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(54) **Method for manufacturing an austenitic stainless steel from a nickel laterite ore and a chromite ore**

(57) A method for manufacturing an austenitic stainless steel from a nickel laterite ore and a chromite ore includes the steps of determining a nickel content of the nickel laterite ore; processing the nickel laterite ore into a nickel-containing precursor based on the determination; obtaining a molten ferrochrome from the chromite

ore; transferring the nickel-containing precursor into a converter, and hot charging the molten ferrochrome into the converter to obtain a molten stainless steel; and charging the molten stainless steel into a continuous casting machine to obtain a stainless steel slab.

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Description

[0001] The invention relates to a method for manufacturing an austenitic stainless steel, more particularly to a method for manufacturing an austenitic stainless steel from a nickel laterite ore and a chromite ore.

[0002] In a conventional method for manufacturing an austenitic stainless steel, scrap and ferroalloy are used as main raw materials and are smelted into a molten metal in an electric furnace. The molten metal is then transferred to a converter along with adding a ferronickel and/or a ferrochrome into the converter in a ratio determined according to the specific steel to be made (for example, 200 or 300 series stainless steel), thereby obtaining an austenitic stainless steel. Since the cost for a noble metal such as nickel is about 40-50% of the total cost for the stainless steel, the profit of the stainless steel manufacturer is easily affected or even lost due to the price volatility of the noble metal.

[0003] There has been developed a process for producing a stainless steel master alloy by directly smelting a nickel laterite ore and a chromite ore as raw materials in an electric furnace or a blast furnace, as disclosed in Chinese Patent Publication Nos. CN 102212691 A and CN 101701312 A, so as to save the cost for manufacturing a stainless steel. However, in the process disclosed in the aforesaid prior art, the nickel laterite ore and the chromite ore are not pretreated to remove free water and crystallization water prior to the smelting procedure, and a relatively great amount of energy is consumed to remove water during the smelting procedure. Furthermore, there are other disadvantages in the process of the aforesaid prior art, such as difficulty in control of the nickel content in the molten metal, relatively great amount of impurities, and inferior recovery rate. Additionally, rare metal such as cobalt usually contained in the nickel laterite ore cannot be extracted and recovered in the process of the aforesaid prior art.

[0004] Therefore, the object of the present invention is to provide a cost-effective method for manufacturing an austenitic stainless steel from a nickel laterite ore and a chromite ore.

[0005] According to a first aspect of this invention, there is provided a method for manufacturing an austenitic stainless steel from a nickel laterite ore and a chromite ore. The method includes steps of:

a) crushing, screening, and blending the nickel laterite ore, followed by roasting the nickel laterite ore in a rotary kiln to remove free water and crystallization water along with charging a reducing agent into the rotary kiln to obtain a calcine, and smelting the calcine in an electric furnace to obtain a molten ferronickel;

b) sintering the chromite ore in a sintering device to obtain a sintered chromite ore, followed by smelting the sintered chromite ore along with a coke particle in another electric furnace to obtain a molten ferro-

chrome;

c) hot charging the molten ferronickel and the molten ferrochrome into a converter to obtain a molten stainless steel; and

d) charging the molten stainless steel into a continuous casting machine to obtain a stainless steel slab.

[0006] According to a second aspect of this invention, there is provided a method for manufacturing an austenitic stainless steel from a nickel laterite ore and a chromite ore. The method includes steps of:

a) crushing the nickel laterite ore and pulping the nickel laterite ore with water to form a pulp material, followed by agitating the pulp material with a sulfuric acid solution under a high pressure atmosphere to form a mixture, filtering a leach solution containing nickel and cobalt out of the mixture, separating the leach solution by solvent extraction into an extraction solution containing nickel and an anti-extraction solution containing cobalt, and electrolyzing the extraction solution and the anti-extraction solution to obtain pure nickel and pure cobalt, respectively;

b) sintering the chromite ore in a sintering device to obtain a sintered chromite ore, followed by smelting the sintered chromite ore in an electric furnace to obtain a molten ferrochrome;

c) transferring the pure nickel into a converter, and hot charging the molten ferrochrome into the converter to obtain a molten stainless steel; and

d) charging the molten stainless steel into a continuous casting machine to obtain a stainless steel slab.

