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(54) **Operation method of moving hearth furnace**

(57) An operation method of a moving hearth furnace, in which a reduced metal is obtained by reducing by heating a metal oxide loaded into the moving hearth furnace, includes the steps of supplying and burning a fuel including combustible wastes as a heat source for

the operation. According to the operation method of a moving hearth furnace, the resources can be used effectively and costs can be reduced by using industrial wastes as a fuel.

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Description

[0001] The present invention relates to methods for manufacturing reduced metals by reducing metal oxides by heating. In particular, the present invention relates to an operation method of a moving hearth furnace which is used

[0002] Hitherto, various methods for obtaining reduced metals by reducing metal oxides such as iron ores, steel mill waste, and nickel oxides have been proposed. For example, a shaft-furnace method represented by Midrex method is known as a manufacturing method of reduced iron by directly reducing an iron oxide source such as an iron ore or an iron oxide by using a carbonaceous material or a reducing gas. By this method, metallic iron is obtained by reducing an iron oxide by using a reducing gas which is manufactured from natural gas or the like. However, since the reducing gas reformed from natural gas or the like is used as a reducing agent, the cost of the gas significantly affects the cost of the final product, and the reduction of the cost is difficult.

[0003] A smelting reduction method such as a DIOS method is known as another method for obtaining reduced iron by directly reducing iron oxide. However, this method requires complex operations and is lack of versatility with respect to the productivity and the equipment cost.

[0004] The inventors paid attention to the above-described circumstances and proposed a method for manufacturing reduced iron by using a rotary-hearth furnace, which is a type of moving hearth furnace, by reducing an agglomerate which includes a carbonaceous reducing agent and an iron oxide (hereinafter referred to as "iron oxide pellet including carbonaceous reducing agent" or simply as "pellet") (for example, in Japanese Unexamined Patent Application Publication No. 11-61216). By this method, the carbonaceous material, which is necessary for reduction, is incorporated with pellets, and another carbonaceous material is applied to the surfaces of the pellets in order to suppress re-oxidation at the surfaces of the reduced pellets, whereby the ash content of the carbonaceous material included in the reduced pellets is reduced, thereby elevating the quality level of the reduced iron.

[0005] In this method for manufacturing reduced iron by using a moving hearth furnace, the metal oxide pellet including carbonaceous reducing agents are loaded onto the hearth of a moving hearth furnace, the pellets are heated mainly with heat of combustion of burners and the radiant heat from furnace walls, and the iron oxide is reduced by the incorporated carbonaceous material. That is, the pellets must be supplied with heat from the outside, because the reduction reaction is an endothermic reaction, when the iron oxide included in the pellets including carbonaceous reducing agent is reduced by the carbonaceous material included in the pellets. Therefore, heavy oil, natural gas, pulverized coal, and/or the like has been hitherto used as a fuel for the burners and an auxiliary fuel. However, there is a limit to the amount of production of the above fuels, and in particular, heavy oil and natural gas are comparatively expensive; therefore, reduction of the manufacturing cost has been difficult.

[0006] The inventors have studied to develop technologies in which metallic iron having high iron purity can be obtained efficiently in a simple process from iron oxides having high iron-contents as a matter of course and also from iron ores and the like which have relatively a low iron-content. As a result, the inventors developed a method described below and proposed the same in, for example, Japanese Unexamined Patent Application Publication No. 9-256017.

[0007] The method is characterized in that when metallic iron is manufactured by reducing metal oxide pellet including carbonaceous reducing agents by heating, an outer skin of the metallic iron is formed and developed by reducing an iron oxide in a solid phase, the solid-phase reduction is advanced until the inside iron oxide substantially disappears, heating continues such that slag flows to the outside of the outer skin of the metallic iron, and the metallic iron and the slag are separated from each other. The high-purity metallic iron obtained by this method and the produced slag are solidified by cooling, the solidified slag is crushed, and the granulated metallic iron is separated from the slag by magnetic separation or by using a screen, or the metallic iron and the slag are melted by being heated and are separated from each other by using the difference of specific gravities. Through these processes, metallic iron having high iron-purity of 95% or more, or 98% or more is obtainable.

[0008] In the viewpoint of effective use of limited resources, a technology for using combustible waste materials such as waste oil and waste plastics as fuel for blast furnaces and converters has been also proposed. However, the combustible waste materials are most likely to include chlorides or sulfides which form HCl or SO_x as a source of air pollution. Additional facilities are required for disposing of the source of air pollution included in the exhaust gas; therefore, it has been difficult to efficiently use the combustible waste materials.

[0009] In processes in which reduced iron is obtained by reducing metal oxides such as iron ores, steel mill waste, or nickel oxides, an exhaust gas which includes acid such as HCl and SO_x deriving from chlorides and sulfides included in the source ores and the like is discharged, the exhaust gas causing environmental pollution. Therefore, various technologies for resolving this problem have been proposed.

[0010] For example, in Japanese Unexamined Patent Application Publication No. 2001-32024, a problem in the reduction of a metallic oxide using a rotary-hearth furnace is pointed out in that relatively a large amount of sulfur is brought onto the rotary hearth because coal, coke, or oil coke as a reducing agent and heavy oil as an auxiliary fuel, which contain sulfur, are generally used, thereby increasing sulfur concentration in the exhaust gas. In order to over-

come this problem, a technology for desulfurizing the exhaust gas has been proposed, in that the amount of an alkali metal to be supplied together with the raw material is set to be not smaller than twice the amount of the chemical equivalent which reacts to a sulfur oxide to be released into the exhaust gas. However, although the sulfur concentration in the exhaust gas can be reduced by this technology, the harmful components of the exhaust gas other than sulfur (in particular, chlorine, dioxin, and the like which derive from the chlorides contained in the raw material) are not considered, and such a problem is left to be solved.

