(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 937 427 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
28.10.2015 Bulletin 2015/44

(21) Application number: **12890530.4**

(22) Date of filing: **27.12.2012**

(51) Int Cl.:
C21B 13/10 $^{(2006.01)}$ ***C22B 1/16*** $^{(2006.01)}$

(86) International application number:
PCT/KR2012/011650

(87) International publication number:
WO 2014/098300 (26.06.2014 Gazette 2014/26)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **18.12.2012 KR 20120148940**

(71) Applicant: **Posco**
Gyeongsangbuk-do 790-300 (KR)

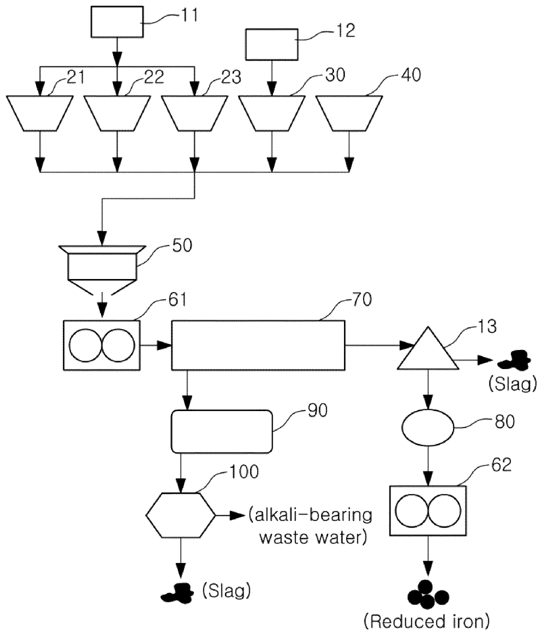
(72) Inventors:
- **SON, Sang Han**
  Gwangyang-si
  Jeollanam-do 545-090 (KR)
- **CHO, Byung Kook**
  Gwangyang-si
  Jeollanam-do 545-090 (KR)
- **JEONG, Hae Kwon**
  Gwangyang-si
  Jeollanam-do 545-090 (KR)

(74) Representative: **Zech, Stefan Markus**
Meissner, Bolte & Partner GbR
Postfach 86 06 24
81633 München (DE)

(54) REDUCED-IRON PRODUCTION METHOD AND PRODUCTION DEVICE

(57) The present invention relates to a reduced-iron production method and production device, and, more specifically, relates to a reduced-iron production method and production device whereby reduced iron having an outstanding rate of reduction is produced by using iron ore containing large amounts of the impurities phosphorus, zinc and alkali elements within the iron ore, while at the same time the phosphorus, zinc and alkali elements are recovered.

Fig. 1



EP 2 937 427 A1

Printed by Jouve, 75001 PARIS (FR)

Description

Technical Field

[0001] The present invention relates to a method and apparatus for producing reduced iron. More particularly, the present invention relates to a method and apparatus for producing high reduced rate iron from iron ore abundant in phosphorous, zinc and alkali element impurities, with the concomitant recovery of phosphorous, zinc and alkali elements.

Background Art

[0002] In blast furnaces, convertors or electric furnaces, reduced iron is used as a material for making molten iron or molten steel.

[0003] Reduced iron is produced from reduction of an oxidized iron source, such as iron ore or oxidized iron by a carbonaceous reducing agent (hereinafter referred to as "carbonaceous material") or a reducing gas. This process, called direct reduction, is most commonly used to produce reduced iron.

[0004] For producing direct reduced iron (DRI), a rotary hearth furnace (RHF) is utilized in which pellets composed of extremely trace iron ore are reduced.

[0005] With regard to processes of producing reduced iron using RHF, for example, reference may be made to Korean Patent Application Examined Publication No. 10-2010-0043095 titled "Process for producing reduced iron pellets, and process for producing pig iron"(Patent Document 1), and Korean Patent Application Unexamined Publication No. 10-2010-0122946, titled "Process for production of direct-reduced iron" (Patent Document 2).

[0006] Both Patent Documents 1 and 2 are directed to the production of reduced iron using a rotary furnace. In Patent Document 1, particle sizes of raw materials are controlled to improve reactivity, thereby producing a reduced iron pellet in which a metallization ratio is increased while Patent Document 2 discloses the production of iron ore rich in zinc.

[0007] Because conventional rotary furnaces are compactly configured to reduce iron ore at up to 1,350ºC in a reducing atmosphere, it is difficult to maintain the reducing atmosphere within such furnaces. In addition, conventional rotary furnaces are not suitable for use in mass scale production due to their annual capacity of production amounting only to 150,000 ~ 500,000 tons.

[0008] Due to the limitations of rotary furnaces, a new process is required for the mass production of reduced iron.

[0009] In an effort to overcome the limitations of conventional rotary furnaces, production of partially reduced iron under an oxidative atmosphere in a furnace has been suggested. However, the reducing agent carbon is burnt with oxygen from the oxidative atmosphere within the furnace to generate the heat of combustion. That is, since a larger amount of carbon is used as an energy source than as a reducing agent for iron ore, the reduction efficiency of iron ore is poor.

[0010] Further, even though iron ore is reduced in a furnace with an oxidative atmosphere, the reduced iron may be re-oxidized by the oxidative atmosphere, which is also a cause of poor reduction rate.

[0011] Meanwhile, phosphorus (P), zinc (Zn) and alkali oxides (K_2O+Na_2O) within iron ore are impurities that may cause various defects in the final reduced iron product. Iron ore that has a lower content of phosphorus (P), zinc (Zn), and alkali oxides (K_2O+Na_2O) is preferred.

[0012] With the gradual depletion of iron ore having a low impurity content, the cost of quality iron ore has recently increased. Together with the high material cost, the depletion makes it more difficult to produce quality iron ore. In this context, suggestion has been made of a steel making technique characterized by removing the impurities. However, this technique requires various subsidiary materials necessary for the removal of such impurities, and an additional process of removing impurities, thus increasing the production cost.

