous material as the fuel (setting material) thereon. A compression-agglomerated particle which is coated by carbonaceous material thereon may be applied. The coating carbonaceous material is preferably in amounts of 1 to 4% by mass to 100%' by mass of total of iron ore and auxiliary raw material.

[0127] The specification of carbonaceous material quantity in the core part as 10 to 20% by mass to 100% by mass of iron ore and auxiliary raw material is given because that range allows effectively reducing the iron ore in the quasi-particles while leaving very little unreacted coke behind. By selecting the quantity of carbonaceous material to coat the core part to 1 to 4% by mass to 100% by mass of total of iron ore and auxiliary raw material, the sintering of iron ore is adequately progressed.

[0128] Similar to the first to third embodiments, the sintering machine is preferably a bottom-suction type endless mobile sintering machine. In that case, the quasi-particles which are the granules of raw materials for sintering and the compression-agglomerated particles are supplied onto the endless traveling grate to form the raw material layer thereon. The raw material layer is ignited by the ignition furnace located in the moving route of the traveling grate, thus conducting the sintering of raw material layer. At directly beneath the traveling grate, pluralities of blast boxes are arranged to suck gas above the raw material layer downward through the individual blast boxes during sintering stage.

[0129] Charge of raw materials for sintering into the sintering machine may be done after mixing the compression-agglomerated particles with the granules, or may be done separately, followed by mixing on forming the raw material layer. When the charge of compression-agglomerated particles gives a distribution, it is preferred to adopt separate charge using, for example, an apparatus illustrated in Fig. 10.

[0130] On charging the compression-agglomerated particles into the sintering machine, it is preferable to charge them to the lower three-quarter zone of the rawmaterial layer in the sintering machine. In a zone close to the surface of raw material layer, the temperature during sintering is relatively low, and the holding time at high temperatures is short. Since the charge of compression-agglomeratedparticles into the surface zone improves the permeation, the tendency further increases, thereby ending the reduction reaction of agglomerated particles insufficiently compared with the condition of lower three-quarter zone.

[0131] The mixing ratio of the compression-agglomerated particles to the granules being charged into the sintering machine, or the mixing ratio of compression-agglomerated particles in the raw material layer, is preferably in a range from 5 to 50% by mass. If the mixing ratio exceeds 50% by mass, or if the quantity of the compression-agglomerated particles becomes equal or larger than the quantity of the granules, the permeability likely become excessive, which likely induces un-sintered portion. If the mixing ratio is less than 5% by mass, the effect of mixed charge of compression-agglomerated particles becomes small. A preferable range of the mixing ratio is from 10 to 50% by mass.

Examples

[0132] The following is the description about the examples of the present invention referring to comparative examples.

1. First Example

[0133] The First Example corresponds to the above-described first embodiment, including the following Comparative Example 1, Examples 1 to 4, Comparative Example 2, and Examples 5 to 9.

(Comparative Example 1)

[0134] Raw materials mixture for sintering was prepared by adding coke fines in an amount of, (not included in total), 4.4% by mass to the raw materials prepared by mixing: fine iron ore having particle sizes of 8 mm or smaller and average particle size of 2.3 mm, and containing 3.5% by mass of SiO_2; recycle dust; serpentine having particle sizes of 3 mm or smaller; limestone having particle sizes of 5 mm or smaller; burnt lime as binder; and sintered powder of -5 mm sieve, at the respective mixing ratios given in Table 1. Thus prepared mixed rawmaterials for sintering were blended in a drum mixer for 3 minutes while humidifying the contents. After that, the mixture was granulated to ordinary quasi-particles having an average size of 4.0 mm for 3 minutes. The quasi-particles were put in a batch type sinter pot having 300 mm in diameter to a specific layer thickness. The applied recycle dust was blast furnace dust, mill scale, and in-house recovered dust, respectively, (same is applied to the following examples). The average particle size is the arithmetic mean particle diameter of mass basis, (same is applied to the following examples). The arithmetic mean particle diameter D is derived by sizing the particles into a plurality of particle diameter ranges, and is expressed by the following formula

$$D = \Sigma(W \cdot d)/\Sigma W$$

where, d is the representative particle diameter within the respective particle size ranges (median value in the range), and W is the total mass of particles in the particle size range.

[0135] The charge quantity of the quasi-particles was 45 kg. The surface of the packed raw material layer was ignited by heating the surface for 2 minutes using an ignition burner with propane gas fuel, while sucking the atmosphere in the sintering furnace under a suction pressure of -2 kPa. Then, the suction pressure was increased to -10 kPa, thus conducting sintering of the raw material layer to manufacture the sinter. The composition of the sinter is given in Table 2. The observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 3. As seen in Table 3, although the productivity, defect rate of products at or larger than 5 mm in size, and shutter strength were within allowable range, the obtained sinter did not contain metallic Fe.

(Example 1)

[0136] There were mixed fine iron ore having particle sizes of 8 mmor smaller and average particle size of 2.3 mm, and carbonaceous material (coke fines) in an amount of, (not included in total), 10% by mass to the fine iron ore, in a drum mixer for 3 minutes while humidifying the contents. Then, the mixture was agglomerated by a disk pelletizer having 1300 mm in diameter and 150 mm in depth for 5 minutes while humidifying the contents. The pellets were screened by a 5 mm opening sieve to obtain particles for manufacturing reduced iron having diameters of 5 to 12 mm. A 13.5 kg of thus obtained particles for manufacturing reduced iron and 31.5 kg of quasi-particles manufactured under the same condition to that of Comparative Example 1 were mixed in a drum mixer for 1 minute. The mixture was charged in the batch type sinter pot having a diameter of 300 mm, used in Comparative Example 1, to a specific thickness layer. The contents were sintered under the same condition to that of Comparative Example 1. Similar to Comparative Example 1, the composition of the sinter is given in Table 2, and the observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 3. As shown in Table 3, the obtained sinter showed the content of metallic Fe as high as 8.5% by mass, and also gave favorable productivity, defect rate of products at or larger than 5 mm in size, and shutter strength.

(Example 2)

[0137] There were mixed 13.5 kg of particles for manufacturing reduced iron, manufactured by the same method to that of Example 1, and 31.5 kg of quasi-particles manufactured under the same condition as that of Comparative Example 1, similar to Example 1, except for adopting the mixing ratio of the carbonaceous material in the particles for manufacturing reduced iron in an amount of, (not included in total), 15% by mass to the fine iron ore. The mixture was then charged into the batch type sintering pot having 300 mm in diameter, used in Comparative Example 1, to a specific layer thickness. The contents were sintered under the condition same to that of Comparative Example 1. Similar to Comparative Example 1, the composition of the sinter is given in Table 2, and the observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 3. As shown in Table 3, the obtained sinter showed the content of metallic Fe as high as 15.5% by mass, and also gave favorable productivity, defect rate of products at or larger than 5 mm in size, and shutter strength.

(Example 3)

[0138] There were mixed 13.5 kg of particles for manufacturing reduced iron, manufactured by the same method to that of Example 1, and 31.5 kg of quasi-particles manufactured under the same condition to that of Comparative Example 1, similar to Example 1, except for adopting the mixing ratio of the carbonaceous material in the particles for manufacturing reduced iron in an amount of, (not included in total), 20% by mass to the fine iron ore. The mixture was then charged into the batch type sintering pot having 300 mm in diameter, used in Comparative Example 1, to a specific layer thickness. The contents were sintered under the condition same to that of Comparative Example 1. Similar to Comparative Example 1, the composition of the sinter is given in Table 2, and the observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 3. As shown in Table 3, although the obtained sinter showed the content of metallic Fe as high as 19.7% by mass, the productivity decreased to some extent, giving 1.41 t/m^2/h because there was appeared excess fusion state in a part of peripheral area of particles for manufacturing reduced iron. Both the defect rate of products at or larger than 5 mm in size and the shutter strength were favorable.

(Example 4)

[0139] There were mixed 13.5 kg of particles for manufacturing reduced iron, manufactured by the same method to that of Example 1, and 31.5 kg of quasi-particles manufactured under the same condition as that of Comparative Example 1, similar to Example 1, except for adopting the mixing ratio of the carbonaceous material in the particles for manufacturing reduced iron in an amount of, (not included in total), 5% by mass to the fine iron ore. The mixture was then charged into the batch type sintering pot having 300 mm in diameter, used in Comparative Example 1, to a specific layer thickness. The contents were sintered under the condition same to that of Comparative Example 1. Similar to Comparative Example 1, the composition of the sinter is given in Table 2, and the observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 3. As shown in Table 3, although the obtained sinter showed the content of metallic Fe of 0.8% by mass, which level was lower than other examples, the effect to decrease the reducing material ratio in blast furnace was lower than that in other examples. Although the productivity was high, both the defect rate of products at or larger than 5 mm in size and shutter strength were lower than those in other examples.

(Comparative Example 2)

[0140] Only the particles for manufacturing reduced iron manufactured by the same method to that of Example 1 were charged into the batch type sintering pot having 300 mm in diameter, used in Example 1, to a specific layer thickness, except for adopting the mixing ratio of the carbonaceous material in the particles for manufacturing reduced iron in an amount of, (not included in total), 20% by mass to the fine iron ore. The contents were sintered under the condition same to that of Example 1. Similar to Comparative Example 1, the composition of the sinter is given in Table 2, and the observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 3. As shown in Table 3, although the obtained sinter showed the content of metallic Fe as high as 15.5% by mass, significant excess fusion appeared at 3 to 5 cm below the top of the bed in the batch type sinter pot, while leaving large amount of un-sintered particle in the middle to low layers. Thus the productivity and the defect rate of products at or larger than 5 mm in size significantly decreased.