[0007] According to a third aspect of this invention, there is provided a method for manufacturing an austenitic stainless steel from a nickel laterite ore and a chromite ore. The method includes steps of:

a) determining whether a nickel content of the nickel laterite ore is less than 1.5 wt% based on total weight of the nickel laterite ore;

b) processing the nickel laterite ore into a nickel-containing precursor based on the determination made in step a);

c) sintering the chromite ore in a sintering device to obtain a sintered chromite ore, followed by smelting the sintered chromite ore along with a coke particle in an electric furnace to obtain a molten ferrochrome;

d) transferring the nickel-containing precursor into a converter, and hot charging the molten ferrochrome into the converter to obtain a molten stainless steel; and

e) charging the molten stainless steel into a continuous casting machine to obtain a stainless steel slab.

[0008] A method for manufacturing an austenitic stainless steel from a nickel laterite ore and a chromite ore according to a first preferred embodiment of the present

invention includes steps of:

steel slab.

i) obtaining a molten ferronickel:

The nickel laterite ore is dried in a drying kiln at a drying temperature ranging from 600 °C to 700 °C to remove free water contained in the nickel laterite ore from 30-35% to 10-20%. The nickel laterite ore is then crushed, screened, and blended, followed by roasting in a rotary kiln at a roasting temperature ranging from 800 °C to 950 °C to remove residual free water and crystallization water from the nickel laterite ore. When the nickel laterite ore is roasted in the rotary kiln, a reducing agent such as anthracite coal is fed into the rotary kiln to obtain a pre-reduced calcine. The calcine is molten in an electric furnace to obtain the molten ferronickel. The tapping temperature of the slag is controlled in a range from 1550 °C to 1650 °C and the tapping temperature of the molten ferronickel is controlled in a range from 1400 °C to 1500 °C so as to obtain a better effect for separating the slag from the molten ferronickel. The molten ferronickel includes: 8-15 wt% of Ni, less than 4 wt% of C, less than 2 wt% of Si, and less than 0.06 wt% of P.

ii) obtaining a molten ferrochrome:

The chromite ore (content of Cr_2O_3 : less than 62 wt%) is mixed with a coke powder and is pressed in a ball press machine to form chromite pellets, followed by drying the chromite pellets to remove water. The dried chromite pellets are then sintered in a sintering device at a temperature ranging from 1350 °C to 1450 °C to obtain a sintered chromite ore having a particle size less than 30 mm. The sintered chromite ore along with a coke particle is then molten in another electric furnace to obtain the molten ferrochrome. The tapping temperature of the slag is controlled in a range from 1600 °C to 1700 °C. The molten ferrochrome includes: less than 60 wt% of Cr, less than 9 wt% of C, less than 5 wt% of Si, and less than 0.03 wt% of P.

iii) obtaining a molten stainless steel:

The molten ferronickel and the molten ferrochrome are transferred into a converter in a hot charging manner to obtain the molten stainless steel.

iv) obtaining a stainless steel slab:

The molten stainless steel is charged into a continuous casting machine to obtain the stainless

[0009] The aforesaid steps iii) and iv) can be conducted in a manner well known in the art, and thus are not described in detail herein.

[0010] The molten ferronickel and the molten ferrochrome can be added into the converter in a ratio determined according to the specific stainless steel to be manufactured. For example, the 202 series stainless steel contains 4-6 wt% of Ni and 17-19 wt% of Cr, and the 304 series stainless steel contains 8-10.5 wt% of Ni and 17.5-19.5 wt% of Cr. When the molten ferronickel obtained in step i) contains 8 wt% of Ni, and the molten ferrochrome obtained in step ii) contains 50 wt% of Cr, the 202 series stainless steel can be manufactured by formulating 65 wt% of the molten ferronickel with 35 wt% of the molten ferrochrome. When the molten ferronickel obtained in step i) contains 15 wt% of Ni, and the molten ferrochrome obtained in step ii) contains 40 wt% of Cr, the 304 series stainless steel can be manufactured by formulating 55 wt% of the molten ferronickel with 45 wt% of the molten ferrochrome.

[0011] In the aforesaid preferred embodiment, the molten ferronickel and the molten ferrochrome are obtained respectively from the nickel laterite ore and the chromite ore, the stainless steel of various series can be manufactured by formulating the molten ferronickel with the molten ferrochrome in a specific ratio of the molten ferronickel to the molten ferrochrome, which can be easily adjusted and controlled according to the specific stainless steel to be manufactured. Therefore, the consumption of fuel and electricity can be reduced due to the reduction of the repeated melting times, and the manufacturing cost can be effectively controlled so as to raise the profit for the manufacturer.