[Related Art Document]

[Patent Document]

[0013]

(Patent document 1) Korean Patent Application Unexamined Publication No. 10-2010-0043095 (2010. 04. 27)
(Patent document 2) Korean Patent Application Unexamined Publication No. 10-2010-0122946 (2010. 11. 23)

Disclosure

Technical Problem

[0014] The present invention provides a method for and an apparatus of producing reduced iron under an oxidative atmosphere in an open-type furnace.

[0015] In the method and the apparatus, a mixture of iron ore and carbonaceous material is molded into ore agglomerates and sufficiently reduced under an oxidative atmosphere in a reducing furnace.

[0016] In addition, the present invention provides a method and apparatus for producing reduced iron by which a broad spectrum of iron ores including iron ores rich in one or more of phosphorus (P), zinc (Zn), or alkali oxide (K_2O+Na_2O can be used to effectively produce reduced iron.

[0017] Also, the present invention provides a method and apparatus for producing reduced iron by which phosphorus (P), zinc (Zn) and alkali oxides (K_2O+Na_2O) can be separated and recovered from the iron ores.

Technical Solution

[0018] In accordance with an aspect thereof, the present invention provides a method for producing reduced iron, comprising: mixing an iron material bearing phosphorus, zinc and alkali oxides with a carbonaceous material to prepare a mixture; forming the mixture into ore agglomerates; reducing the ore agglomerates in an open-type reducing furnace, with concomitant removal of phosphorus, zinc and alkali elements from the ore agglomerates; crushing the reduced ore agglomerates to separate reduced iron from phosphorus-bearing slag; and agglomerating the reduced iron while recovering the slag.

[0019] In the mixing step, the mixture contains phosphorus (P) in an amount of 0.06 % by weight or greater, zinc (Zn) in an amount of 0.02 % by weight or greater, and an alkali oxide (K_2O+Na_2O) in an amount of 0.1 % by weight or greater.

[0020] In one embodiment of the method, the iron material is selected from among an iron ore having a phosphorus (P) content of 0.06 % or greater, an iron ore having a zinc (Zn) content of 0.02 % or greater, an iron ore having an alkali oxide (K_2O+Na_2O) content of 0.1 % or greater, and a combination thereof.

[0021] In the mixing step, the carbonaceous material contains carbon-bearing dust generated from a coal mining site or a steelworks or both.

[0022] In the mixing step, the mixture has a basicity (CaO/SiO_2) of 1 or greater.

[0023] In the mixing step, the mixture has an alkali oxide content of 0.5 % or greater.

[0024] In the mixing step, the mixture is further supplemented with a subsidiary material for adjusting basicity and an alkali oxide content, said subsidiary material including CaO to adjust the basicity of the mixture, and Na_2CO_3 and K_2CO_3 to adjust the alkali oxide content of the mixture.

[0025] In another embodiment of the present invention, the carbonaceous material is used in an amount of 10 parts by weight or greater, based on 100 parts by weight of the mixture.

[0026] In another embodiment of the present invention, the reducing furnace maintains an oxidative atmosphere therein during the reducing step in which gas is generated upon the reduction of the carbonaceous material within the ore agglomerates, forming a gas film that surrounds the ore agglomerates and thus blocks the ore agglomerates from the oxidative atmosphere.

[0027] In another embodiment of the present invention, the open-type reducing furnace is heated to a temperature of 1,000ºC or higher to calcine the ore agglomerates, and operated for a limited period of time at maximum such that carbon is completely depleted of the ore agglomerates.

[0028] In another embodiment of the present invention, the reducing step comprises recovering the zinc within the ore agglomerates as a dust in an exhaust gas from the open-type furnace, water granulating the recovered dust to separate zinc oxide (ZnO), and recovering the zinc oxide.

[0029] In another embodiment of the present invention, wherein the zinc within the ore agglomerates is vaporized during the reduction step in the reducing furnace, discharged together with the exhaust gas, and reacted with oxygen of the exhaust gas to form zinc oxide (ZnO), said zinc oxide being recovered as a dust.

[0030] In another embodiment of the present invention, the recovered dust is water granulated during which the alkali element is separated and recovered together with the water.

[0031] In another embodiment of the present invention, the reduced iron is separated from the slag using a magnetic seperator.

[0032] In accordance with another aspect thereof, the present invention provides a method for producing reduced iron, comprising: mixing an iron material with a carbonaceous material to form ore agglomerates, and reducing the ore agglomerates in an open-type furnace.

[0033] In one embodiment of this method, the carbonaceous material is used in an amount of 10 parts by weight or greater, based on 100 parts by weight of the ore agglomerates, and wherein the reducing furnace maintains an oxidative atmosphere therein during the reducing step in which gas is generated upon the reduction of the carbonaceous material within the ore agglomerates, thus forming a gas film that surrounds the ore agglomerates and blocks the ore agglomerates from the oxidative atmosphere.

[0034] In accordance with a further aspect thereof, the present invention provides am apparatus of producing reduced iron, comprising: a plurality of raw material hoppers for respectively storing different types of iron ores therein; a carbonaceous material hopper for storing a carbonaceous material therein; a mixer for mixing the effluent of different types of iron ores from the raw material hoppers with the carbonaceous material from the carbonaceous material hopper; a first molding press for forming the mixture into ore agglomerates; an open-type reducing furnace for reducing the ore agglomerates in an oxidative atmosphere; a spaller for crushing the ore agglomerates reduced in the reducing furnace; a magnetic separator for separating the crushed, reduced particles into reduced iron and slag by magnetism; and a second molding press for molding the reduced iron

[0035] In one embodiment, the apparatus may further comprise: a collector for collecting dust from an exhaust gas from the reducing furnace; and a water granulator for granulating the collected dust with water to separate zinc oxide from alkali element-bearing waste water.