(Example 5)

[0141] There were mixed 13.5 kg of particles for manufacturing reduced iron, manufactured by the same method to that of Example 1, and 31.5 kg of quasi-particles manufactured under the same condition to that of Comparative Example

1, similar to Example 1, except that the particles for manufacturing reduced iron was prepared by mixing burnt lime in an amount of, (included in total), 6% by mass to the fine iron ore, and carbonaceous material in an amount of, (not included in total), 15% by mass to the fine iron ore. The mixture was then charged into the batch type sintering pot having 300 mm in diameter, used in Comparative Example 1, to a specific layer thickness. The contents were sintered under the condition same to that of Comparative Example 1. Similar to Comparative Example 1, the composition of the sinter is given in Table 2, and the observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 3. As shown in Table 3, the obtained sinter showed the content of metallic Fe as high as 17.9% by mass, and both the productivity and the defect rate of products at or larger than 5 mm in size were within allowable range, further the shutter strength was at a favorable level.

(Example 6)

[0142] To fine iron ore, there were added limestone having particle sizes of 5 mm or smaller in an amount of, (included in total), 8% bymass, and carbonaceous material in an amount of, (not included in total), 15% by mass. The mixture was blended in a Henshell mixer for 5 minutes while adding starch and water thereto. The mixture was then fed to a double-roll agglomeratingmachine having 400 mm in diameter for each drum, and having almond-shape concavities having sizes of 16.2 mm x 12 mm x 8.8 mm on the surface of the roll to manufacture briquettes having 1 cm^3 of volume under 20 tons of agglomerating pressure. Thus prepared briquettes were adopted as the particles for manufacturing reduced iron. A 13. 5 kg of thus prepared particles for manufacturing reduced iron, and 31.5 kg of quasi-particles manufactured under the same condition to that in Comparative Example 1 were mixed together as in the case of Example 1. The mixture was charged into the batch type sinter pot, used in Comparative Example 1, having 300 mm in diameter to a specific layer thickness. The layer was sintered under the same condition to that of Comparative Example 1. Similar to Comparative Example 1, the composition of the sinter is given in Table 2, and the observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 3. As shown in Table 3, the obtained sinter showed the content of metallic Fe as high as 21.2% by mass, and also gave favorable productivity, defect rate of products at or larger than 5 mm in size, and shutter strength. In particular the shutter strength gave highest value among examples.

(Example 7)

[0143] The ingredients were mixed together similar to Example 1 except that the mixing ratio of burnt lime in the particles for manufacturing reduced iron was 3.8% by mass, (included in total), to the fine iron ore and that the mixing ratio of carbonaceous material was in an amount of 15% by mass, (not included in total), to the fine iron ore. The mixture was blended similar to Example 1, which was then charged into the batch type sinter pot having 300 mm in diameter, used in Comparative Example 1, to a specific layer thickness. The contents were sintered under the same condition to that of Comparative Example 1. Separately, only the particles for manufacturing reduced iron, prepared by the same procedure to that of Comparative Example 1, were charged into the batch type sinter pot having 300 mm in diameter to a specified thickness, thus formed raw material layer was then sintered. Similar to Comparative Example 1, the composition of the sinter is given in Table 2, and the observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 3. As shown in Table 3, the obtained sinter showed the content of metallic Fe of 5.2% by mass, and all the productivity, the defect rate of products at or larger than 5 mm in size, and the shutter strength were slightly low levels. The obtained sinter showed a trace of excess fusion.

(Example 8)

[0144] The particles for manufacturing reduced iron were prepared by the same mixing method to that of Example 1 except that the mixing ratio of carbonaceous material in the particles for manufacturing reduced ironwas 5% bymass, (not included in total), to the prudery iron ore. A 20.0 kg of thus prepared particles for manufacturing reduced iron was mixed with 25.0 kg of quasi-particles prepared under the same condition to that of Example 1. The mixture was then charged into the batch type sinter pot having 300 mm in diameter, used in Comparative Example 1, to a specific layer thickness. The contents were sintered under the condition same to that of Comparative Example 1. Similar to Comparative Example 1, the composition of the sinter is given in Table 2, and the observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 3. As shown in Table 3, the obtained sinter showed the content of metallic Fe of 2.2% by mass. All of the productivity, the defect rate of products at or larger than 5 mm in size, and the shutter strength were at favorable levels.

(Example 9)

[0145] The particles for manufacturing reduced iron were prepared by the same method to that of Example 1 except that the mixing ratio of carbonaceous material in the particles for manufacturing reduced iron was 20% by mass, (not included in total), to the fine iron ore. A 2.4 kg of thus prepared particles for manufacturing reduced iron was mixed with 42.6 kg of quasi-particles prepared under the same condition to that of Comparative Example 1. The mixture was then charged into the batch type sintering pot having 300 mm in diameter, used in Comparative Example 1, to a specific layer thickness. The contents were sintered under the condition same to that of Comparative Example 1. Similar to Comparative Example 1, the composition of the sinter is given in Table 2, and the observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 3. As shown in Table 3, the content of metallic Fe was 3.2% by mass. Although there was appeared excess fusion state in a part of peripheral area of particles for manufacturing reduced iron, all of the productivity, the defect rate of products at or larger than 5 mm in size, and the shutter strength were at favorable levels.

[0146] As described above, the Examples within the range of the present invention showed that the obtained sinter was reduced in a part, and contained metallic Fe. Consequently, use of that type of sinter in blast furnace gives decrease in the reducing material ratio in the blast furnace and decrease in the CO_2 emissions, as described above. Furthermore, it was confirmed that the productivity, the defect rate, and the shutter strength are equal or higher level than that of ordinary sinter (Comparative Example 1).

Table 1

	Material	Mixing ratio (mass%)										
		Comparative Example 1	Example 1	Example 2	Example 3	Example 4	Comparative Example 2	Example 5	Example 6	Example 7	Example 8	Example 9
Raw materials for sintering	Fine iron ore	68.0	47.6	47.6	47.6	47.6	0.0	47.6	47.6	47.6	38.1	64.6
	Blast furnace dust	1.3	0.9	0.9	0.9	0.9	0.0	0.9	0.9	0.9	0.7	1.2
	Mill scale	1.9	1.3	1.3	1.3	1.3	0.0	1.3	1.3	1.3	1.0	1.8
	In-house recovered dust	4.3	3.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	2.4	4.1
	Minus sieve sinter	9.6	6.7	6.7	6.7	6.7	0.0	6.7	6.7	6.7	5.4	9.1
	Serpentine	1.4	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	0.8	1.3
	Limestone	7.8	5.4	5.4	5.4	5.4	0.0	5.4	5.4	5.4	4.3	7.3
	Burnt lime	1.5	1.1	1.1	1.1	1.1	0.0	1.1	1.1	1.1	0.9	1.5
	Total	95.8	67.0	67.0	67.0	67.0	0.0	67.0	67.0	67.0	53.6	90.9
	Added coke fines	4.2	3.0	3.0	3.0	3.0	0.0	3.0	3.0	3.0	2.4	4.1
Particles for manufacturing reduced iron	Fine iron ore	0.0	27.3	26.1	25.0	28.5	83.3	24.5	24.0	25.1	41.8	4.2
	Burnt lime	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	1.0	0.0	0.0
	Limestone	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0
	Added coke fines	0	2.7	3.9	5.0	1.5	16.7	3.9	3.9	3.9	2.2	1.8
Basicity of particles for manufacturing reduced iron	CaO/SiO_2	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.1	0.9	0.0	0.0

Table 2

(mass %)										
	Comparative Example 1	Example 1	Example 2	Example 3	Example 4	Comparative Example 2	Example 5	Example 6	Example 7	Example 8	Example 9
Total Fe	59.3	62.1	65.0	68.1	60.3	67.9	64.6	65.2	61.8	62.2	60.4
Metallic Fe	0	8.5	15.5	19.7	0.8	23.2	21.2	17.9	5.2	2.2	3.2

Table 3

	Comparative Example 1	Example 1	Example 2	Example 3	Example 4	Comparative Example 2	Example 5	Example 6	Example 7	Example 8	Example 9
Productivity	1.42	1.45	1.44	1.41	1.46	0.63	1.42	1.44	1.40	1.48	1.43
+5mm	78.3	79.2	80.1	82.3	77.2	49.2	83.8	85.3	76.0	80.0	80.5
S.I. + 10 (%)	84.2	86.3	88.2	85.7	80.1	86.4	86.7	88.5	82.2	85.4	84.7

2. Second Example

[0147] The Second Example corresponds to the above-described second embodiment, including the following Comparative Example 11, Examples 11 to 14, Comparative Example 12, and Examples 15, and Comparative Examples 13 and 14.

(Comparative Example 11)

[0148] Raw materials mixture for sintering was prepared by adding coke fines in an amount of, (not included in total), 4.0% by mass to the raw materials prepared by mixing: fine iron ore having particle sizes of 8 mm or smaller and average particle size of 2.3 mm, and containing 3.5% by mass of SiO_2; recycle powder such as blast furnace dust and mill scale; serpentine having particle sizes of 3 mm or smaller; limestone having particle sizes of 5 mm or smaller; burnt lime and sintered powder of -5 mm sieve as the binder in an amount of Table 4, and particles of 125 μm or smaller sizes in an amount of 45% by mass. Thus prepared raw material mixtures for sintering were blended in a drum mixer for 3 minutes while humidifying the contents. After that, the mixture was granulated to ordinary quasi-particles having an average size of 4.0 mm for 3 minutes. The quasi-particles were put in a test batch type sinter pot having 300 mm in diameter to a specific layer thickness. The charge quantity of the quasi-particles was 45 kg by dry weight. The surface of the packed raw material layer was ignited by heating the surface for 2 minutes using an ignition burner with propane gas fuel, while sucking the atmosphere in the sintering furnace under a suction pressure of -2 kPa. Then, the evacuating pressure was increased to -10 kPa, thus conducting sintering of the raw material layer to manufacture the sinter. The composition of the sinter is given in Table 5. The observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 6. As seen in Table 6, although the productivity, defect rate of products at or larger than 10 mm in size, and shutter strength were within allowable range, the obtained sinter ore not contain metallic Fe.