[0011] Accordingly, an object of the present invention is to provide an operation method of a moving hearth furnace, by which effective utilization of resources can be advanced and the cost can be reduced by using industrial wastes as a fuel for the moving hearth furnace for reducing metal oxides. Another object of the present invention is to provide an operation method of a moving hearth furnace, by which air-pollution problems can be overcome.

[0012] To these ends, according to the present invention, an operation method of a moving hearth furnace, in which a reduced metal is obtained by loading a metal oxide into the moving hearth furnace and reducing the metal oxide by heating, comprises the steps of supplying a fuel including combustible wastes as a heat source into the moving hearth furnace and burning the fuel.

[0013] According to the present invention, the type of the fuel including combustible wastes and the way of supply of the fuel as a heat source into a moving hearth furnace may be one selected from or may be an appropriate combination of those described below.

(1) A liquid is used as the fuel, and one part of the fuel or the entire fuel is sprayed into the moving hearth furnace.

(2) A liquid is used as the fuel, and one part of the fuel or the entire fuel is poured into the moving hearth furnace.

(3) One part of the fuel or the entire fuel is mixed with the metal oxide, and the mixture is loaded into the moving hearth furnace.

[0014] In the above-described method (1), the diameter of each orifice of a spray for spraying the fuel is preferably set to be not smaller than 1.1 mm, the temperature in the furnace is preferably set to be not lower than 150°C, and the fuel is preferably ignited by a pilot burner which is disposed in the vicinity of a position at which the fuel is sprayed, whereby stable combustion of the fuel can be maintained.

[0015] In the above-described methods (2) and/or (3), the temperature in the furnace is preferably set to be not lower than 1100°C and the residence time of the fuel in the furnace is preferably set to be not shorter than three minutes, whereby a stable operation can be maintained.

[0016] The operation method of a moving hearth furnace, according to the present invention, preferably further comprises the step of including an alkali metal to the fuel. The amount of the alkali metal to be included in the fuel is preferably controlled in accordance with the amount of S and Cl generated in the furnace during the reduction by heating.

[0017] According to the present invention, the cost of fuel for reduction by heating can be significantly reduced by using effectively a fuel including combustible wastes as a fuel for the reduction by heating of a metal oxide in a moving hearth furnace.

[0018] Fig. 1 is an illustration showing a rotary-hearth furnace and processes of treating exhaust gas which is discharged from the rotary-hearth furnace, according to the present invention.

[0019] Fig. 2 is an illustration of the rotary-hearth furnace according to the present invention.

[0020] Fig. 3 is a sectional view along line A-A of the rotary-hearth furnace shown in Fig. 2.

[0021] Fig. 4 is a sectional view of the rotary-hearth furnace shown in Fig. 2 extended in the longitudinal direction.

[0022] The inventors have studied to overcome the above-described problems from different angles. As a result, they have found a solution of the above problems in that a reduced metal having the same quality as that of a known reduced metal can be obtained efficiently at a low cost by using a fuel including combustible wastes as a heat source which is necessary to reduce a metal oxide by heating in a moving hearth furnace. The present invention will be described in detail as follows.

[0023] There are various methods for reducing metal oxides by heating, as described above. A high-quality reduced metal could be easily obtained by using the method for reducing by heating a metal oxide in a moving hearth furnace, which the inventors had proposed. However, heat must be supplied for the reduction by heating of the metal oxide, and it was a burner that was generally used as a heat source and that used heavy oil or natural gas, as a fuel, which are limited resources. Therefore, it is inevitable that the cost of the fuel continues increasing.

[0024] In contrast, the present invention is characterized in that the cost of fuel is reduced by using a fuel including combustible wastes as a heat source, thereby effectively utilizing the wastes as secondary resources, when manufacturing a reduced metal by reducing a metal oxide by heating in a moving hearth furnace. According to the present invention, the amount of use of the heavy oil and the natural gas can be reduced, and dumping of combustible wastes or incineration costs thereof can be suppressed.

[0025] The wastes include industrial wastes, specially controlled industrial wastes, and domestic wastes. In particular,

the industrial wastes and the specially controlled industrial wastes discharged constantly and in a large volume from particular business places are conveniently used. The industrial wastes include substances regulated by "Wastes Disposal and Public Cleaning Law" and an enforcement ordinance thereof, such as burnt residuals, sludge, waste oil, waste acid, waste alkali, waste plastics, wastepaper, waste woods, waste textiles, animal and vegetable residuals, waste rubber, waste metals, waste glass and ceramics, slag, construction and demolition wastes, animal feces and urine, animal carcasses, and ash dust.

[0026] According to the present invention, combustible wastes among the above industrial wastes are used as a matter of course, because since a metal oxide is reduced in the moving hearth furnace, when the fuel includes incom-
 bustible wastes, substances which have not burned remain in the furnace, and the substances are mixed in the reduced
 metal, whereby the purity (quality level) of the reduced metal is lowered or complex operations become necessary for
 selection of the reduced metal from the substances which have not burned.

[0027] Therefore, according to the present invention, combustible wastes such as the waste oil and waste plastics among the above-described wastes are used; one or a mixture of two or more of these combustible wastes may be used. Among these, the wastes including waste oil are particularly useful. These wastes having high combustibility and large combustion energy can also serve to assist the combustion of other wastes which have relatively low combustibility. When the fuel including the combustible wastes is solid, the fuel is preferably crushed in a powdered state so that stable burning is maintained. The fuel including combustible wastes to be used according to the present invention is most preferably liquid, a typical one being waste oil.