[0012] A method for manufacturing an austenitic stainless steel from a nickel laterite ore and a chromite ore according to a second preferred embodiment of the present invention includes steps of:

l) obtaining pure nickel and pure cobalt:

The nickel laterite ore is crushed and pulped with water to form a pulp material, followed by agitating the pulp material with a sulfuric acid solution under a high pressure atmosphere to form a mixture. A solid-liquid ratio of the nickel laterite ore to the sulfuric acid solution is about 1:4 in the mixture. The pulp material is agitated with the sulfuric acid solution under a pressure ranging from 4 to 5 MPa and at a temperature ranging from 250°C to 300°C. A leach solution containing nickel and cobalt is then filtered out of the mixture. The leach solution is separated by solvent extraction into an extraction solution containing nickel and an anti-extraction solution containing cobalt. The extraction solution and the anti-extraction solution are electrolyzed to

obtain pure nickel and pure cobalt, respectively. The purity of the pure nickel is greater than 99 wt%, and the recovery rate of the pure nickel and cobalt is greater than 90% in the preferred embodiment.

II) obtaining a molten ferrochrome:

This step can be conducted in a manner identical to the aforesaid step ii) in the first preferred embodiment.

III) obtaining a molten stainless steel:

The pure nickel is transferred into a convertor via a belt conveyor, and the molten ferrochrome is hot charged into the convertor to obtain the molten stainless steel.

IV) obtaining a stainless steel slab:

This step can be conducted in a manner identical to the aforesaid step iv) in the first preferred embodiment.

[0013] When the pure nickel obtained in step I) has a purity of 99 wt%, and the molten ferrochrome obtained in step II) contains 24 wt% of Cr, the aforesaid 202 series stainless steel can be manufactured by formulating 5 wt% of the pure nickel, 75 wt% of the molten ferrochrome, and 20 wt% of a carbon steel scrap. The aforesaid 304 series stainless steel can be manufactured by formulating 9 wt% of the pure nickel, 76 wt% of the molten ferrochrome, and 15 wt% of a carbon steel scrap.

[0014] In addition to the aforesaid effect achievable in the first preferred embodiment, in which the stainless steel of various series can be manufactured by formulating the pure nickel, the molten ferrochrome, and the carbon steel scrap in a specific ratio thereof, valuable pure cobalt can be obtained in the aforesaid step I) along with the pure nickel so as to obtain an additional economic benefit.

[0015] A method for manufacturing an austenitic stainless steel from a nickel laterite ore and a chromite ore according to a third preferred embodiment of the present invention includes steps of:

A) determining a nickel content of a nickel laterite ore:

When the nickel content of the nickel laterite ore is determined to be not less than 1.5 wt% based on total weight of the nickel laterite ore, the following steps are performed.

B) obtaining a molten ferronickel:

This step can be conducted in a manner identical to the aforesaid step i) in the first preferred em-

bodiment.

C) obtaining a molten ferrochrome:

This step can be conducted in a manner identical to the aforesaid step ii) in the first preferred embodiment.

D) obtaining a molten stainless steel:

This step can be conducted in a manner identical to the aforesaid step iii) in the first preferred embodiment.

E) obtaining a stainless steel slab:

This step can be conducted in a manner identical to the aforesaid step iv) in the first preferred embodiment.

[0016] As described above, the molten ferronickel and the molten ferrochrome can be added into the converter in a ratio determined according to the specific stainless steel to be manufactured.

[0017] On the other hand, when the nickel content of the nickel laterite ore is determined to be less than 1.5 wt% based on total weight of the nickel laterite ore, the following steps are performed.

[0018] B') obtaining pure nickel and pure cobalt:

This step can be conducted in a manner identical to the aforesaid step I) in the second preferred embodiment.

[0019] C') obtaining a molten ferrochrome:

This step can be conducted in a manner identical to the aforesaid step ii) in the first preferred embodiment.

[0020] D') obtaining a molten stainless steel:

This step can be conducted in a manner identical to the aforesaid step III) in the second preferred embodiment.

[0021] E') obtaining a stainless steel slab:

This step can be conducted in a manner identical to the aforesaid step IV) in the second preferred embodiment.

[0022] As described above, the stainless steel of various series can be manufactured by formulating the pure nickel with the molten ferrochrome along with the carbon steel scrap in a specific ratio, which can be easily adjusted and controlled according to the specific stainless steel to be manufactured. Furthermore, other noble metals,

such as pure cobalt, can be obtained along with the pure nickel in the electrolytic step. Therefore, the economic value of the method for manufacturing an austenitic stainless steel of the present invention can be further raised.