(Example 11)

[0149] To fine iron ore similar to that of Comparative Example 11, coke fines was added by an amount of, (not included in total), 15% by mass. The mixture was blended for 3 minutes in a drum mixer while adding water to the mixture. Then the mixture was blended in a mixer equipped with an agitation screw for 2 minutes while adding an aqueous solution of 40 (mass)% α-starch to the mixture as the binder. The mixture was agglomerated to almond-shape briquettes having a size of 35 mm in length, 24 mm in width, and 16 mm in thickness, in a double-roll agglomerating machine under a compression pressure of 1470 kN/m. Thus prepared briquettes were blended with quasi-particles prepared in Comparative Example 11 by an amount of, (included in total), 10% by mass. A sample of 40 kg of the mixture was sintered in similar procedure to that of Comparative Example 11. The composition of the sinter is given in Table 5. The observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 6. As shown in Table 6, the obtained sinter showed the content of metallic Fe of 3.4% by mass, and gave favorable productivity, defect rate of products at or larger than 10 mm in size, and shutter strength.

(Example 12)

[0150] Briquettes were manufactured using the same procedure to that of Example 11 except that the mixing ratio of coke fines was 20% by mass to the fine iron ore, (not included in total). The briquettes were blended with quasi-particles prepared in Comparative Example 11 by an amount of, (included in total), 10% by mass. A sample of 40 kg of thus prepared mixture was sintered by the same procedure to that of Comparative Example 11. The composition of the sinter is given in Table 5. The observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 6. As shown in Table 6, the obtained sinter showed the content of metallic Fe of 5.6% by mass, and gave favorable productivity, defect rate of products at or larger than 10 mm in size, and shutter strength.

(Example 13)

[0151] Sintering was given using similar procedure to that of Example 12 except that the mixing ratio of briquettes was 5% by mass, (not included in total), to obtain sinter. The composition of the sinter is given in Table 5. The observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 6. As shown in Table 6, the obtained sinter showed the content of metallic Fe of 3.0% by mass, and gave favorable productivity, defect rate of products at or larger than 10 mm in size, and shutter strength.

(Example 14)

[0152] Briquettes were manufactured using the same procedure to that of Example 11 except that the size of briquette was selected to 19 mm x 14 mm x 8 mm. The briquettes were blended with quasi-particles prepared in Comparative Example 11 in an amount of, (included in total), 30% by mass. The mixture was sintered similar to Example 11. The composition of the sinter is given in Table 5. The observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 6. As shown in Table 6, the obtained sinter showed the content of metallic Fe as 10.2% by mass, and gave favorable productivity, defect rate of products at or larger than 10 mm in size, and shutter strength.

(Example 15)

[0153] Briquettes were manufactured using similar procedure to that of Example 12 except that the mixing ratio of coke fines in the briquettes was selected to 25% by mass. The briquettes were blended with quasi-particles to sinter them in similar procedure to that of Example 12. The composition of the sinter is given in Table 5. The observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 6. The briquettes contained metallic Fe by an amount of 2.1% by mass, though they were fused to a significant degree.

(Example 16)

[0154] Briquettes were manufactured using the same procedure to that of Example 11 except that coke fines was added by an amount of, (not included in total), 20% by mass to the raw materials prepared by mixing fine iron ore with binder and burnt lime as CaO source in an amount of 6.0% by mass. The briquettes were blended with quasi-particles prepared in Comparative Example 11 in an amount of, (included in total), 10% by mass. A sample of 40 kg of the mixture was sintered in similar procedure to that of Comparative Example 11. The composition of the sinter is given in Table 5. The observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 6. As shown in Table 6, the obtained sinter showed the content of metallic Fe as 7.3% by mass, and gave favorable productivity, defect rate of products at or larger than 10 mm in size, and shutter strength.

(Example 17)

[0155] Briquettes were manufactured using the same procedure to that of Example 11 except that coke fines was added in an amount of, (not included in total), 20% by mass to the raw materials prepared by mixing fine iron ore with binder and burnt lime as CaO source in an amount of 2.0% by mass. The briquettes were blended with quasi-particles prepared in Comparative Example 11 by an amount of, (included in total), 10% by mass. A sample of 40 kg of the mixture was sintered in similar procedure to that of Comparative Example 11. The composition of the sinter is given in Table 5. The observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 6. As shown in Table 6, the obtained sinter showed the content of metallic Fe of 4.8% by mass, and gave allowable range of productivity, defect rate of products at or larger than 10 mm in size, and shutter strength.

(Example 18)

[0156] Briquettes were manufactured using the same procedure to that of Example 11 except that the briquette was prepared in a spherical shape having 5 mm in diameter. The briquettes were blended with quasi-particles prepared in Comparative Example 11 by an amount of, (included in total), 50% by mass. The mixture was sintered in similar procedure to that of Example 11. The composition of the sinter is given in Table 5. The observed productivity, defect rate of products at or larger than 5 mm in size, and shutter strength are given in Table 6. As shown in Table 6, the obtained sinter showed the content of metallic Fe of 3.8% by mass, and had pores presumably came from excess fusion of briquette. The sinter gave allowable range of productivity, defect rate of products at or larger than 10 mm in size, and shutter strength.

[0157] As described above, the Examples within the range of the present invention showed that the obtained sinter was reduced in a part, and contained metallic Fe. Consequently, use of that type of sinter used in blast furnace gives decrease in the reducing material ratio in the blast furnace and decrease in the CO_2 emissions, as described above. Furthermore, it was confirmed that the productivity, the defect rate, and the shutter strength are equal or higher level than that of ordinary sinter (Comparative Example 11).

Table 4

	(Dry mass%)
Fine iron ore	71.0
In-house recycle powder	8.0
Serpentine	1.5
Minus sieve sinter	10.0
Limestone	8.0
Burnt lime	1.5
-125 μm	45.0

Table 5

(mass %)

		Comparative Example 11	Example 11	Example 12	Example 13	Example 14	Example 15	Example 16	Example 17	Example 18
Agglomerated particle	Mixing ratio of coke fines	-	15	20	20	15	25	20	20	15
	Mixing ratio	-	10	10	5	30	10	10	10	50
	CaO/SiO_2	-	0	0	0	0	0	1.5	0.52	0
Agglomerate	Total Fe	59.3	60.2	61.6	59.8	63	59.7	62.5	59.9	60.8
	Metallic Fe	0	3.4	5.6	3	10.2	2.1	7.3	4.8	3.8

Table 6

	Comparative Example 11	Example 11	Example 12	Example 13	Example 14	Example 15	Example 16	Example 17	Example 18
Productivity (t/m^{2}h)	1.5	1.48	1.46	1.53	1.51	1.46	1.55	1.49	1.48
+5mm (%)	78	82	85	82.3	81.4	76.3	83.8	83.2	76.0
S.I. + 10	82	85	87.3	81.8	85.3	83.2	88.9	84.2	82.2

3. Third Example

[0158] Third Example corresponds to the third embodiment. The iron ore adopted pellet feed, the CaO-based auxiliary raw material adopted limestone and burnt lime, and the carbonaceous material adopted coke fines. Their compositions are given in Table 7.

[0159] Granules and compression-agglomerated particles were prepared using the above raw materials for sintering. Table 8 and Table 9 show the mixing ratio of raw materials in core part of granules and the mixing ratio of raw materials in compression-agglomerated particles, respectively. The granules were the ones prepared by coating coke fines on the core part given in Table 8 as a setting material in an amount of 3% by mass to the charged raw materials. The compression-agglomerated particles were the ones having sizes and volumes as A, B, and C, respectively, in Table 10.

[0160] With thus prepared granules and compression-agglomerated particles, sinter pot test was conducted. The preliminary treatment of raw materials was given under the same mixing and granulating conditions for all cases. The raw material packed bed had 270 mm in diameter and 300 mm in height. The test was carried out under a suction pressure of -6 kPa. The result is given in Table 11.

[0161] In Table 11, Comparative Example 21 is the case of manufacture of sinter not using compression-agglomerated particles but using only granules. Example 21 is the case of adding the compression-agglomerated particles of A in Table 10 as the raw material for charging into the sintering machine in an amount of 33% by mass to the composition of raw materials for sintering applied in Comparative Example 21, and of charging the mixture over the whole area of the packed bed of the raw materials for sintering. Then the raw materials were sintered. Both the productivity and the defect rate of products were equivalent to those of Comparative Example 21, the reduction degree at the portion of granules was also equivalent to that of Comparative Example 21. However, the reduction degree at the portion of compression-agglomerated particles was as high as 60%, and the reduction degree for total sinter was 46.6%, which was significantly higher than the basis 1.

[0162] Example 22 is the same case to Example 21 except for charging and sintering the compression-agglomerated particlesto the lower three-quarter zone of the packed bed of rawmaterials for sintering. Both the productivity and the defect rate of products were equivalent to those in Comparative Example 21 and Example 21. The reduction degree at granule portion was also 40%, which was equivalent to that in Comparative Example 21 and Example 21. However, the reduction degree at compression-agglomerated particle portion was as high as 67%, and the reduction degree of total sinter was 49%, which was significantly higher than that in Comparative Example 21.

[0163] Example 23 is the same case to Example 22 except for increasing the size of compression-agglomerated particles, and for adopting B in Table 10. Increased size of compression-agglomerated particles improved the permeation of packed bed during sintering. As a result, the productivity improved to 1.2 T/m^2/hr owing to the shortened sintering time, though the defect rate of products deteriorated. In addition, the reduction degree at compression-agglomerated particle portion was high, giving the reduction degree of 47.3% for the total sinter, which was significantly higher value than that of Comparative Example 21.

[0164] Example 24 is the same case to Example 23 except for sintering the compression-agglomerated particles by charging them to the lower half zone in the packed bed of raw materials for sintering. Both the productivity and the defect rate of products were equivalent to those in Comparative Example 21, and the reduction degree at granule portion was 40%, which was equivalent to that in Comparative Example 21. However, the reduction degree at compression-agglomerated particle portion was as high as 69%, and the reduction degree of total sinter was 49.6%, which was significantly higher than that of Comparative Example 21.