[0028] The type of waste oil is not particularly specified, and waste oil such as waste mineral oil, waste vegetable oil, and waste animal oil can be used effectively. The waste oil includes, for example, sludge from oil tanks; sludge of gas oil, kerosene, gasoline, naphtha, and the like; mineral oil waste of machine oil, lubricant oil, cutting oil, and the like; oil-press residuals of vegetable oil, such as rapeseed oil, soybean oil, rice bran oil, cottonseed oil, corn oil, palm oil, and sunflower seed oil; oil wastes of the above vegetable oil used as materials for food; terpene-based plant oil wastes such as rosin; and animal oil wastes including animal fat-and-oil waste liquids of beef, pork, mutton, chicken, fish, and the like. The above-described types of waste oil may be used independently. However, they are preferably used as a mixture in an appropriate proportion between several types thereof, thereby maintaining a stable combustion state.

[0029] In the operation method of a moving hearth furnace according to the present invention, a liquid fuel including combustible wastes is supplied into the furnace in methods described below:

<1> A method in which the fuel is sprayed into the moving hearth furnace.

<2> A method in which the fuel is poured into the moving hearth furnace.

<3> A method in which the fuel including combustible wastes is mixed with a metal oxide and the mixture is supplied into the moving hearth furnace.

[0030] The methods <1> to <3> may be individually used, or a combination of two or more of the methods <1> to <3> may be used. Preferred embodiments of the above methods <1> to <3> are described in more detail as follows.

<1> Case of spraying the fuel into the moving hearth furnace

[0031] Since the composition of the fuel including combustible wastes is not always uniform, and a certain content of moisture is contained in the wastes, the calorific value is generally instable. However, the fuel can be burned efficiently when being sprayed by using a spray.

[0032] In this method, the diameter of orifice of the spray for spraying the fuel is preferably $\phi 1.1$ mm or more, more preferably $\phi 2.2$ mm or more, and more preferably $\phi 3.0$ mm or more, whereby clogging of the orifices can be suppressed and stable spraying can be maintained. Since the fuel including combustible wastes sometimes includes waste textile, wastepaper, waste rubber, mineral sludge, and the like, clogging of the orifices can be suppressed by controlling the diameter of the orifices, as described above. No maximum limit is set to the value of the diameter of the orifices; it may be any value as long as the spray can maintain a spray state such that stable combustion is maintained.

[0033] The temperature in the furnace, when the fuel including combustible wastes is sprayed into the furnace, is preferably set to 150°C or higher, and more preferably to 500°C or higher. The moving hearth furnace is preferably operated such that a pilot burner disposed in the vicinity of a position at which the fuel is sprayed ignites the fuel. That is, when the fuel is sprayed into the furnace in which the temperature is set to 150°C or higher, the moisture contained in the fuel vaporizes and only combustible substances remain, whereby the fuel burns efficiently. The combustion starts smoothly with the pilot burner igniting the fuel, thereby preventing the fuel including combustible wastes from being sprayed into the furnace without being ignited. On the other hand, when the temperature in the furnace is lower than 150°C, the fuel including combustible wastes is not adequately ignited nor burned, and it is difficult to provide a stable combustion state.

[0034] As a result of confirmation by the inventions, when the temperature in the furnace is set to 600°C or higher, or preferably to 1000°C or higher, the fuel including combustible wastes is self-ignited, and a stable combustion state is obtained.

[0035] Although the method of spraying the fuel including combustible wastes is not particularly specified, a method which uses compressed air or vapor as a spraying medium may be used. However, since the water content in the fuel must be kept as small as possible in order to maintain a stable combustion in the furnace, it is preferable to use compressed air.

<2> Case of pouring the fuel into the moving hearth furnace

[0036] According to the present invention, the fuel including combustible wastes may be supplied by being poured onto the hearth of the moving hearth furnace, whereby the fuel can be easily supplied. The position from which the fuel is poured is not particularly specified. The fuel may be poured through an inlet for supplying a metal oxide into the furnace, or a supply port for the fuel may be provided in the furnace wall or ceiling.

[0037] It is recommended to control the flow of the fuel while measuring the amount of supply of the fuel, which is sprayed (in the above method <1>) or is poured (in the above method <2>) into the furnace, by using a flowmeter. In this case, there is a risk in that the flowmeter is damaged or cannot maintain stable supply when it is a positive-displacement meter because the fuel including combustible wastes generally includes sludge and the like. Therefore, when a flowmeter is used in the line of supply of the fuel, it is preferably an electromagnetic flowmeter or a Coriolis-type flowmeter which has no moving parts in the line. However, when the electric conductivity of the fuel is low and unstable, measurement by using an electromagnetic flowmeter is difficult; therefore, a Coriolis-type flowmeter is most preferable.

<3> Case of mixing the fuel including combustible wastes and a metal oxide (raw material) and supplying the mixture into a moving hearth furnace

[0038] According to the present invention, a metal oxide as a raw material for manufacturing a metal and the fuel including combustible wastes may be mixed with each other so as to form agglomerate, and the agglomerated mixture may be supplied into the furnace such that the fuel is burned in the furnace. When a method in which the fuel is mixed in advance with a raw material to be reduced is used, the fuel can also serve as a binder and the amount of binder for forming agglomerate of the raw material can be thereby reduced. A carbonaceous reducing agent which is necessary for the reduction of a metal oxide is preferably mixed with the agglomerated raw material.

[0039] Any type of carbonaceous reducing agent, such as pulverized coal processed simply through crushing, screening, and the like after mining, crushed coke, for example, processed by heating such as dry distillation, or petroleum coke, may be used. For example, blast furnace dust collected as wastes including carbon may be also used. However, since the carbonaceous reducing agent is used for efficiently advancing reduction reaction by heating, the carbon content, which is not strictly specified though, is preferably 70% or more by mass, and more preferably 80% or more by mass.

[0040] The above agglomerated mixture includes the mixture formed in an arbitrary shape such as a lump shape, a granule shape, a briquette-shape, a pellet-shape, and a rod-shape. The method of agglomeration is not particularly specified. For example, tumbling granulation or pressing may be used.