[0023] Alternatively, in the third preferred embodiment, both the molten ferronickel and the pure nickel can be transferred into the convertor, and the molten ferrochrome is hot charged into the convertor so as to obtain the molten stainless steel.

[0024] In the method for manufacturing an austenitic stainless steel of the present invention, the nickel laterite ore can be effectively treated to obtain a molten ferronickel or a pure nickel. Therefore, the method for manufacturing an austenitic stainless steel of the present invention is relatively flexible and cost-effective as compared to the prior art.

Claims

1. A method for manufacturing an austenitic stainless steel from a nickel laterite ore and a chromite ore, said method being **characterized by** steps of:

- a) crushing, screening, and blending the nickel laterite ore, followed by roasting the nickel laterite ore in a rotary kiln to remove free water and crystallization water along with charging a reducing agent into the rotary kiln to obtain a calcine, and smelting the calcine in an electric furnace to obtain a molten ferronickel;
- b) sintering the chromite ore in a sintering device to obtain a sintered chromite ore, followed by smelting the sintered chromite ore along with a coke particle in another electric furnace to obtain a molten ferrochrome;
- c) hot charging the molten ferronickel and the molten ferrochrome into a converter to obtain a molten stainless steel; and
- d) charging the molten stainless steel into a continuous casting machine to obtain a stainless steel slab.

2. The method for manufacturing an austenitic stainless steel as claimed in Claim 1, **characterized in that**, in step (a), a roasting temperature of the rotary kiln ranges from 800°C to 950°C and a tapping temperature of the molten ferronickel ranges from 1400°C to 1500°C.

3. The method for manufacturing an austenitic stainless steel as claimed in Claim 1, further **characterized by** steps of pressing the chromite ore with a coke powder in a ball press machine to form chromite pellets and drying the chromite pellets to remove water prior to step b).

4. The method for manufacturing an austenitic stain-

less steel as claimed in Claim 1, **characterized in that** the sintered chromite ore has a particle size less than 30 mm.

5. The method for manufacturing an austenitic stainless steel as claimed in Claim 1, further **characterized by** a step of drying the nickel laterite ore in a drying kiln to remove a portion of the free water prior to step a).

6. A method for manufacturing an austenitic stainless steel from a nickel laterite ore and a chromite ore, said method being **characterized by** steps of:

- a) crushing the nickel laterite ore and pulping the nickel laterite ore with water to form a pulp material, followed by agitating the pulp material with a sulfuric acid solution under a high pressure atmosphere to form a mixture, filtering a leach solution containing nickel and cobalt out of the mixture, separating the leach solution by solvent extraction into an extraction solution containing nickel and an anti-extraction solution containing cobalt, and electrolyzing the extraction solution and the anti-extraction solution to obtain pure nickel and pure cobalt, respectively;
- b) sintering the chromite ore in a sintering device to obtain a sintered chromite ore, followed by smelting the sintered chromite ore in an electric furnace to obtain a molten ferrochrome;
- c) transferring the pure nickel into a converter, and hot charging the molten ferrochrome into the converter to obtain a molten stainless steel; and
- d) charging the molten stainless steel into a continuous casting machine to obtain a stainless steel slab.

7. The method for manufacturing an austenitic stainless steel as claimed in Claim 6, **characterized in that**, in step (a), a solid-liquid ratio of the nickel laterite ore to the sulfuric acid solution is about 1:4, and the pulp material is agitated with the sulfuric acid solution under a pressure ranging from 4 to 5 MPa and at a temperature ranging from 250°C to 300°C.

8. The method for manufacturing an austenitic stainless steel as claimed in Claim 6, further **characterized by** steps of pressing the chromite ore with a coke powder in a ball press machine to form chromite pellets and drying the chromite pellets to remove water prior to step b).

9. The method for manufacturing an austenitic stainless steel as claimed in Claim 6, **characterized in that**, in step (b), the sintered chromite ore has a particle size less than 30 mm.