[0165] Example 25 is the same case to Example 23 except for charging and sintering the compression-agglomerated particles as the raw material for charging into the sintering machine in an amount of 50% by mass. Both the productivity and the defect rate of products were equivalent to those in Comparative Example 21, and the reduction degree at granule portion was 40%, which was equivalent to that in Comparative Example 21. However, the reduction degree at compression-agglomerated particle portion was as high as 60%, and the reduction degree of total sinter was 50%, which was significantly higher than that of Comparative Example 21.

[0166] Example 26 is the same case to Example 23 except for charging and sintering the compression-agglomeratedparticles in an amount of 4% by mass to the total of raw materials for charging into the sintering machine. Both the productivity and the defect rate of products were equivalent to those in Comparative Example 21. The reduction degree of total sinter was 41%, which was slightly higher than that of Comparative Example 21, though lower than that of Example 23.

[0167] Example 27 is the same case to Example 23 except for changing the mixing rate of compression-agglomerated particles to 55% by mass to the total raw materials for charging into the sintering machine. The defect rate of products was equivalent to that of Comparative Example 21, and the productivity was higher than that of Comparative Example 21. However, the permeability became excessively high, and the reduction degree of compression-agglomerated particles decreased. As a result, the reduction degree of total sinter became 46%, which was lower than that of Example 23, though higher than that of Comparative Example 21.

[0168] Example 28 is the same case to Example 23 except for sintering the decreased size of compression-agglomerated particles. Both the productivity and the defect rate of products were equivalent to those of Comparative Example 21. However, the sintering tended to become instable, and the reduction degree of total sinter was 44%, which was lower than that of Example 23, though higher than that of Comparative Example 21.

[0169] Example 29 is the same case to Example 23 except for decreasing the ratio of CaO to SiO_2 in the compression-agglomerated particles to 0.9. Both the productivity and the defect rate of products were equivalent to those of Comparative Example 21. Since, however, the ratio of CaO to SiO_2 was small, the reduction degree of compression-agglomerated particles decreased, and the reduction degree of total sinter became 43%, which was lower than that of Example 23, though slightly higher than the basis 1.

Table 7

(mass %)

	Total Fe	FeO	Al_2O_3	CaO	SiO_2
Pellet feed	67.66	0.12	0.72	0.04	1.44
Limestone	0.09	0	0.16	54.9	0.49
Burnt lime	0.35	0	0.08	94.7	0.2
Coke fines	0.56	0.82	3.56	0.31	6.2
Silica rock	1.3	0.68	0.68	0.10	92.22

Table 8

(mass %)

Inner layer	Iron core	55.5
	Burnt lime	5.5
	Coke fines (-1mm)	10.5
Outer layer	Iron ore	28.5

Table 9

(mass %)

	(1)	(2)
Pellet feed (-1 mm)	78.5	78.5
Limestone (-5 mm)	9	6.7
Coke fines (-1 mm)	12.5	12.5
Silica rock (-1 mm)	0	2.3

Table 10

	A	B	C
Size (mm)	19x14x8	36x26x20	6x4x4
Volume (cm^3)	1.2	10	0.05

Table 11

	Comparative Example 21	Example 21	Example 22	Example 23	Example 24	Example 25	Example 26	Example 27	Example 28	Example 29
Use rate of compression-agglomerated particles (mass%)	0	33	33	33	33	50	4	55	33	33
Use rate of granules (mass%)	100	67	67	67	67	50	96	45	67	67
Ratio of agglomerated particles to granules (-)	0	0.5	0.5	0.5	0.5	1.0	0.04	1.2	0.2	0.5
Mixing ratio of compression-agglomerated particles ( ): Ratio of CaO/SiO_2 of agglomerated particles	(1) (2.6)	(1) (2.6)	(1) (2.6)	(1) (2.6)	(1) (2.6)	(1) (2.6)	(1) (2.6)	(1) (2.6)	(1) (2.6)	(2) (0.9)
Size of compression-agglomerated particle	-	A	A	B	B	B	B	B	C	B
Position of charge of compression-agglomerated particles	-	All area	3/4	3/4	1/2	3/4	3/4	3/4	3/4	3/4
Productivity ($T/m^2/hr$)	1.1	1.2	1.1	1.2	1.1	1.2	1.1	1.4	1.0	1.2
Defect rate of products (+5 mm) (%)	87	87	88	87	87	86	87	87	87	87
Reduction degree (at compression-agglomerated particle portion) (%)	-	60	67	62	69	60	65	50	-	49
Reduction degree (at granule portion) (%)	40	40	40	40	40	40	40	41	-	40
Reduction degree (total) (%)	40	46.6	49	47.3	49.6	50	41	46	44	43

4. Fourth Example

[0170] Fourth Example corresponds to the fourth embodiment. The iron ore adopted pellet feed, the CaO-based auxiliary raw material adopted limestone and burnt lime, and the carbonaceous material adopted coke fines. Their compositions are given in Table 12.

[0171] Granules and compression-agglomerated particles were prepared using the above raw materials for sintering. Table 13 shows the mixing ratio of rawmaterials at core part in the granules and the mixing ratio of raw materials in the compression-agglomerated particles. The granules were the ones prepared by coating coke fines on the core part given in Table 2 as a setting material in an amount of 3% by mass to the charged raw materials. The compression-agglomerated particles were the ones having size and volume given in Table 14.

[0172] With thus prepared granules and compression-agglomerated particles, sinter pot test was conducted. The preliminary treatment of raw materials was done under the same mixing and granulating conditions for all cases. The raw material packed bed had 270 mm in diameter and 300 mm in height. The test was carried out under a suction pressure of -6 kPa. The mixing ratio and the characteristics of the compression-agglomerated particles are given in Table 15. The result is given in Table 16.

[0173] In Tables 15 and 16, Examples 31 and 32 are the case of charging compression-agglomerated particles as the raw material for charging into the sintering machine in an amount of 33% by mass. Example 31 is the case of using limestone as the CaO source, while Example 32 is the case of using burnt lime as the CaO source. For both of Example 31 and Example 32, the value of Fe/CaO in the compression-agglomerated particle was the same to that of granules, and starch was added as the binder in an amount of 1.4% by mass. Regarding the crushing strength and the drop strength of compression-agglomerated particles, Example 32 gave higher values than Example 31. According to the sintering test under mixing with the granules, Example 31 and Example 32 gave equivalent level of productivity, defect rate of products, and reduction degree.

[0174] Example 33 is the same case to Example 31 except for changing burnt lime which has a binder effect instead of starch as binder and of limestone as CaO source. Also Example 33 is the same case to Example 32 without addition of starch. These conditions are within the range of the present invention. The crushing strength and the drop strength of compression-agglomerated particles were equivalent to those of Example 31, though lower than those of Example 32. According to the sintering test under mixing with the granules, Example 33 gave equivalent level of productivity and defect rate of products equivalent to those of Example 31, and the reduction degree was slightly lower than that of Example 31, which level, however, does not raise problems.

[0175] Example 34 is the same case to Example 31 except for using fine raw materials as the mixing raw materials. For the raw materials after mixed, the percentage of particles at or smaller than 125 μm was 75% by mass, compared with 55% by mass in Example 31. Thus, the crushing strength and the drop strength of products were lower than those of Example 31, which levels, however, do not raise problems on handling. Sintering test mixed with granules gave levels of productivity and defect rate of products equivalent to those of Example 31. The reduction degree at compression-agglomerated particle portion, however, was 68%, which improved than 60% in Example 31

[0176] Example 35 is the same case to Example 31 except for decreasing the mixing ratio of CaO. The value of Fe/CaO was 0.7, different from Example 31, which is within the range of the present invention. Sintering test mixed with granules gave levels of productivity and defect rate of products equivalent to those of Example 31. The reduction degree at compression-agglomerated particle portion, however, was 65%, which improved from 60% in Example 31

[0177] Example 36 is the same case to Example 31 except for decreasing the mixing ratio of CaO. The value of Fe/CaO was 0.4, different from basis 1, which is within the range of the present invention. Sintering test mixed with granules gave levels of productivity and defect rate of products equivalent to those of Example 31. The reduction degree at compression-agglomerated particle portion, however, was 63%, which improved from 60% in Example 31

[0178] Example 37 is the same case to Example 32 except for decreasing the mixing ratio of CaO. The value of Fe/CaO was 0.7, different from Example 32, which is within the range of the present invention. Sintering test mixed with granules gave levels of productivity and defect rate of products equivalent to those of Example 32. The reduction degree at compression-agglomerated particle portion, however, was 68%, which improved from 62% in Example 31

[0179] Example 38 is the same case to Example 32 except for decreasing the mixing ratio of CaO. The value of Fe/CaO was 0.4, different from Example 32, which is within the range of the present invention. Sintering test mixed with granules gave levels of productivity and defect rate of products equivalent to those of Example 32. The reduction degree at compression-agglomerated particle portion, however, was 65%, which improved from 62% in Example 31

[0180] Example 39 is the same case to Examples 31 and 32 except for using fine iron ore having 3 mm or smaller size as the raw material for compression-agglomerated particles instead of pellet feed. Although the productivity and the defect rate of products were equivalent to those of Examples 31 and 32, the reduction degree of compression-agglomerated particle portion was 48%, which is lower than that of Examples 31 and 32.

[0181] Example 40 is the same case to Example 39 except for pulverizing the fine iron ore to 1 mm or smaller sizes before mixing. The percentage of particles at or smaller than 125 μm was 40% by mass to total mixed raw materials, which is in the range of the present invention. Sintering test mixed with granules gave levels of productivity and defect rate of products equivalent to those of Example 39. The reduction degree at compression-agglomerated particle portion, however, was 56%, which improved from 48% in Example 39.

[0182] Example 41 is the same case to Example 39 except for pulverizing the fine iron ore to 1 mm or smaller sizes before mixing. The percentage of particles at or smaller than 125 μm was 58% by mass to total mixed raw materials, which is in the range of the present invention. Sintering test mixed with granules gave levels of productivity and defect rate of products equivalent to those of Example 39. The reduction degree at compression-agglomerated particle portion, however, was 62%, which improved from 48% in Example 39.