[0041] According to the present invention, when the fuel is poured into a moving hearth furnace (in the method <2>) or the fuel is mixed with a metal oxide and is supplied into the moving hearth furnace (in the method <3>), the temperature in the furnace is preferably set to 1100°C or higher, more preferably to 1200°C or higher, or more preferably to 1250°C or higher, and the residence time of the fuel in the furnace is preferably set to 3 minutes or longer, more preferably to 5 minutes or longer, or more preferably to 7 minutes or longer. When the temperature in the furnace is lower than 1100°C, the combustion of the fuel including combustible wastes is instable, and a part of the fuel remains unburned, the part of the fuel being discharged to the outside of the system without being burned, whereby there is a risk of reduction of the utilization efficiency. When the residence time of the fuel in the furnace is shorter than 3 minutes, a part of the fuel may remain unburned. The residence time of 3 minutes or longer does not mean that the fuel remains in the same form as when it was supplied into the furnace, but that it takes at least 3 minutes for the fuel to completely burn out after the fuel is supplied into the furnace.

[0042] When the fuel including combustible wastes burns in the moving hearth furnace, a sulfur oxide such as SO_x, or gaseous chlorine such as Cl₂ or HCl is generated from sulfur or chlorine included in the wastes and is discharged as exhaust gas. The acid gas causes acid corrosion or corrosion by low melting temperature compound and also air pollution.

[0043] Accordingly, the inventors studied means to avoid problems caused by the acid gas. As a result, it was found that an alkali metal contained in the fuel serves to avoid the problems. When an alkali metal is included in the fuel, the

alkali metal is simultaneously vaporized during combustion and is discharged as exhaust gas. In the high-temperature exhaust gas, the alkali metal reacts with Cl in the exhaust gas and is solidified as an alkali chloride such as NaCl or KCl. In the same manner, SO_x in the exhaust gas reacts with the alkali metal and is solidified as a sulfate such as Na₂SO₄ or K₂SO₄. When the exhaust gas containing the alkali chloride and the sulfate is cooled in exhaust-gas treatment facilities, the alkali chloride and the sulfate are separated and the concentration of chlorine and sulfur in the exhaust gas can be thereby lowered. Therefore, desulfurization and dechlorination facilities are not required and the amount of use of slaked lime can be reduced.

[0044] When carrying out the present invention, the amount of the alkali metal to be blended with the fuel is preferably controlled in accordance with the amount of S or Cl which is generated in the furnace during reduction by heating. With this arrangement, chloric gas such as Cl₂ or HCl and sulfur oxides such as SO_x are prevented from being discharged to the outside. The above-described chlorine and sulfur can be captured in the same fashion by an alkali metal component which may be contained in the agglomerate (for example, oxide-containing cores) to be used for the manufacture of a reduced metal. However, since the alkali metal contained in the fuel is released into exhaust gas more efficiently than the alkali metal contained in the agglomerate, it is more effective to control the amount of the alkali metal contained in the fuel.

[0045] In consideration of the above, according to the present invention, the amount of the alkali metal to be blended and the amount of S and Cl generated in the furnace are preferably controlled so as to satisfy the following expression.

$$\begin{aligned}
 &[(\text{Alkali-metal-molar content in fuel}) + (\text{Alkali-metal-} \\
 &\text{molar content released from raw material agglomerate into} \\
 &\text{exhaust gas}) + (\text{Alkali-metal-molar content released from} \\
 &\text{other fuel into exhaust gas})] \geq [(\text{S-molar content in fuel}) \times \\
 &2 + (\text{S-molar content released from raw material agglomerate} \\
 &\text{into exhaust gas}) \times 2 + (\text{S-molar content released from other} \\
 &\text{fuel into exhaust gas}) \times 2 + (\text{Cl-molar content in fuel}) + \\
 &(\text{Cl-molar content released from raw material agglomerate} \\
 &\text{into exhaust gas}) + (\text{Cl-molar content released from other} \\
 &\text{fuel into exhaust gas})] \quad (1)
 \end{aligned}$$

[0046] In the expression (1), "other fuel" means additional fuel which does not include a combustible waste. The examples of "other fuel" are heavy oil, pulverized coal and so on.

[0047] Although the method of adding the alkali metal to the fuel is not particularly specified, a method of adding a lubricant containing the alkali metal to the fuel may be used. By controlling the amount of the lubricant to be blended, the amount of the alkali metal can be easily controlled.

[0048] S and Cl captured by the alkali metal pass a bag filter mounted in exhaust-gas treating facilities, in which there is a problem in that the alkali metal in collecting dust increases, thereby increasing moisture absorption by and deliquescence of the dust and clogging the bag filter. Therefore, a casing of the bag filter disposed in the facilities for treating the exhaust gas of the moving hearth furnace is preferably heat-insulated so that the surface temperature of the bag filter is higher than the acid dew point by at least 10°C. With this arrangement, the moisture in the exhaust gas is prevented from condensation in the bag filter, thereby suppressing clogging of the bag filter.

[0049] According to the present invention, the above-described fuel may be used as a fuel for the burner disposed in the furnace, or may be used as an auxiliary fuel by being supplied through a supply port (for example, a spray) disposed in addition to the burner. The present invention is also applicable to a case in which the above-described fuel including combustible wastes is used as a mixture with a conventional fuel (for example, heavy oil). The moving hearth furnace according to the present invention is not particularly specified. The present invention is also applicable to a rotary-hearth furnace or a straight hearth furnace.

[0050] The present invention is described below further in detail according to embodiments. The invention is not limited to these embodiments, and the embodiments may be modified in design within the technical scope of the present

invention to the effect described above and below.