Advantageous Effects

[0036] As described above, iron ores avoided for use in conventional iron making processes due to their high impurity content can be employed for producing reduced iron on a mass scale under an oxidative atmosphere using an open-type furnace in accordance with the present invention.

[0037] For a detailed description, the method of the present invention is provided for producing reduced iron, comprising: mixing an iron material with a carbonaceous material to form ore agglomerates; and reducing the ore agglomerates in an open-type furnace, wherein the reducing furnace maintains an oxidative atmosphere therein during the reducing step in which gas is generated upon the reduction of the carbonaceous material within the ore agglomerates, thus forming a gas film that surrounds the ore agglomerates and blocks the ore agglomerates from the oxidative atmosphere.

[0038] Further, impurities such as phosphorus (P), zinc (Zn), and alkali oxides (K_2O+Na_2O) contained in iron ores can be utilized in the reducing step, and can be recovered from the iron.

[0039] Consequently, a broad spectrum of iron ores can be utilized, which leads to a decrease in the cost of raw materials used in making iron. In addition, phosphorus (P), zinc (Zn) and alkali oxides (K_2O+Na_2O) can be recovered the process.

Description of Drawings

[0040]

FIG. 1 is a schematic view illustrating an apparatus of and a method for producing reduced iron.

FIG. 2 is a graph illustrating phosphorus recovery rates in slag versus basicity after the reduction of ore agglomerates at 1,200ºC for 20 min.

FIG. 3 is a graph illustrating phosphorus recovery rates of slag versus alkali oxide content in ore agglomerates after the reduction of ore agglomerates having a basicity of 1 at 1200ºC for 20 min.

FIG. 4 is a graph showing the metallization ratio of ore agglomerates versus the temperature of the open-type reducing furnace according to the amount of the carbonaceous material.

Best Mode

[0041] Embodiments of the present invention are described with reference to the accompanying drawings in order to describe the present invention in detail so that those having ordinary knowledge in the technical field to which the present invention pertains can easily practice the present invention. It should be noted that same reference numerals are used to designate the same or similar elements throughout the drawings. In the following description of the present invention, detailed descriptions of known functions and configurations which are deemed to make the gist of the present invention obscure will be omitted.

[0042] First, a description will be given of an apparatus by which a method for producing reduced iron can be embodied in accordance with an embodiment of the present ivnention.

[0043] With reference to FIG. 1, there is a schematic view illustrating an apparatus and method for producing reduced iron.

[0044] As can be seen FIG. 1, the apparatus of producing reduced iron in accordance with one embodiment of the present invention comprises a first spaller 11 for crushing iron ore; a plurality of hoppers 21, 22 and 23 for storing the iron ore crushed in the first spaller 11 by type therein; a second spaller 12 for crushing a carbonaceous material, such as coal; a carbonaceous material hopper 30 for storing the carbonaceous material crushed by the second spaller 12 therein; a mixer 50 for mixing effluent from different types of iron ore from the raw material hoppers 21, 22 and 23 with the crushed carbonaceous material from the carbonaceous material hopper 30; a first molding press 61 for forming the mixture into ore agglomerates; an open-type reducing furnace 70 for reducing the ore agglomerates in an oxidative atmosphere; a third spaller 13 for crushing the ore agglomerates reduced in the reducing furnace 70; a magnetic separator 80 for separating the crushed, reduced particles into reduced iron and slag by magnetism; and a second molding press 62 for molding the reduced iron. Optionally, the apparatus may further comprise at least one subsidiary material hopper 40 for storing a subsidiary material therein; a collector 90 for collecting dust from an exhaust gas from the reducing furnace; and a water granulator 100 for granulating the collected dust with water to separate zinc oxide from alkali element-bearing waste water.

[0045] The open-type reducing furnace has an internal space that is open rather than closed. So long as it can heat ore agglomerates while continuously transporting the ore agglomerates, any reducing furnace, without limitations to specific configurations, may be employed. By way of example, an open-type reducing furnace may be provided with a transport means for transporting ore agglomerates in a conveyer manner. A furnace body defining an internal space in which the ore agglomerates are conveyed and reduced is located above the transport means. The internal space of the furnace body is heated by a plurality of burners installed therein. In addition, a suction means for aspirating air from the internal space of the furnace body is provided below the transport means. In this structure, ore agglomerates are conveyed by the transport means while heat flows downwardly from an upper space of the ore agglomerates by the combustion of the burners and the aspiration of the suction means. In such an open-type furnace, ore agglomerates can be arranged in a multi-layer pattern and can be continuously reduced to produce reduced iron on a mass scale.

[0046] Each of the first molding press 61 and the second molding press 62 is a twin role structure.

[0047] Next, the production of reduced iron using the apparatus illustrated above will be described.

[0048] Various iron ores are crushed in the first spaller 11 shown in FIG. 1 and individually stored in the iron raw hoppers 21, 22 and 23 by type. The iron ores may have a phosphorus (P) content of 0.06 % or greater, a zinc (Zn) content of 0.02 % or greater, an alkali oxide (K_2O+Na_2O) content of 0.1 % or greater, or a combination thereof. Separately, a carbonaceous material is crushed in the second spaller 12 and stored in the carbonaceous material hopper 30. The carbonaceous material may contain carbon-bearing dust generated from a coal mining site or a steelworks or both. In this regard, the carbonaceous material preferably has a particle size of 0.1 mm or less so as to enhance reactivity.

[0049] In addition, the subsidiary material hopper 40 stores a subsidiary material for adjusting basicity and a subsidiary material for adjusting the content of alkali oxides, in combination or separately, therein. For instance, CaO may be used as a subsidiary material for adjusting basicity, and the content of alkali oxides may be adjusted with Na_2CO_3 or K_2CO_3 or both.

[0050] After being prepared like this, the iron ore, the carbonaceous material, and the subsidiary materials are each weighed, introduced into the mixer 50, and mixed to give a mixture.