[0183] Example 42 is the same case to Example 34 except for varying the ratio of CaO to SiO_2 at compression-agglomerated particle portion to 1.1. Although the productivity and the defect rate of products were equivalent to those of Example 34, the reduction degree at compression-agglomerated particle portion was 55%, which is lower than that of Example 34.

Table 12

					(mass %)
	Total Fe	FeO	Al_2O_3	CaO	SiO_2
Pellet feed	67.66	0.12	0.72	0.04	1.44
Fine iron ore	66.45	0.42	0.62	0.09	0.70
Limestone	0.09	0	0.16	54.9	0.49
Burnt lime	0.35	0	0.08	94.7	0.2
Coke fines	1.3	0.68	0.68	0.10	92.22
Silica rock	0.56	0.82	3.56	0.31	6.2

Table 13

		(mass %)
Inner layer	Iron core	55.5
	Burnt lime	5.5
	Coke fines (-1mm)	10.5
Outer layer	Iron ore	28.5

Table 14

Size (mm)	36 x 26 x 20
Volume (cm^3)	6

Table 15

		Example 31	Example 32	Example 33	Example 34	Example 35	Example 36	Example 37	Example 38	Example 39	Example 40	Example 41	Example 42
Mixing ratio of agglomerated particles (mass%)	Pellet feed	78.5 (-1 mm)	81.6 (-1 mm)	81.6 (-1 mm)	78.5 (fine)	75.6	69.1	79.4	77.0	0	0	0	78.5 (fine)
	Fine iron ore	0	0	0	0	0	0	0	0	78.5 (-3 mm)	78.5 (-1 mm)	78.5 (-0.5 mm)	0
	Burnt lime	0	5.4 (-1 mm)	5.4 (-1 mm)	0	0	0	7.9	10.8	0	0	0	0
	Limestone	9.0 (-5 mm)	0	0	9.0 (fine)	12.4	19.8	0	0	9.0 (-5 mm)	9.0 (-5 mm)	9.0 (-5 mm)	7.4 (-5 mm)
	Silica rock	0	0	0	0	0	0	0	0	0	0	0	1.6 (-1 mm)
	Coke fines	12.5 (-1 mm)	13.0 (1 mm)	13.0 (1 mm)	12.5 (fine)	12.1	11.0	12.7	12.3	12.5 (-1 mm)	12.5 (-1 mm)	12.5 (-1 mm)	12.5 (-1 mm)
	Added amount of binder (starch, % (not included in total))	1.4	1.4	0	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
	CaO/SiO$_2$ in agglomerated particle	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	1.1
Ratio of Fe/CaO in agglomerated particle to Fe/CaO in granule		1.0	1.0	1.0	1.0	0.7	0.4	0.7	0.4	1.0	1.0	1.0	1.4
Percentage of particles at or smaller than 125 µm after mixing		55	58	58	75	-	-	-	-	24	40	58	77
Crushing strength (kg)		92.9	125.3	95.6	88.2	-	-	-	-	82.2	89.8	92.5	91.2
Drop strength (+10 mm) (%)		93.2	96.6	93.0	84.3	-	-	-	-	91.0	92.4	92.6	93.0
Drop strength (+5 mm) (%)		95.5	97.8	95.7	86.6	-	-	-	-	93.4	94.8	95.1	95.4

Table 16

	Example 31	Example 32	Example 33	Example 34	Example 35	Example 36	Example 37	Example 38	Example 39	Example 40	Example 41	Example 42
Use rate of compression-agglomerated particles (mass%)	33	33	33	33	33	33	33	33	33	33	33	33
Use rate of granules (mass%)	67	67	67	67	67	67	67	67	67	67	67	67
Productivity (T/m^2/hr)	1.18	1.22	1.18	1.20	1.19	1.18	1.18	1.17	1.19	1.20	1.22	1.18
Defect rate of products (+5 mm) (%)	87	88	79	88	89	87	88	89	87	88	87	89
Reduction degree (at compression-agglomerated particle portion) (%)	60	62	45	68	65	63	68	65	48	56	62	55
Reduction degree (at granule portion) (%)	40	39	40	41	42	42	42	40	40	40	41	42
Reduction degree (total) (%)	46.7	46.7	41.7	50.0	49.7	49.0	50.7	49.0	42.6	45.3	47.9	46.3

Claims

1. A semi-reduced sinter manufactured by a method comprising the steps of:

   providing an iron ore, a carbonaceous material, and a CaO-based auxiliary raw material, as raw materials for sintering;
   charging the raw materials into a sintering machine to form a raw material layer therein; and
   sintering the raw material layer to reduce a part of the iron ore, thereby forming the semi-reduced sinter,
   wherein at least the iron ore and the carbonaceous material are agglomerated to produce a plurality of particles for manufacturing a reduced iron, the plurality of particles forming a part of the raw material layer; and
   wherein a part of the iron ore is reduced by sintering, thereby producing the semi-reduced sinter containing metallic Fe.

2. The semi-reduced sinter according to claim 1, wherein the plurality of particles for manufacturing the reduced iron is 5 to 50% by mass relative to the raw material layer.

3. The semi-reduced sinter according to claim 1 or 2, wherein one particle of the plurality of particles has a volume of 10 cm^3 or less.

4. A method for manufacturing a semi-reduced sinter, comprising the steps of:

   providing an iron ore, a carbonaceous material, and a CaO-based auxiliary raw material, as raw materials for sintering;
   charging the raw materials for sintering into a sintering machine to form a raw material layer therein; and
   sintering the raw material layer to produce a semi-reduced sinter,
   wherein a plurality of particles for manufacturing a reduced iron is produced by agglomerating the iron ore and the carbonaceous material in an amount of, (not included in total), 5% by mass or more to the iron ore, the plurality of particles are mixed with the raw materials as a part of the raw material layer, and the raw material layer is sintered to reduce a part of the iron ore, thereby producing the semi-reduced sinter containing metallic Fe.

5. A method for manufacturing a semi-reduced sinter, comprising the steps of:

   providing an iron ore, a carbonaceous material, and a CaO-based auxiliary raw material, as raw materials for sintering;
   charging the raw materials for sintering into a sintering machine to form a raw material layer therein; and
   sintering the raw material layer to produce the semi-reduced sinter in which a part of the iron ore is reduced,
   wherein a plurality of particles for manufacturing reduced iron is prepared by agglomerating a fine mixture of the iron ore and the CaO-based auxiliary raw material with the carbonaceous material, the carbonaceous material being in an amount of, (not included in total), 5% by mass or more to the fine mixture, the CaO-based auxiliary raw material being blended so that a mass ratio of CaO to SiO_2 as the components excluding the ignition loss of the particles for manufacturing reduced iron is 1 or more, then the particles for manufacturing reduced iron are mixed with the raw materials as a part of the raw material layer, thereby sintering the raw material layer to reduce a part of the iron ore to manufacture the semi-reduced sinter containing metallic Fe.

6. The method according to claim 4 or 5, wherein the particles for manufacturing reduced iron are prepared by compressing the raw materials using a roll-molding machine or by pelletizing the raw materials.

7. A method for manufacturing semi-reduced sinter, comprising the steps of:

   providing an iron ore, a carbonaceous material, and a CaO-based auxiliary raw material, as raw materials for sintering;
   charging the raw materials for sintering into a sintering machine to form a raw material layer therein; and
   sintering the raw material layer to produce the semi-reduced sinter in which a part of the iron ore is reduced,
   wherein the iron ore is mixed with the carbonaceous material in an amount of, (not included in total), 10 to 20% by mass to the iron ore, further with water and, at need, a binder, to produce a mixture;
   the mixture is compressed into agglomerated particles by using a roll-molding machine;
   the raw materials containing the agglomerated particles in an amount of, (included in total), 5 to 50% by mass are prepared;

and
a part of the iron ore is reduced by sintering to produce the semi-reduced sinter containing metallic Fe in amounts of 3% by mass or more as an average of total sinter.

8. The method according to claim 7, wherein the raw materials for manufacturing the agglomerated particles have 8 mm or less size of iron ore and 5 mm or less size of carbonaceous material.

9. The method according to claim 8, wherein the raw materials for manufacturing the agglomerated particles contain particles having 125 μm or less size in an amount of 40% by mass or more.

10. A method for manufacturing semi-reduced sinter, comprising the steps of:

providing an iron ore, a carbonaceous material, and a CaO-based auxiliary raw material, as raw materials for sintering;
charging the raw materials for sintering into a sintering machine to conduct sintering thereof to produce the semi-reduced sinter,
wherein the iron ore is mixed with the CaO-based auxiliary rawmaterial to prepare a fine mixture, and further the carbonaceous material is added to the fine mixture, and further water and, at need, a binder are added to mix them together, the carbonaceous material being in an amount of, (not included in total), 10 to 20% by mass to the fine mixture, the CaO-based auxiliary raw material being blended so that a mass ratio of CaO to SiO_2 as the components excluding the ignition loss of the particles for manufacturing reduced iron is 1 or more;
the fine mixture is compressed into agglomerated particles by using a roll-molding machine;
the raw materials for sintering containing the agglomerated particles in amounts of, (included in total), 5 to 50% by mass are prepared;
a part of the iron ore is reduced by sintering to produce the semi-reduced sinter containing metallic Fe by in amounts of 3% by mass or more as an average of total sinter.

11. The method according to claim 10, wherein the raw materials for manufacturing the agglomerated particles have 8 mm or less size of iron ore, 5 mm or less size of carbonaceous material, and 5 mm or less size of CaO-based auxiliary raw material.

12. The method according to claim 11, wherein the raw materials for manufacturing the agglomerated particles contain particles having 125 μm or less size in amounts of 40% by mass or more.

13. The method according to any of claims 7 to 12, wherein the agglomerated particles compressed by using the roll-molding machine are a plurality of briquettes formed into a specified shape by theroll-agglomerating machine, or are particles obtained by pulverizing a plate shape, sheet shape, or rod shape form agglomerated by the roll-molding machine into a specified size.