[0051] Fig. 1 shows a rotary-hearth furnace used for reduction by heating of a metal oxide and exhaust-gas treating facilities for exhaust gas discharged during the reduction by heating. Numeral 5 in the drawing denotes a rotary-furnace (extension of a rotary-furnace shown in Fig. 2). The exhaust gas from the rotary-hearth furnace produced during the reduction by heating of the metal oxide flows via a path 11. Coarse powder dust and the like are removed from the exhaust gas in a gas-cooling tower 21. The treated exhaust gas flows via a path 12 into a heat exchanger 23, and is cooled by exchanging heat with the air supplied by an air blower 22. The heated air as combustion air is supplied via a path 14 to a burner which is mounted to the rotary-hearth furnace 5. The surplus heated-air is discharged via a path 13 and is used as a heat source for related facilities (boiler and the like).

[0052] The exhaust gas cooled by exchanging heat in the heat exchanger 23 is sent to an off-gas bag filter 24 for cleaning via a path 15 and is released from a stack 26 via a path 16 and an ID fan 25.

[0053] A fuel such as heavy oil or natural gas is supplied to the rotary-hearth furnace 5 via a line 17, and another fuel including combustible wastes is supplied thereto via a line 10.

[0054] Figs. 2 to 4 are schematic illustrations for describing in detail the rotary-hearth furnace 5 shown in Fig. 1, the rotary-hearth furnace 5 including a dome structure having a donut-shaped rotary hearth. Fig. 2 is a schematic perspective view. Fig. 3 is a sectional view along line A-A of the rotary-hearth furnace 5 shown in Fig. 2. Fig. 4 is a schematic sectional view of the rotary-hearth furnace shown in Fig. 2 extended in the rotational direction thereof for facilitating description. Numeral 1 in the drawings denotes a rotary hearth and numeral 2 denotes a furnace body which covers the rotary hearth. The rotary hearth 1 can be driven for rotation at a proper speed by a driving mechanism not shown.

[0055] A plurality of burners 3 are provided at appropriate positions of walls of the furnace body 2. Combustion heat of the burners 3 and radiation heat therefrom are transferred to an agglomerate on the rotary hearth 1, thereby reducing by heating the formed body. The inside of the furnace body 2 is divided into a first zone Z_1 , a second zone Z_2 , an exhaust zone, a third zone Z_3 , and a fourth zone Z_4 by four baffle walls K_1 , K_2 , K_3 , and K_4 . Loading means 4 for raw materials and raw-material additives is disposed opposing the rotary hearth 1 at the uppermost streamside in the rotational direction of the furnace body 2. Discharging means 6 for a reduced metal produced by reduction by heating is provided at the lowermost streamside in the rotational direction (and directly upstream the loading means 4 in the rotational direction).

[0056] In the operation of the reduction furnace, an agglomerate including iron oxide waste generated in a steel mill and a carbonaceous material is supplied by the loading means 4 so as to accumulate by an appropriate thickness on the rotary hearth 1 which rotates at a given speed. The zones Z_1 to Z_4 are heated by the burners 3 so that the temperature therein becomes 1100°C to 1350°C. The burners 3 are supplied with a fuel such as heavy oil or natural gas via the line 17 and with combustion air via the path 14.

[0057] Although according to the present embodiment, the burners 3 are disposed at the sidewalls, the burners 3 may be disposed at the ceiling. The inside of the rotary furnace is divided into each zone by the four baffle walls K_1 to K_4 . However, the configuration of the furnace according to the present invention is not limited to this embodiment, and it may be modified appropriately in accordance with the size of the furnace, the targeted production capacity, the operation pattern, and the like.

[Test 1]

[0058] The amount of supply of natural gas was compared between a case in which the burners 3 shown in Fig. 3 were supplied with natural gas as a fuel for manufacturing a reduced metal and another case in which a fuel including combustible wastes was supplied to sprays 7, which were provided in addition to the burners 3, and was burned in the furnace as an auxiliary fuel. The burners 3 are supplied with the natural gas from the line 17 and with heated air via the path 14. The sprays 7 are supplied with the fuel including combustible wastes from the line 10 and with the heated air via the path 14, and spray the fuel into the furnace with compressed air supplied via a path 18. Pilot burners 8 are provided in the vicinities of the sprays 7 for igniting the fuel.

[0059] A material including iron-oxide-containing dust was used as a metal oxide, which was formed as pellets having sizes of approximately 12 to 18 mm by using a disc pelletizer having a diameter of 3000 mm. Regarding the content of carbon, the carbon concentration is controlled in accordance with the requirement for the reduction of the metal oxide and the downstream melting process.

[0060] A mixture of waste mineral oil, waste vegetable oil, waste animal oil, and the like was used as the fuel including combustible wastes (hereinafter sometimes referred to simply as "the fuel"), and was controlled so as to have a viscosity of 15 cP at 25°C and a higher calorific value of 18.0 to 21.3 MJ/kg. The composition of the fuel is shown in table 1. The fuel contains moisture of 37 to 49% by mass.

Table 1

Composition (% by mass)				
C	H	N	O	S
38 to 46	10 to 12	0.5 to 1.5	37 to 50	0.1 to 0.5

[0061] When only the burners 3 shown in Fig. 3 were used for reducing by heating a metal oxide included in pellets weighing 2000 kg which were loaded by the loading means 4 for raw materials and raw-material additives for the rotary-hearth furnace shown in Fig. 4, the calorific value required of the combustion heat from the supply gas was 20.9 GJ. When the burners 3 and the sprays 7 were together used, the calorific value of 6.3 GJ required of the combustion heat from the supply gas was sufficient. That is, according to the present invention, the fuel cost can be significantly reduced.

[Test 2]

[0062] The relationship between the diameter of the orifices of the sprays 7 and clogging of the orifices was studied, in which the fuel including combustible wastes was sprayed into the furnace by using the sprays 7 while changing the diameter of the orifices of the sprays 7. As a result, the orifices clogged in approximately 15 minutes after the spray of the fuel started when the diameter of the orifices was 0.6 mm, and the spray of the fuel could not continue. On the other hand, when the diameter of the orifices was set to 1.1 mm, the spray of the fuel could continue for an hour without cleaning of the orifices. When the diameter of the orifices was set to 2.2 mm, the fuel could continue to be stably sprayed for 24 hours without cleaning of the orifices.