[0051] Preferably, the mixture comprises phosphorus (P) in an amount of 0.06 % or greater, zinc (Zn) in an amount of 0.02 % or greater, and an alkali oxide (K_2O+Na_2O) in an amount of 0.1 % or greater, which are mostly derived from the iron ore and the carbonaceous material. However, the ore agglomerates, as will be described later, are preferably maintained to have a high basicity and a high alkali oxide content in order to sufficiently isolate phosphorus during the reduction of ore agglomerates. Accordingly, CaO, Na_2CO_3, and K_2CO_3 are preferably added in such amounts as to adjust the basisicity (CaO/SiO_2) of the mixture to 1 or higher and to maintain an alkali oxide content of 0.5 % in the mixture. The reason why the basicity and the alkali oxide content are limited will be revealed later in the description given in conjunction with FIGS. 2 and 3.

[0052] The mixture thus obtained is fed to the first molding press 61 where homogeneously sized ore agglomerates are formed.

[0053] Subsequently, the ore agglomerates are introduced into the open-type reducing furnace 70 where iron (Fe) of the ore agglomerates is reduced in an oxidative atmosphere while separating phosphorus, zinc and alkali elements from the iron. In this context, the oxidative atmosphere means exposure to air without any atmospheric control.

[0054] Reactions in the reduction process will be detailed. Iron oxides within the ore agglomerates react (are reduced), as shown in the following Chemical Formula 1, to generate Fe and CO. Then, this CO reacts with (reduces) the iron oxides of the ore agglomerates as shown in the following Chemical Formula 2, with the concomitant generation of iron (Fe) and CO_2. This CO_2 may be converted into CO by reaction with carbon within the ore agglomerates. The CO and CO_2 gases that are generated by reactions between iron oxides and carbon within the ore agglomerates are exhausted externally, forming a gas film surrounding the ore agglomerates. As the gas film serves to block the ore agglomerates from the oxidative atmosphere of the open-type reducing furnace 70, the reduction of the ore agglomerates can be facilitated in the open-type reducing furnace 70.

[0055] In a preferred embodiment, a sufficient amount of the gas film is formed by fully reacting iron oxides of the ore agglomerates with carbon. For this, a sufficient amount of carbon is contained in the ore agglomerates. In this regard, the carbonaceous material is preferably mixed in an amount of 10 parts by weight or greater, based on 100 parts by weight of the total mixture.

[0056] In addition, the open-type reducing furnace 70 is preferably maintained to have a calcination temperature of 1,000ºC or higher to reduce the ore agglomerates.

[0057] FIG. 4 is a graph showing the metallization ratio of ore agglomerates versus the temperature of the open-type reducing furnace according to the amount of the carbonaceous material. As can be seen, ore agglomerates containing a carbonaceous material in an amount of 10 parts by weight were found to allow sufficient metallization.

[0058] Since the gas film is formed as a result of a reaction with the carbon of the ore agglomerates, the time of the reduction of the ore agglomerates is preferably limited at maximum to an extent that carbon is completely depleted of the ore agglomerates.

[0059] During the reduction of the ore agglomerates in the open-type furnace 70, phosphorus, oxygen and CaO elements of the ore agglomerates undergo a reaction to form a slag containing the elements in the form of, for example, $CaO{\cdot}(P_2O_5)$. Hence, the ore agglomerates are in the mixture of reduced iron and slag.

[0060] Turning to zinc contained in the ore agglomerates, zinc oxide and alkali oxides (K_2O+Na_2O) are reduced at lower temperatures than are iron oxides, and are discharged as an exhaust gas.

[0061] When discharged together with the exhaust gas, the zinc (Zn) vaporized during the reduction of the ore agglomerates reacts with oxygen in the exhaust gas to form a zinc oxide (ZnO) that is then collected as a dust by the collector 90.

[0062] During the reduction of the ore agglomerates, the alkali elements are also vaporized, exhausted as a gas, and reacted with oxygen of the exhaust gas to form an alkali oxide. Likewise, this oxide is collected as a dust by the collector 90.

[0063] After the dust collected by the collector 90 is treated in the water granulator 100, waste water containing crude zinc oxide and alkali elements is recovered.

[0064] Meanwhile, the ore agglomerates in mixture with reduced iron and slag are crushed in the third spaller 13 and separated into reduced iron and slag by magnetism in the magnetic separator 80. The reduced iron thus obtained is formed into briquettes of a predetermined size in the second molding press 62 while the slag rich in CaO and phosphorus may be recycled as a fertilizer material.

EXAMPLES

[0065] A better understanding of the present invention may be obtained through the following examples that are set forth to illustrate, but are not to be construed as limiting the present invention.

[0066] Compositions of iron ores used in experiments are summarized in Table 1, below.

[0067] Iron ores rich in phosphorus, zinc and alkali elements (Na_2O, K_2O) were used. Each iron ore was formed into briquettes rich in phosphorus, zinc and alkali elements. Optionally, zinc oxide, phosphorus oxide and alkali oxides, all in a reagent grade, were added to maximize contents of zinc, phosphorus and alkali elements.

[0068] For comparison, the composition of an iron ore that is used in a typical iron making process (iron ore C) is also given in Table 1. As can be in Table 1, iron ore C, which is used in a typical iron making process, has a phosphorus content of about 0.06% or less, a zinc content of about 0.02 % or less, and an alkali oxide content of 0.03 % or less whereas both iron ores A and B are relatively rich in phosphorus, zinc, and alkali oxide.

TABLE 1

Classification	T. Fe	SiO_2	Al_2O_3	CaO	MgO	P	Zn	K_2O	Na_2O
Iron Ore A	41.1	17.8	2.41	3.20	13.7	0.013	0.103	0.687	-
Iron Ore B	55.3	8.5	0.90	4.38	0.21	0.52	0.019	0.039	0.10
Iron Ore C	65.7	1.87	1.19	0.01	0.09	0.023	0.009	0.036	0.012

[0069] Iron ores A and B were independently mixed with coal (20 % by weight) and formed into briquettes. In order to increase basicity and alkali oxide content in the briquettes, CaO, K_2O, and Na_2O in a reagent grade were added. Under a reducing furnace simulated condition, the briquettes were reduced.