14. The method according to any of claims 7 to 13, wherein the agglomerated particles have 10 cm^3 or less volume per single particle.

15. A method for manufacturing semi-reduced sinter, comprising the steps of:

charging an iron ore, a carbonaceous material, and an auxiliary raw material, as raw materials for sintering, into a sintering machine;
sintering thus charged raw materials to reduce a part of the iron ore by using the carbonaceous material,
wherein a part of the iron ore and a part of the carbonaceous material in the raw materials for sintering, or a part of the iron ore, a part of the carbonaceous material, and a part of the auxiliary raw material in the raw materials for sintering are preliminarily compressed into compression-agglomerated particles, while residual amount of the rawmaterials for sintering is formed into agglomerates, then blending them to sinter.

16. The method according to claim 15, wherein the compression-agglomerated particles have 10 cm^3 or less volume per single particle.

17. The method according to claim 15 or 16, wherein the compression-agglomerated particles are charged into the sintering machine in a lower three-quarter zone of the raw material layer.

18. The method according to any of claims 15 to 17, wherein the mixing rate of the compression-agglomerated particles is 50% by mass or less.

19. A method for manufacturing a semi-reduced sinter, comprising the steps of:

providing an iron ore, a carbonaceous material, and an auxiliary raw material, as raw materials for sintering;
uniformly mixing preliminarily a part of the iron ore and a part of the carbonaceous material, or a part of the iron ore, a part of the carbonaceous material, and a part of the auxiliary raw material, to form a mixture;
compressing the mixture to form compression-agglomerated particles;
agglomerating residual amount of the raw materials for sintering into agglomerates;
blending the compression-agglomerated particles and the agglomerates to sinter to reduce a part of the iron ore by the carbonaceous material,
wherein the iron and the carbonaceous material as the raw materials for structuring the compression-agglomerated particles contain, as the total, 40% by mass or more of particles having 125 μm or less size.

20. The method according to claim 19, wherein the iron ore and the carbonaceous material as the raw materials for structuring the compression-agglomerated particles contain, as the total, 70% by mass or more of particles having 125 μm or less size.

21. A method for manufacturing semi-reduced sinter, comprising the steps of:

providing an iron ore, a carbonaceous material, and an auxiliary raw material, as raw materials for sintering;
uniformly mixing preliminarily a part of the iron ore, a part of the carbonaceous material, and a part of the auxiliary raw material in the raw materials for sintering;
compressing the mixture to form compression-agglomerated particles;
forming residual amount of the raw materials for sintering into agglomerates;
mixing the compression-agglomerated particles and the agglomerates to sinter to reduce a part of the iron ore by the carbonaceous material,
wherein the auxiliary raw material contains a CaO source, and a part or total of the CaO source is burnt lime, then the compression-agglomerated particle is formed without using binder, while containing burnt lime therein.

22. A method for manufacturing semi-reduced sinter comprising the steps of:

providing an iron ore, a carbonaceous material, and an auxiliary raw material, as raw materials for sintering;
uniformly mixing preliminarily a part of the iron ore, a part of the carbonaceous material, and a part of the auxiliary raw material in the raw materials for sintering;
compressing the mixture to form compression-agglomerated particles;
forming residual amount of the raw materials for sintering into agglomerates;
blending the compression-agglomerated particles and the agglomerates to sinter to reduce a part of the iron ore by the carbonaceous material,
wherein the auxiliary raw material contains a CaO source, and the content of CaO source in the compression-agglomerated particles is adjusted to 1 or more of the ratio of CaO to SiO_2, existing in the compression-agglomerated particles.

FIG. 1

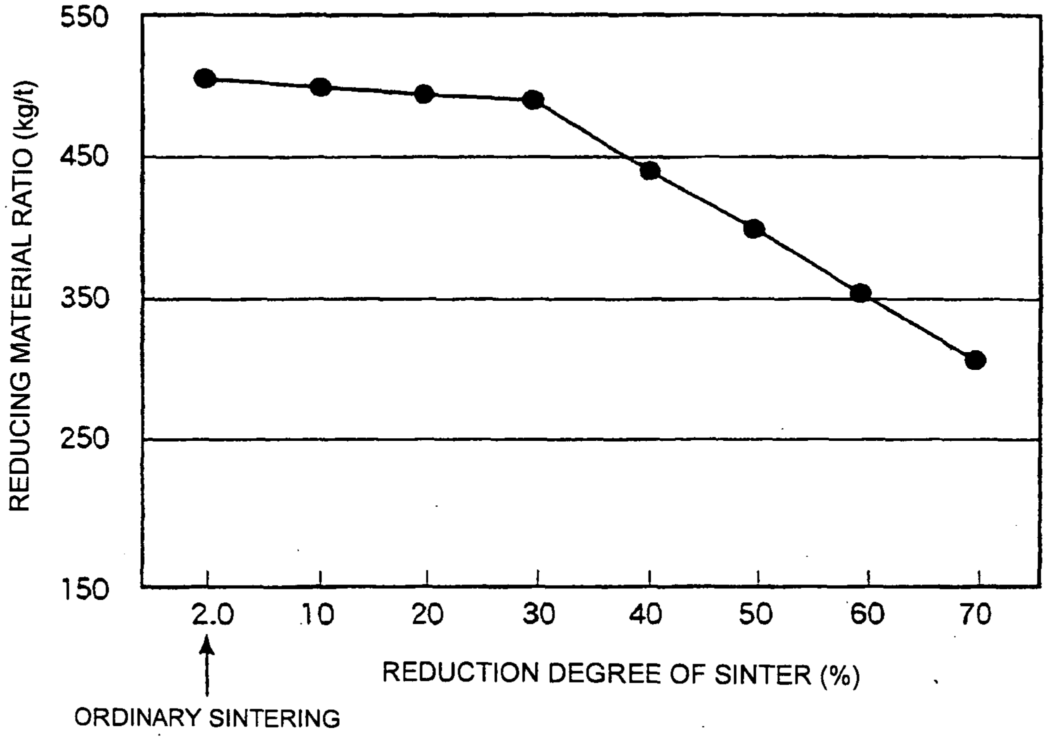

550
450
350
250
150
REDUCING MATERIAL RATIO (kg/t)
2.0
10
20
30
40
50
60
70
REDUCTION DEGREE OF SINTER (%)
ORDINARY SINTERING

FIG. 2

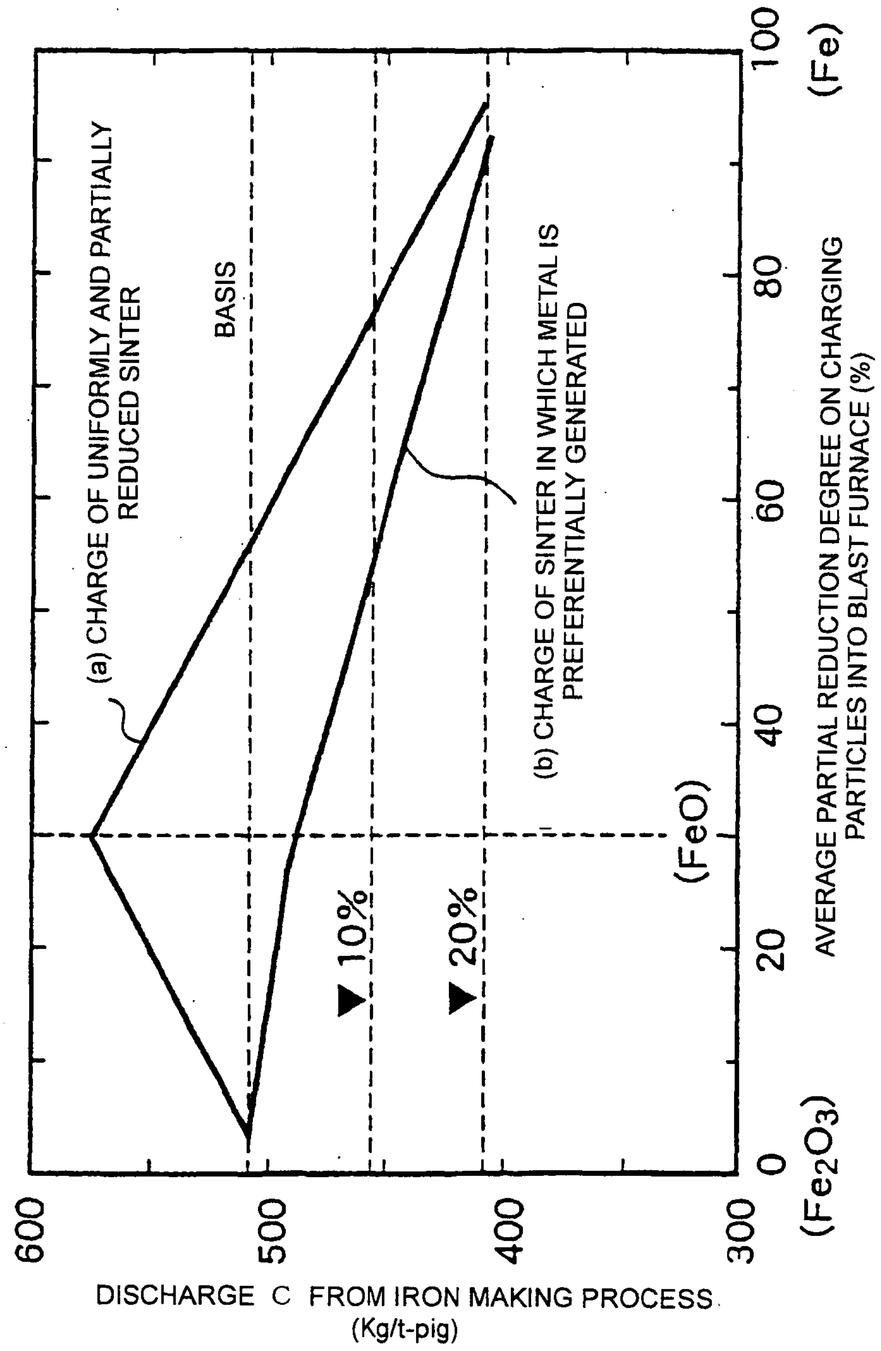

(a) CHARGE OF UNIFORMLY AND PARTIALLY REDUCED SINTER
BASIS
(b) CHARGE OF SINTER IN WHICH METAL IS PREFERENTIALLY GENERATED
▼10%
▼20%
(Fe2O3)
(FeO)
(Fe)
0
20
40
60
80
100
AVERAGE PARTIAL REDUCTION DEGREE ON CHARGING PARTICLES INTO BLAST FURNACE (%)
600
500
400
300
DISCHARGE C FROM IRON MAKING PROCESS (Kg/t-pig)