[Test 3]

[0063] A flowmeter to be appropriately used for measuring the flow rate (spray amount) of the fuel was studied. As a result, measurement by using a positive displacement meter was impossible because foreign substances included in the fuel were bitten. When an electromagnetic flowmeter was used, the fuel could continue to be sprayed because there were no moving parts in flow paths. However, electric conductivity varied according to the variation in the composition of the fuel, whereby the flow amount could not be correctly measured sometimes. A stable measurement was possible with a Coriolis-type flowmeter.

[Test 4]

[0064] The relationship between the temperature in the furnace and the combustion of the fuel was studied. As shown in Fig. 3, the sprays 7 were provided and the pilot burners 8 were disposed in the vicinities of the sprays 7. The fuel was sprayed by the sprays 7 and was burned. As a result, the pilot burners 8 did not ignite the fuel when the temperature in the furnace was 100°C. When the temperature in the furnace was increased to 200°C, the fuel was ignited and burned although slightly instable. When the temperature in the furnace was increased to 560°C, the fuel was ignited immediately after it was sprayed into the furnace and a stable combustion state could be maintained. Therefore, the temperature in the furnace is preferably controlled so as to be not lower than 150°C in order to stably ignite and burn the fuel.

[Test 5]

[0065] The relationship between the temperature in the furnace and the combustion of the fuel was studied, in which the fuel was supplied by being sprayed by the sprays 7 shown in Fig. 3 and the pilot burners 8 were not used. The temperature in the zone Z1 of the furnace was controlled so as to be 500°C, 700°C, and 1000°C and the combustion state of the fuel sprayed into the furnace at each temperature was monitored. As a result, combustion was difficult and the fuel was not self-ignited at a temperature of 500°C in the furnace. When the temperature in the furnace was 700°C, the fuel was burned although slightly instable. When the temperature in the furnace was 1000°C, the fuel was self-ignited. Since the calorific value of the fuel varies depending on the composition thereof, the temperature in the furnace is preferably not lower than 600°C so that the fuel including combustible wastes sprayed into the furnace is burned (self-burned).

[Test 6]

[0066] The effect on reduction of the amount of gas was studied, in which a mixture of mixed dust of the metal oxide, a carbonaceous reducing agent, and the fuel including combustible wastes formed as pellets (briquettes) was loaded into the furnace. Five units of mass of the fuel including combustible wastes and 100 units of mass of the dust of the metal oxide mixed with each other were kneaded by a mixer, were compression-molded to be formed as pellets, and were thrown into the furnace by the loading means 4 for raw materials and raw-material additives. Only the burners 3 were used as a heat source for the reduction by heating. As a result, the calorific value from the gas as a fuel for the burners 3 required for reducing by heating the mixed dust of 1 ton could be reduced by 0.4 GJ, in comparison with the case where the fuel does not include combustible wastes.

[Test 7]

[0067] The fuel was poured, without using the sprays 7, into the zone Z_1 shown in Fig. 4 of the furnace. The fuel was poured into the furnace through a fuel-pouring nozzle 9 shown in Fig. 3 (although the fuel was poured into the furnace from an upper part thereof, it may be poured from a wall or the like). As a result, although the fuel was accumulated on the pellets immediately after it was poured, it was found to have been burned out from the hearth when viewed approximately 3 minutes after the fuel was poured. No fuel content was detected in the mixed-dust agglomerates (reduced agglomerates) which were discharged approximately 12 minutes after the fuel was poured into the furnace. In this case, the calorific value from the supply gas for the burners 3 could be reduced by 2.1 GJ, in comparison with the case where the fuel does not include combustible wastes.

[0068] When the viscosity of the fuel increases, the fuel becomes difficult to diffuse in the furnace. Therefore, it is difficult to advance combustion of the fuel. However, the inventors confirmed that the poured fuel having a viscosity of 50 cP at 20°C was completely burned in approximately 5 minutes. In this case, the calorific value from the burners 3 could be reduced also by 2.1 GJ.

[Test 8]

[0069] The effect of an alkali metal contained in the fuel including combustible wastes was studied.

[0070] The amount of the alkali metal to be included in the fuel was controlled by adding a lubricant which contains the alkali metal to the fuel including combustible wastes. The compositions (only S, Cl, Na, and K) of the fuel which satisfies the above expression (1) are shown in table 2, the fuel being referred to as "fuel containing alkali metal" in the table. A fuel of which the content of alkali metal is less than 0.1% per chemical element is referred to as "fuel not containing alkali metal". The result of computation by using the above expression (1) is as follows.

$$\begin{aligned}
 & (\text{S-molar content in fuel}) \times 2 + (\text{S-molar content} \\
 & \text{released from raw material agglomerate into exhaust gas}) \times 2 \\
 & + (\text{S-molar content released from fuel into exhaust gas}) \times 2 \\
 & + (\text{Cl-molar content in fuel}) + (\text{Cl-molar content released} \\
 & \text{from raw material agglomerate into exhaust gas}) + (\text{Cl-molar} \\
 & \text{content released from fuel into exhaust gas}) = 1029 \text{ mol}
 \end{aligned}$$

<In the case of the fuel containing an alkali metal>

[0071]

$$\begin{aligned}
 & (\text{Alkali-metal-molar content in fuel}) + (\text{Alkali-metal-} \\
 & \text{molar content released from raw material agglomerate into} \\
 & \text{exhaust gas}) + (\text{Alkali-metal-molar content released from}
 \end{aligned}$$

fuel into exhaust gas) = 1170 mol

<In the case of the fuel not containing alkali metal>

[0072]

(Alkali-metal-molar content in fuel) + (Alkali-metal-
molar content released from raw material agglomerate into
exhaust gas) + (Alkali-metal-molar content released from
fuel into exhaust gas) = 984 mol

[0073] The higher calorific value is 18.8 MJ/kg in both cases.