[0070] A reduction experiment was carried out on the briquettes by elevating the temperature at a rate of 50ºC/min to a reduction temperature of 1,200ºC and by maintaining the reduction temperature for 20 min. Then, the briquettes were analyzed for Fe, Zn, and P content while Fe, Zn, P, K, and Na content in the slag is examined.

[0071] FIG. 2 is a graph illustrating phosphorus recovery rates in slag versus basicity after the reduction of ore agglomerates at 1,200ºC for 20 min, and FIG. 3 is a graph illustrating phosphorus recovery rates of slag versus alkali oxide content in ore agglomerates after the reduction of ore agglomerates having a basicity of 1 at 1200ºC for 20 min.

[0072] As is understood from data of FIG. 2, the phosphorous recovery rate in slag gradually increases with an increase in basicity. As for the phosphorus oxide (P_2O_5), its stability is maintained in the condition of high basicity. Particularly, phosphorus oxide in the slag is stable even when a strong alkali such as alkali oxide is added. Therefore, the addition of small amounts of highly basic slag and alkali oxide is effective in preventing phosphorus oxide from being reduced and dissolved into the metal Fe during the reduction of reduced iron, and thus in allowing phosphorus oxide to exist in the slag.

[0073] After completion of the experiment, the briquettes were found to have a reduction rate of approximately 85 ~ 90% irrespective of basicity. In addition, the zinc content in the slag after reduction was decreased to approximately 0.004 % from 0.1 % in the initial phase. Reduction of zinc oxide to metal Zn occurred at a lower temperature than reduction of iron oxide to its metal. Soon after reduction into metal zinc, it was vaporized, exhibiting a high vapor pressure. The gaseous zinc was re-oxidized into and discharged as ZnO in exhaust gas.

[0074] As can be seen in FIG. 3, the recovery rate of phosphorous in slag was observed to increase with an increase in the alkali oxide content of the briquettes. Hence, the use of alkali oxide-rich iron ore in mixture with phosphorus-rich iron ore is advantageous in enhancing phosphorus recovery rates in slag. Accordingly, it was found that phosphorus could be recovered to a desired degree when the mixture was set to have a basicity (CaO/SiO_2) of 1 or higher, and an alkali oxide content of 0.5 % or higher.

[0075] Although the preferred embodiments of the present invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.

<Description of the Reference Numerals in the Drawings>

[0076]

11, 12, 13: Spaller,

21, 22, 23: raw material hopper

30: carbonaceous material hopper

40: subsidiary material hopper

50: mixer

61, 62: molding press

70: open-type reducing furnace

80: magnetic separator

90: collector

100: water granulator

Claims

1. A method for producing reduced iron, comprising:

mixing an iron material bearing phosphorus, zinc and alkali oxides with a carbonaceous material to prepare a mixture;
forming the mixture into ore agglomerates;
reducing the ore agglomerates in an open-type reducing furnace, with concomitant removal of phosphorus, zinc and alkali elements from the ore agglomerates;
crushing the reduced ore agglomerates to separate reduced iron from phosphorus-bearing slag; and
agglomerating the reduced iron while recovering the slag.

2. The method of claim 1, wherein the mixture contains phosphorus (P) in an amount of 0.06 % by weight or greater, zinc (Zn) in an amount of 0.02 % by weight or greater, and an alkali oxide (K_2O+Na_2O) in an amount of 0.1 % by weight or greater.

3. The method of claim 2, wherein the iron material is selected from among an iron ore having a phosphorus (P) content of 0.06 % or greater, an iron ore having a zinc (Zn) content of 0.02 % or greater, an iron ore having an alkali oxide (K_2O+Na_2O) content of 0.1 % or greater, and a combination thereof.

4. The method of claim 1, wherein the carbonaceous material contains carbon-bearing dust generated from a coal mining site or a steelworks or both.

5. The method of claim 1, wherein the mixture has a basicity (CaO/SiO_2) of 1 or greater.

6. The method of claim 1, wherein the mixture has an alkali oxide content of 0.5 % or greater.

7. The method of claim 5 or 6, wherein the mixture is further supplemented with a subsidiary material for adjusting basicity and an alkali oxide content, said subsidiary material including CaO to adjust the basicity of the mixture, and Na_2CO_3 and K_2CO_3 to adjust the alkali oxide content of the mixture.

8. The method of claim 1, wherein the carbonaceous material is used in an amount of 10 parts by weight or greater, based on 100 parts by weight of the mixture.

9. The method of claim 1, wherein the reducing furnace maintains an oxidative atmosphere therein during the reducing step in which gas is generated upon the reduction of the carbonaceous material within the ore agglomerates, forming a gas film that surrounds the ore agglomerates and thus blocks the ore agglomerates from the oxidative atmosphere.

10. The method of claim 9, wherein the open-type reducing furnace is heated to a temperature of 1,000ºC or higher to calcine the ore agglomerates and operated for a period of time limited at maximum to an extent that carbon is completed depleted of the ore agglomerates.

11. The method of claim 1, wherein the reducing step comprises recovering the zinc within the ore agglomerates as a dust in an exhaust gas from the open-type furnace and water granulating the recovered dust to separate zinc oxide (ZnO), and recovering the zinc oxide.

12. The method of claim 11, wherein the zinc within the ore agglomerates is vaporized during the reduction step in the reducing furnace, discharged together with the exhaust gas, and reacted with oxygen of the exhaust gas to form zinc oxide (ZnO), said zinc oxide being recovered as a dust.

13. The method of claim 11, wherein the recovered dust is water granulated during which the alkali element is separated and recovered together with water.