10. A method for manufacturing an austenitic stainless steel from a nickel laterite ore and a chromite ore, said method being **characterized by** steps of:

a) determining whether a nickel content of the nickel laterite ore is less than 1.5 wt% based on total weight of the nickel laterite ore;
 b) processing the nickel laterite ore into a nickel-containing precursor based on the determination made in step a);
 c) sintering the chromite ore in a sintering device to obtain a sintered chromite ore, followed by smelting the sintered chromite ore along with a coke particle in an electric furnace to obtain a molten ferrochrome;
 d) transferring the nickel-containing precursor into a converter, and hot charging the molten ferrochrome into the converter to obtain a molten stainless steel; and
 e) charging the molten stainless steel into a continuous casting machine to obtain a stainless steel slab.

11. The method for manufacturing an austenitic stainless steel as claimed in Claim 10, **characterized in that**, when the nickel content of the nickel laterite ore is determined to be not less than 1.5 wt%, the nickel-containing precursor is a molten ferronickel, and step b) is conducted by crushing, screening, and blending the nickel laterite ore, followed by roasting the nickel laterite ore in a rotary kiln to remove free water and crystallization water along with charging a reducing agent into the rotary kiln to obtain a calcine, and smelting the calcine in another electric furnace to obtain the molten ferronickel.

12. The method for manufacturing an austenitic stainless steel as claimed in Claim 11, **characterized in that** in step b), a roasting temperature of the rotary kiln ranges from 800°C to 950°C and a tapping temperature of the molten ferronickel ranges from 1400°C to 1500°C.

13. The method for manufacturing an austenitic stainless steel as claimed in Claim 11, further **characterized by** a step of drying the nickel laterite ore in a drying kiln to remove a portion of the free water prior to step b).

14. The method for manufacturing an austenitic stainless steel as claimed in Claim 10, **characterized in that**, when the nickel content of the nickel laterite ore is determined to be less than 1.5 wt%, the nickel-containing precursor is pure nickel, and step b) is conducted by crushing the nickel laterite ore and pulping the nickel laterite ore with water to form a pulp material, followed by agitating the pulp material with a sulfuric acid solution under a high pressure

atmosphere to form a mixture, filtering a leach solution containing nickel and cobalt out of the mixture, separating the leach solution by solvent extraction into an extraction solution containing nickel and an anti-extraction solution containing cobalt, and electrolyzing the extraction solution and the anti-extraction solution to obtain pure nickel and pure cobalt, respectively.

15. The method for manufacturing an austenitic stainless steel as claimed in Claim 14, **characterized in that** in step b), a solid-liquid ratio of the nickel laterite ore to the sulfuric acid solution is about 1:4, and the pulp material is agitated with the sulfuric acid solution under a pressure ranging from 4 to 5 MPa and at a temperature ranging from 250°C to 300°C.

16. The method for manufacturing an austenitic stainless steel as claimed in Claim 10, **characterized in that**

when the nickel content of the nickel laterite ore is determined to be not less than 1.5 wt%, the nickel-containing precursor is a molten ferronickel, and step b) is conducted by crushing, screening, and blending the nickel laterite ore, followed by roasting the nickel laterite ore in a rotary kiln to remove free water and crystallization water along with charging a reducing agent into the rotary kiln to obtain a calcine, and smelting the calcine in another electric furnace to obtain the molten ferronickel;

when the nickel content of the nickel laterite ore is determined to be less than 1.5 wt%, the nickel-containing precursor is pure nickel, and step b) is conducted by crushing the nickel laterite ore and pulping the nickel laterite ore with water to form a pulp material, followed by agitating the pulp material with a sulfuric acid solution under a high pressure atmosphere to form a mixture, filtering a leach solution containing nickel and cobalt out of the mixture, separating the leach solution by solvent extraction into an extraction solution containing nickel and an anti-extraction solution containing cobalt, and electrolyzing the extraction solution and the anti-extraction solution to obtain pure nickel and pure cobalt, respectively; and
 in step (d), the nickel-containing precursor transferred into the converter includes the molten ferronickel and the pure nickel.

17. The method for manufacturing an austenitic stainless steel as claimed in Claim 10, further **characterized by** steps of pressing the chromite ore with a coke powder in a ball press machine to form chromite pellets and drying the chromite pellets to remove water prior to step c).

18. The method for manufacturing an austenitic stainless steel as claimed in Claim 10, **characterized in**

that in step c), the sintered chromite ore has a particle size less than 30 mm.

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EUROPEAN SEARCH REPORT

Application Number
EP 13 17 1750

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EPO FORM 1503 03.82 (P04C01)



EUROPEAN SEARCH REPORT

Application Number
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CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EPO FORM 1503 03/02 (P04/C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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