Table 2

	Composition (% by mass)			
	S	Cl	Na	K
Fuel containing alkali metal	0.5	0.1	0.5	0.2
Fuel not containing alkali metal	0.5	0.1	below 0.1	below 0.1

[0074] Agglomerate including a metal oxide having a weight of 2000 kg was reduced by heating by using a "fuel containing an alkali metal" and another "fuel not containing alkali metal", and the volumes of generated SO_x and HCl were measured at a section (A) shown in Fig. 1. The result is shown in table 3.

Table 3

	SO _x	Cl-based gas
Case of fuel containing alkali metal	24 ppm	40 ppm
Case of fuel not containing alkali metal	30 ppm	60 ppm

[0075] As shown in table 3, SO_x and a chloric gas such as HCl included in exhaust gas which is generated during reduction by heating of a metal can be reduced when an alkali metal is contained in the fuel including combustible wastes so that the above expression (1) is satisfied.

[Test 9]

[0076] The operational conditions of a bag filter provided in the exhaust-gas treating facilities of the rotary-hearth furnace were studied. Clogging of the filter was monitored while the casing of the bag filter was not heat insulated and while it was heat insulated. As a result, the filter was clogged in approximately one month when it was not heat insulated. When temperature at the surface of the filter fabric was kept higher than the acid dew point by 10°C, the moisture contained in the exhaust gas was not condensed, and clogging of the bag filter due to condensation of the alkali metal could be suppressed.

Claims

1. An operation method of a moving hearth furnace, in which a reduced metal is obtained by loading a metal oxide into the moving hearth furnace and reducing the metal oxide by heating, the method comprising the steps of:

supplying a fuel including combustible wastes as a heat source into the moving hearth furnace and burning the fuel.

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2. The operation method of a moving hearth furnace, according to claim 1, wherein a liquid is used as the fuel, and one part of the fuel or the entire fuel is sprayed into the moving hearth furnace.
3. The operation method of a moving hearth furnace, according to claim 2, wherein the diameter of each orifice of a spray for spraying the fuel is set to be not smaller than 1.1 mm.
4. The operation method of a moving hearth furnace, according to claim 2 or 3, wherein the fuel is ignited by a pilot burner which is disposed in the vicinity of a position at which the fuel is sprayed.
5. The operation method of a moving hearth furnace, according to one of claims 2 to 4, wherein the temperature in the furnace is set to be not lower than 150°C.
6. The operation method of a moving hearth furnace, according to claim 1, wherein a liquid is used as the fuel, and one part of the fuel or the entire fuel is poured into the moving hearth furnace.
7. The operation method of a moving hearth furnace, according to claim 1, wherein one part of the fuel or the entire fuel is mixed with the metal oxide, and the mixture is loaded into the moving hearth furnace.
8. The operation method of a moving hearth furnace, according to claim 6 or 7, wherein the temperature in the furnace is set to be not lower than 1100°C and the residence time of the fuel in the furnace is set to be not shorter than three minutes.
9. The operation method of a moving hearth furnace, according to one of claims 1 to 8, further comprising the step of including an alkali metal to the fuel.
10. The operation method of a moving hearth furnace, according to claim 9, wherein the amount of the alkali metal to be included in the fuel is controlled in accordance with the amount of S and Cl generated in the furnace during the reduction by heating.

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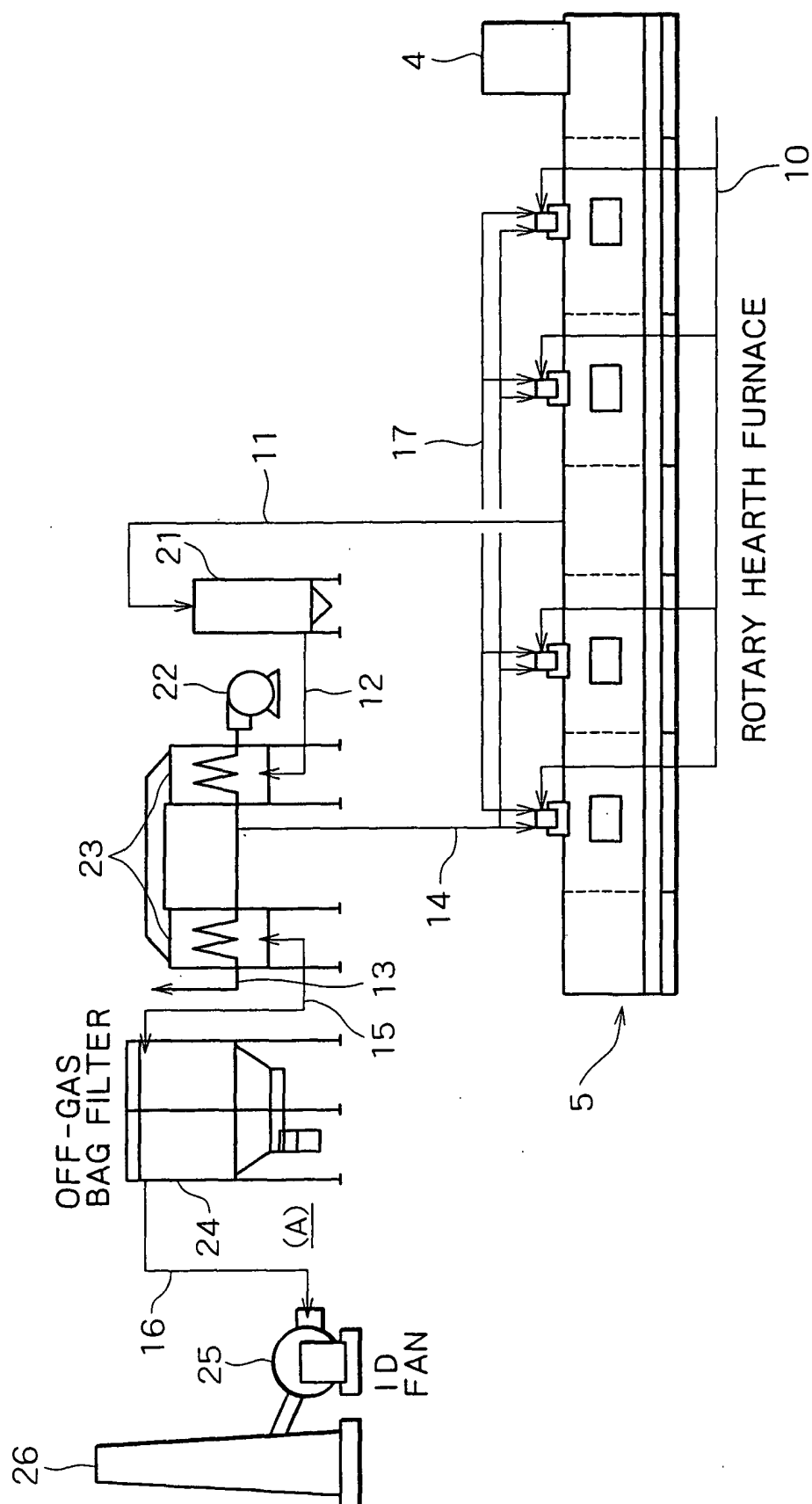