14. The method of claim 1, wherein the reduced iron is separated from the slag using a magnetic separator.

15. A method for producing reduced iron, comprising:

mixing an iron material with a carbonaceous material to form ore agglomerates, and
reducing the ore agglomerates in an open-type furnace.

16. The method of claim 15, wherein the carbonaceous material is used in an amount of 10 parts by weight or greater, based on 100 parts by weight of the ore agglomerates, and wherein the reducing furnace maintains an oxidative atmosphere therein during the reducing step in which gas is generated upon the reduction of the carbonaceous material within the ore agglomerates, thus forming a gas film that surrounds the ore agglomerates and blocks the ore agglomerates from the oxidative atmosphere.

17. An apparatus of producing reduced iron, comprising:

a plurality of raw material hoppers for respectively storing different types of iron ores, therein;
a carbonaceous material hopper for storing a carbonaceous material therein;
a mixer for mixing effluent from different types of iron ores from the raw material hoppers with the carbonaceous material from the carbonaceous material hopper;

a first molding press for forming the mixture into ore agglomerates;
an open-type reducing furnace for reducing the ore agglomerates in an oxidative atmosphere;
a spaller for crushing the ore agglomerates reduced in the reducing furnace;
a magnetic separator for magnetically separating the crushed and reduced particles into reduced iron and slag; and
a second molding press for molding the reduced iron

18. The apparatus of claim 17, further comprising:

a collector for collecting dust from an exhaust gas from the reducing furnace; and
a water granulator for granulating the collected dust with water to separate zinc oxide from alkali element-bearing waste water.

Fig. 1

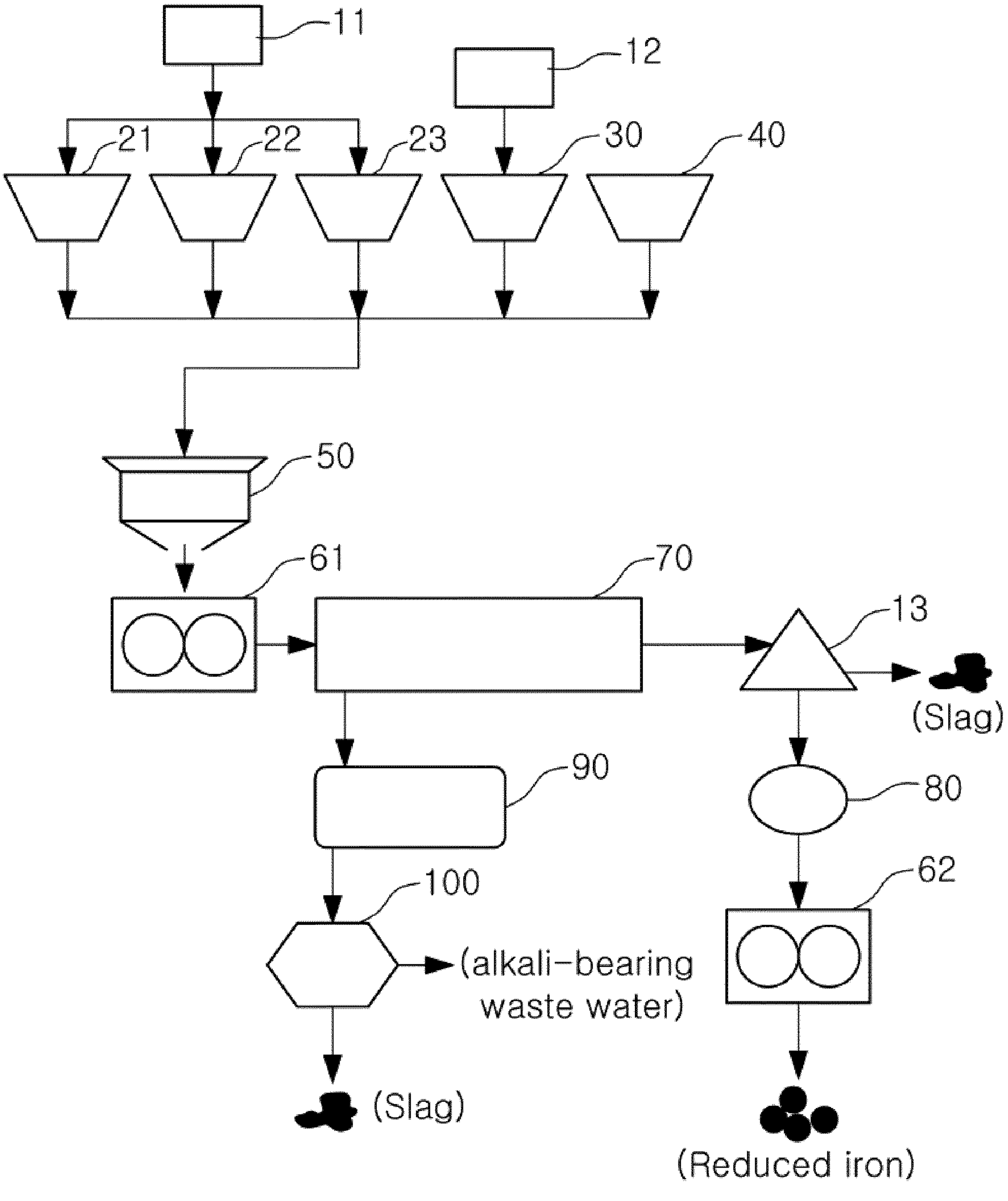

11
12
21
22
23
30
40
50
61
70
13
(Slag)
90
80
100
62
(alkali-bearing waste water)
(Slag)
(Reduced iron)