FIG. 3

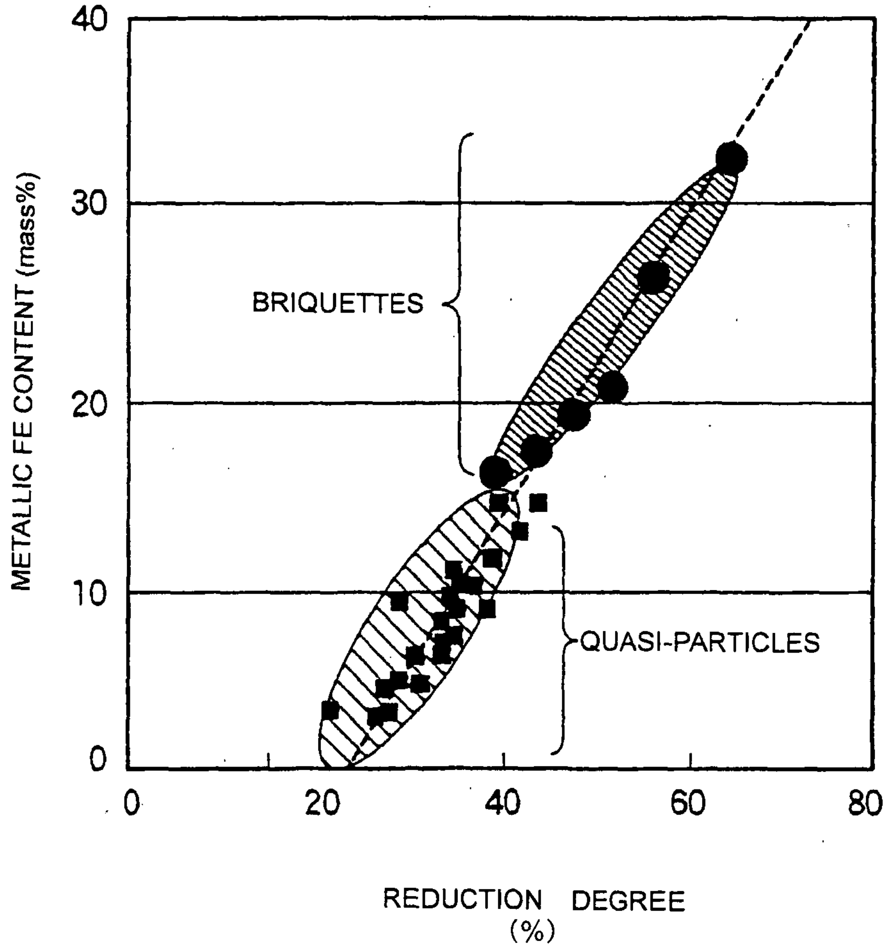

METALLIC FE CONTENT (mass%)
40
30
20
10
0
0
20
40
60
80
BRIQUETTES
QUASI-PARTICLES
REDUCTION DEGREE
(%)

FIG. 4

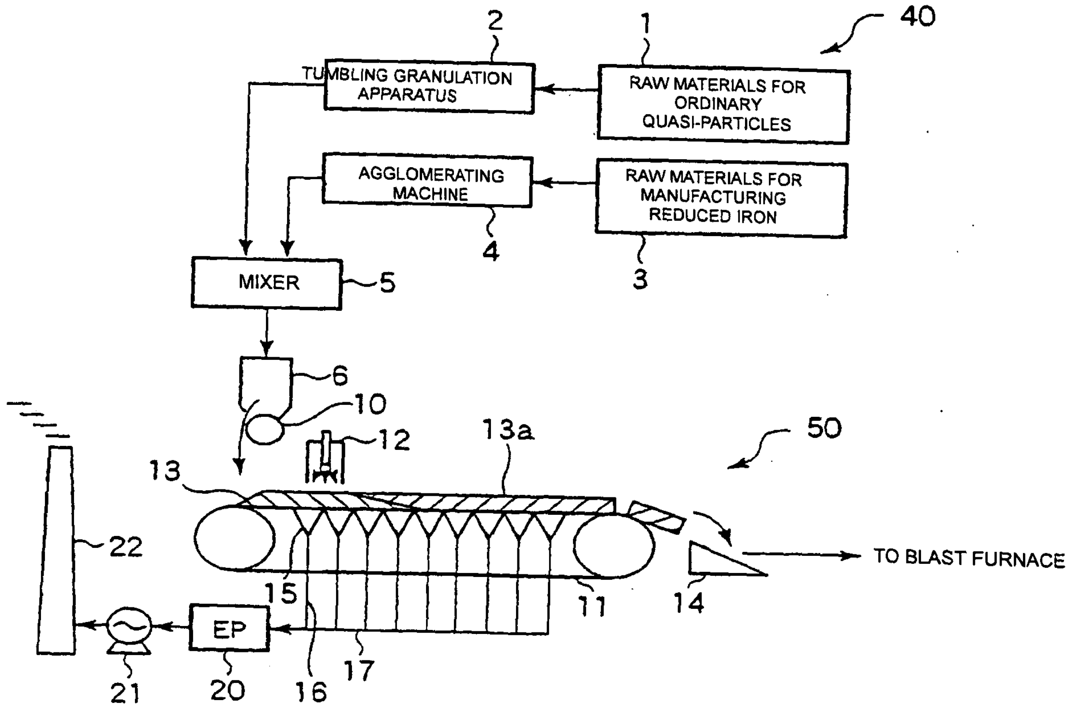

40
1
RAW MATERIALS FOR ORDINARY QUASI-PARTICLES
2
TUMBLING GRANULATION APPARATUS
3
RAW MATERIALS FOR MANUFACTURING REDUCED IRON
4
AGGLOMERATING MACHINE
MIXER
5
6
10
12
13a
13
50
22
TO BLAST FURNACE
15
11
14
EP
21
20
16
17

FIG. 5

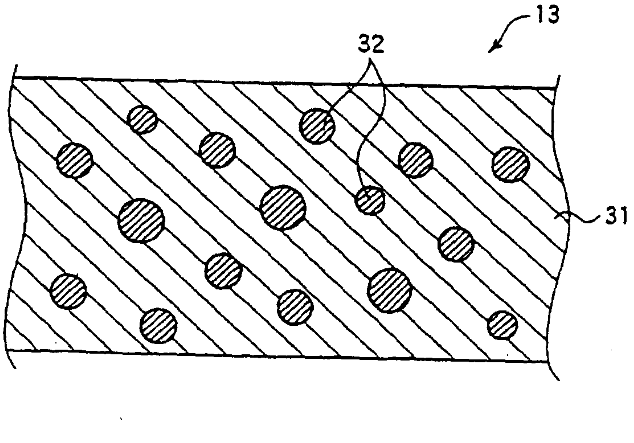

13
32
31

FIG. 6

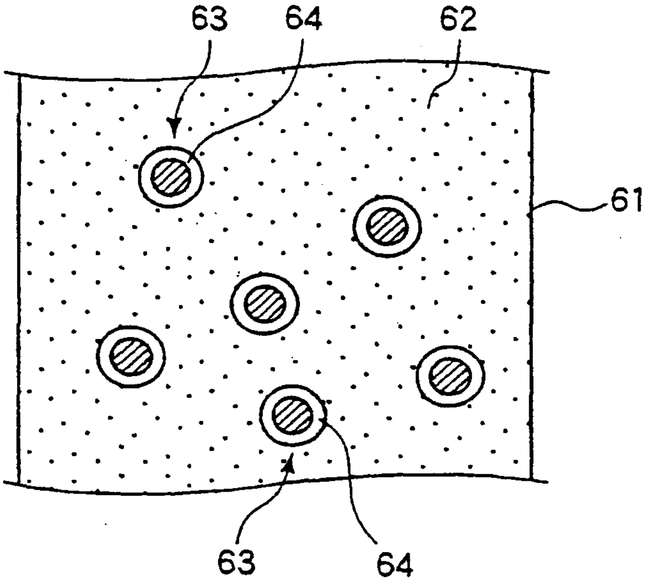

63
64
62
61
63
64

FIG. 7

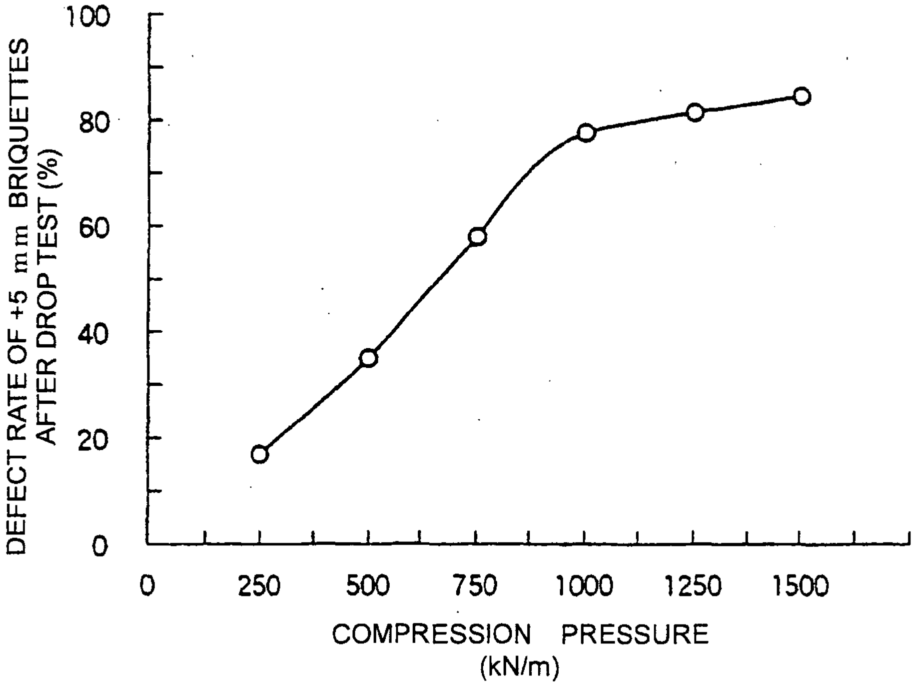

DEFECT RATE OF +5 mm BRIQUETTES AFTER DROP TEST (%)
100
80
60
40
20
0
0
250
500
750
1000
1250
1500
COMPRESSION PRESSURE (kN/m)