FIG. 2

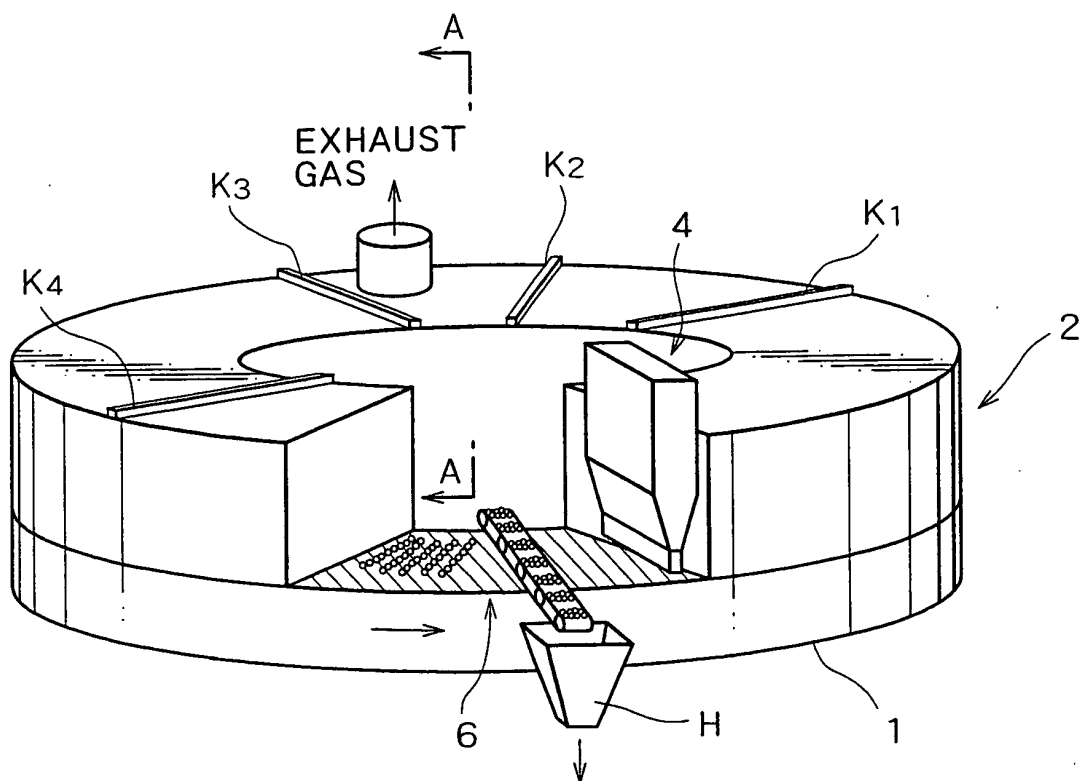


FIG. 3

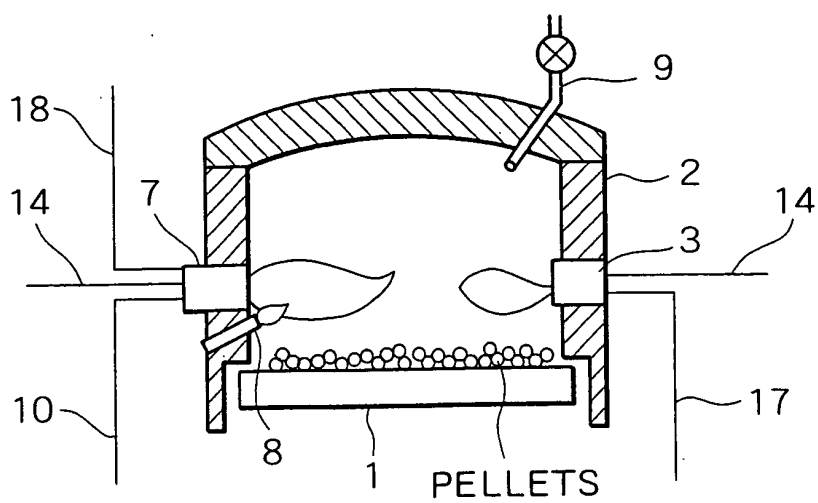


FIG. 4