Fig. 2

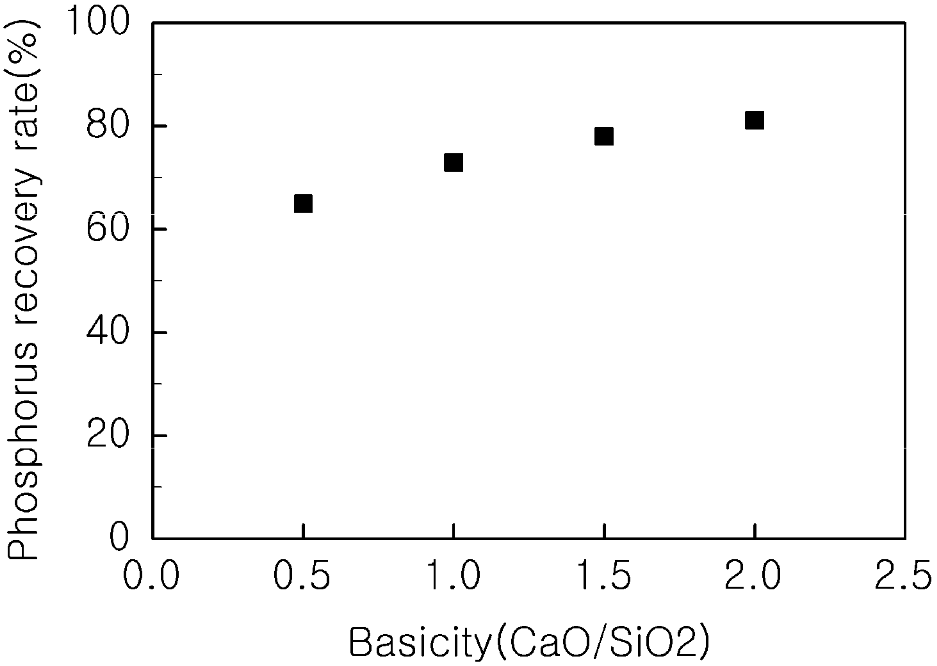

Phosphorus recovery rate(%)
100
80
60
40
20
0
0.0
0.5
1.0
1.5
2.0
2.5
Basicity(CaO/SiO2)

Fig. 3

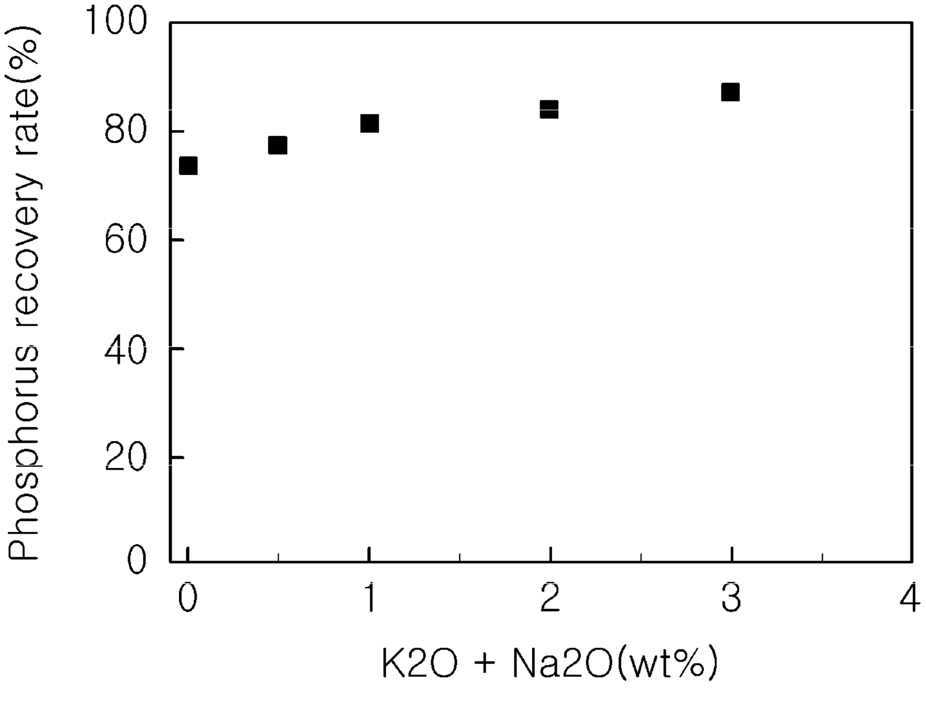
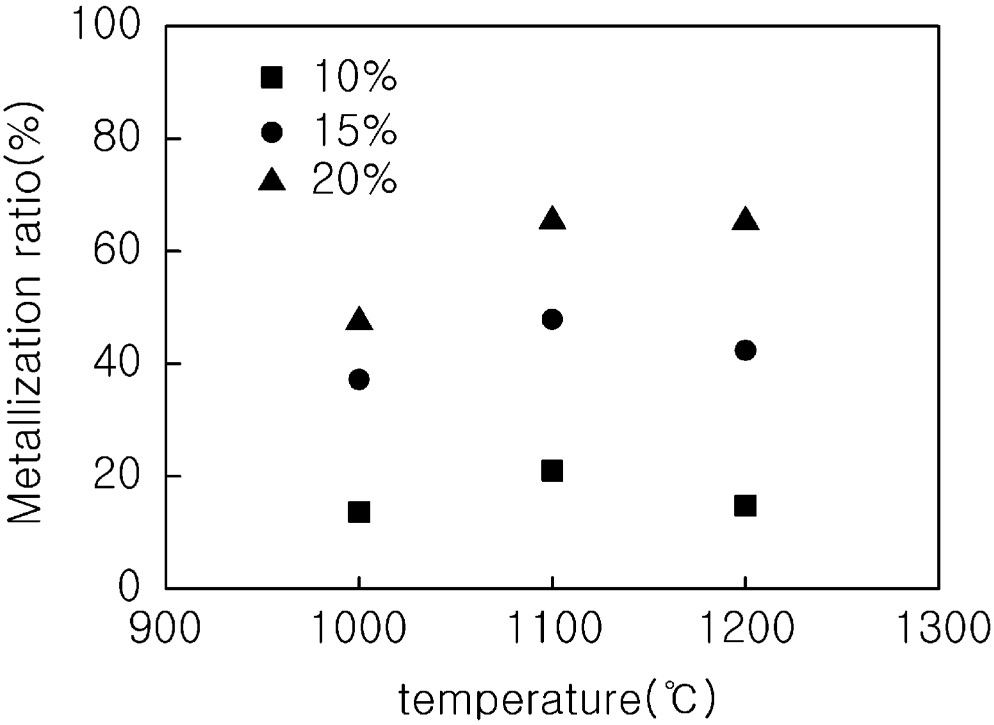