FIG. 8

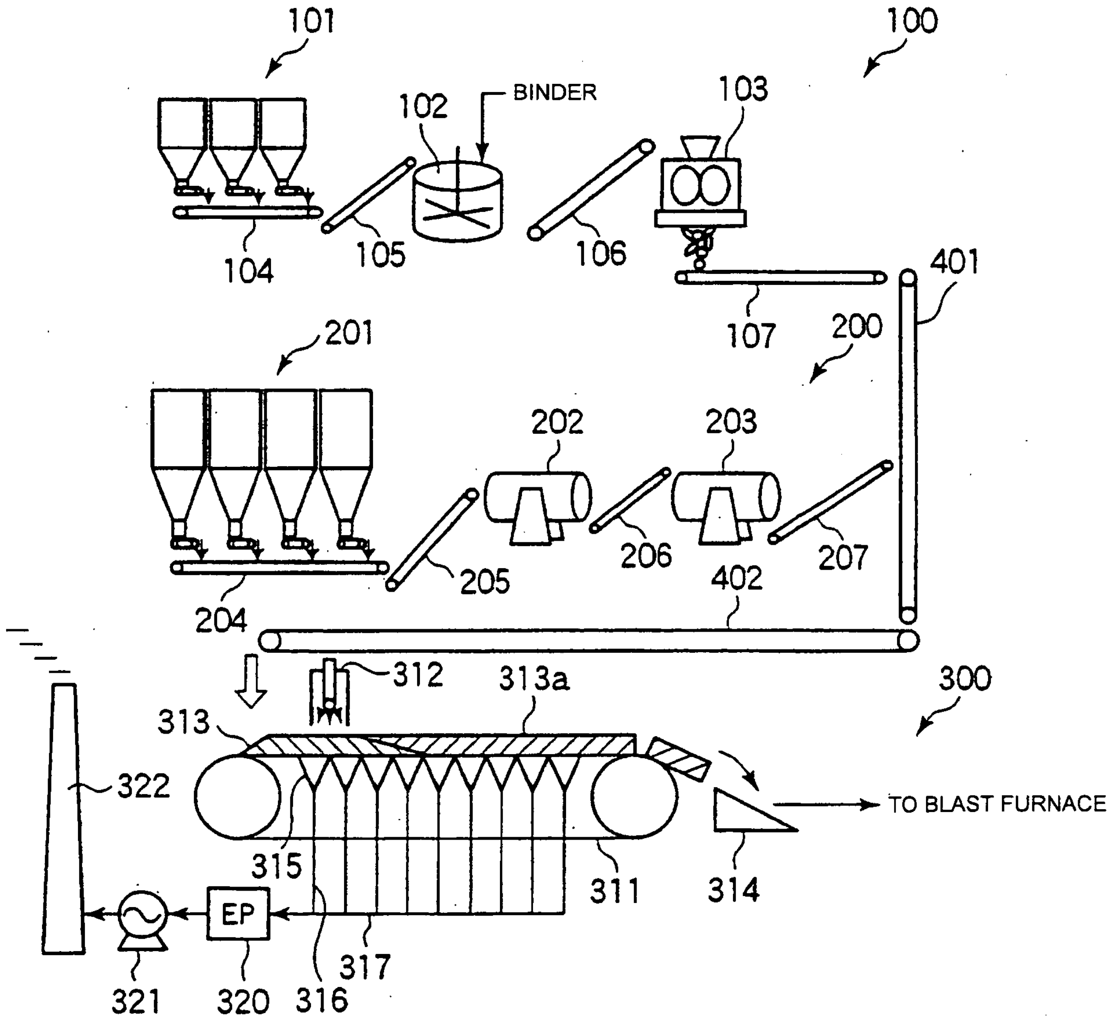

101
100
102
BINDER
103
104
105
106
107
401
201
200
202
203
205
206
207
402
204
312
313a
300
313
322
TO BLAST FURNACE
315
311
314
EP
317
321
320
316

FIG. 9

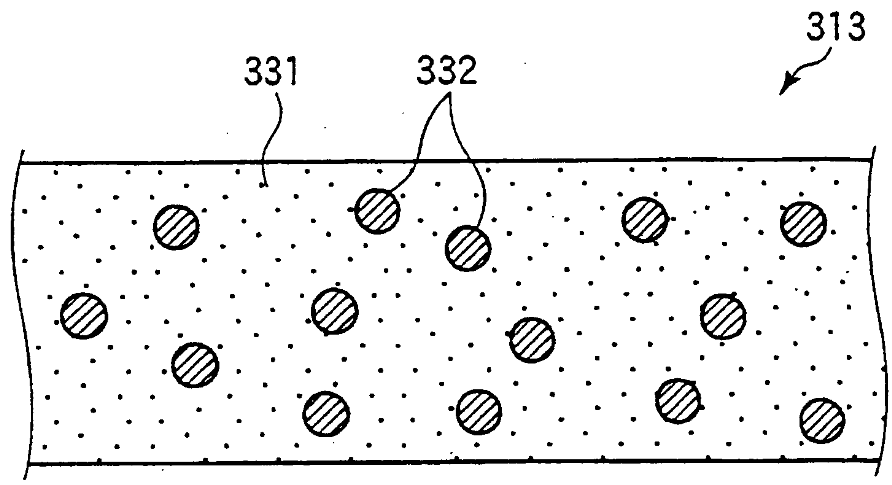
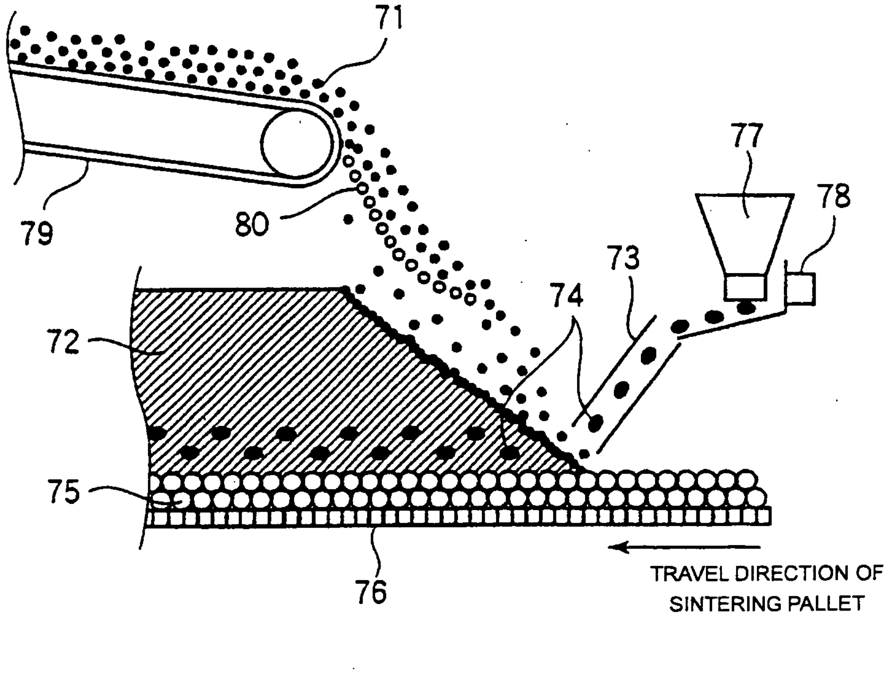

313
331
332

FIG. 10


71
77
78
73
74
79
80
72
75
76
TRAVEL DIRECTION OF SINTERING PALLET

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/009504

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl^7 C22B1/16, 1/20, 1/243

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)
Int.Cl^7 C22B1/16, 1/20, 1/243

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	1996-2005
Kokai Jitsuyo Shinan Koho	1971-2005	Toroku Jitsuyo Shinan Koho	1994-2005

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	JP 3-028331 A (Kawasaki Steel Corp.), 06 February, 1991 (06.02.91), Claims; page 1, lower right column; page 2, lower right column; drawings (Family: none)	1-22
A	JP 4-198427 A (Kawasaki Steel Corp.), 17 July, 1992 (17.07.92), Claims; page 4; drawings (Family: none)	1-22
A	JP 59-232238 A (NKK Corp.), 27 December, 1984 (27.12.84), Claims; page 2, lower right column; drawings (Family: none)	1-22

☒ 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
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"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 26 July, 2005 (26.07.05)	Date of mailing of the international search report 09 August, 2005 (09.08.05)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (January 2004)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/009504

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 56-020129 A (Nippon Steel Corp.), 25 February, 1981 (25.02.81), Claims; page 2, lower right column; page 3, upper right column (Family: none)	1-22
A	JP 1-162729 A (NKK Corp.), 27 June, 1989 (27.06.89), Claims; drawings (Family: none)	1-22
A	JP 60-046330 A (Nippon Steel Corp.), 13 March, 1985 (13.03.85), Claims; drawings (Family: none)	1-22

Form PCT/ISA/210 (continuation of second sheet) (January 2004)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 4210432 A **[0012]**
- JP 2000192154 A **[0012]**