Phosphorus recovery rate(%)
100
80
60
40
20
0
0
1
2
3
4
K2O + Na2O(wt%)

Fig. 4


100
80
60
40
20
0
Metallization ratio(%)
■ 10%
● 15%
▲ 20%
900
1000
1100
1200
1300
temperature(℃)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2012/011650

A. CLASSIFICATION OF SUBJECT MATTER

C21B 13/10(2006.01)i, C22B 1/16(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C21B 13/10; C21B 13/00; C22B 1/16

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Utility models and applications for Utility models: IPC as above
Japanese Utility models and applications for Utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS (KIPO internal) & Keywords: reduced iron, iron ore, oxidized steel, reducing agent, coal ash, agglomerates, molding, mixing, crushing, slag

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-0516507 B1 (KOBE STEEL, LTD.) 25 November 2005 See abstract; page 11, table 1, page 13, lines 22-28, pages 15,16; and figures 8,9.	15,16
Y		17
A		1-14,18
Y	JP 2010-007163 A (SUMITOMO METAL IND. LTD. et al.) 14 January 2010 See abstract; paragraphs [0038],[0039]; and figure 2.	17
A	JP 11-131119 A (KOBE STEEL LTD.) 18 May 1999 See abstract; paragraphs [0011],[0016] and [0035]-[0037]; and figure 7.	1-18
A	US 3443931 A (BEGGS et al.) 13 May 1969 See abstract and column 1, lines 13-23, column 2, lines 29-58.	1-18
A	KR 10-2000-0062353 A (KABUSHIKI KAISHA KOBE SEIKO SHO (KOBE STEEL, LTD.)) 25 October 2000 See abstract; page 4; and figure 1.	1-18

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 21 JUNE 2013 (21.06.2013)	Date of mailing of the international search report **21 JUNE 2013 (21.06.2013)**
Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex-Daejeon, 189 Seonsa-ro, Daejeon 302-701, Republic of Korea Facsimile No. 82-42-472-7140	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2012/011650

Patent document cited in search report	Publication date	Patent family member	Publication date
KR 10-0516507 B1	25.11.2005	AU 1997-19404 B2	20.01.2000
		AU 1997-19404 C	01.10.1997
		AU 715276 C	03.05.2007
		CA 2248273 A1	18.09.1997
		CA 2248273 C	18.05.2010
		CA 2694865 A1	18.09.1997
		CN 1080315 C	06.03.2002
		CN 1198945 C	27.04.2005
		CN 1218516 A	02.06.1999
		CN 1368557 A	11.09.2002
		EP 0888462 A1	23.10.2002
		EP 0888462 B1	04.12.2002
		JP 03845893 B2	15.11.2006
		JP 04149531 B2	10.09.2008
		JP 09-256017 A	30.09.1997
		JP 10-102114 A	21.04.1998
		JP 10-102115 A	21.04.1998
		JP 10-102116 A	21.04.1998
		JP 10-102117 A	21.04.1998
		JP 10-102118 A	21.04.1998
		JP 10-251724 A	22.09.1998
		JP 10-251725 A	22.09.1998
		US 2001-0049980 A1	13.12.2001
		US 2003-0061909 A1	03.04.2003
		US 2009-0025511 A1	29.01.2009
		US 6036744 A	14.03.2000
		US 6432533 B1	13.08.2002
		US 6506231 B2	14.01.2003
		US 7938883 B2	10.05.2011
		WO 97-34018 A1	18.09.1997
JP 2010-007163 A	14.01.2010	NONE	
JP 11-131119A	18.05.1999	AT 217351 T	15.05.2002
		AU 1998-96463 A1	10.05.1999
		AU 1998-96463 B2	31.05.2001
		BR 9812981 A	08.08.2000
		CA 2306805 A1	29.04.1999
		CA 2306805 C	04.01.2005
		CN 1087352 C	10.07.2002
		CN 1276838 A	13.12.2000
		DE 69805321 D1	13.06.2002
		DE 69805321 T2	28.11.2002
		EP 1027461 A1	16.08.2000
		EP 1027461 B1	08.05.2002
		ES 2177069 T3	01.12.2002
		JP 04159634 B2	01.10.2008
		KR 10-0362781 B1	29.11.2002
		RU 2194771 C2	20.12.2002

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2012/011650

Patent document cited in search report	Publication date	Patent family member	Publication date
		US 6210462 B1	03.04.2001
		WO 99-20801 A1	29.04.1999
		ZA 9809374 A	19.04.1999
US 3443931 A		NONE	
KR 10-2000-0062353 A	25.10.2000	AU 1998-53412 B2	13.04.2000
		CA 2276172 A1	09.07.1998
		CA 2276172 C	13.07.2004
		CN 1070923 C	12.09.2001
		CN 1242056 A	19.01.2000
		CN 1242056 C	19.01.2000
		EP 0953058 A1	03.11.1999
		EP 0953058 A1	06.12.2000
		JP 10-195513 A	28.07.1998
		US 6063156 A	16.05.2000
		WO 98-29573 A1	09.07.1998

Form PCT/ISA/210 (patent family annex) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- KR 1020100043095 **[0005] [0013]**
- KR 1020100122946 **[0005] [0013]**