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• XIAO ZHENMIN.: ‘STATUS OF EXPLOTATION OF LATERITE TYPE NICKEL ORE AND APPLICATION OF HIGH PRESSURE ACID LEACHING TECHNOLOGY IN THE WORLD.’
CHINESE MINING. vol. 11, no. 1, XP008099211

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The present invention relates to a method of blast-furnace smelting, more particularly to a metallurgical method of ferronickel production by blast-furnace smelting nickel oxide ore without crystal water.

Global extensive uses of stainless steel and special steel lead to supply shortage and rapid rise in price of nickel metal, a main element used to smelt stainless steel and special steel. Conventional technology is mature that nickel metal is produced by mainly extracting from nickel sulfide ore, which covers 30% of the nickel resources on the earth. But at present, reserves are in shortage and resources are in crises after continuous exploitation for near one century. People have to pay more attention to the extraction of nickel metal from laterite nickel ore (nickel oxide ore) covering 70% of nickel resources on the earth. The main reason that laterite nickel ore haven’t been exploited on a large scale for a long time is that the technology extracting Ni from such mineral resources is characterized by high cost, technological complexity, low yield, severe pollution. At Present, for high-grade laterite nickel ore (nickel content above 2.0%), ore-smelting furnace is generally used to smelt on the international, however, this method is provided with disadvantages such as high power consumption, severe environmental pollution and low yield of intermittent production. For low-grade laterite nickel ore, hydrometallurgy is commonly used, namely, a method of converting solid-state nickel oxide, chromic oxide, ferric oxide or the like in the laterite nickel ore to mixed solution of liquid-state nickel sulfate, chrome sulfate, ferrite sulfate (Fe²⁺) and the like, then separating nickel sulfate thereby, forming nickel metal only accounting for 1-2% of the gross by electrolysis with all the other components wasted. The process equipment is characterized by large one-off investment, complex process, long periodicity, severe environmental pollution. Blast-furnace smelting may also be use, however, because Cr₂O₃ as concomitant commonly exists in laterite-nickel ore, extremely high melting point of its own can lead to large viscosity of molten iron so that molten iron containing nickel and chrome can’t flow out successfully and cause severe results such as frozen furnace and damaged furnace. Many corporations and research organizations at home and abroad have studied the technology for a long time that ferronickel (nickel iron) can be obtained by blast-furnace smelting laterite nickel ore in one-step way, but hitherto no success is reported. Consequently, it is urgent problem to be solved in this business to find an industrial method that nickel iron is smelted directly from laterite nickel ore, which is characterized by high efficiency, low consumption, high yield, low cost and no pollution or little pollution.

JP 622 90843 relates to the blast furnace smelting of Ni ores in order to produce FeNi. Furthermore, 6B 1400 505 discloses a process for production of FeNi from Ni laterite in a shaft furnace.

To solve the above problem, the present invention provides a metallurgical method of ferronickel by blast-furnace smelting nickel oxide ore containing no crystal water in one-step way.

The invention provides a metallurgical method of ferronickel production by blast-furnace smelting nickel oxide ore containing no crystal water, mainly comprising the steps as follows:

- Crushing and sieving raw ores, separating raw ore block in particulate diameter of 10-60 mm and ore powder in grain diameter smaller than 10 mm, and mixing the feed of ore powder in particulate diameter smaller than 10 mm with coke powder, calcium lime/limestone and sintering to obtain sintered ore blocks;
- Crushing and sieving the sintered ore blocks, separating sintered ore blocks in particulate diameter of 10-50 mm and ore powder in particulate diameter smaller than 10 mm, and sintering the ore powder in particulate diameter smaller than 10 mm again;
- Mixing sintered ore blocks in particulate diameter of 10-60 mm, raw ore block in particulate diameter of 10-50 mm, coke, limestone/calcium lime, dolomite and fluorite and blast-furnace smelting to obtain ferronickel, wherein the weight ratio of the following additives to sintered ore is:
  - fluorite: 0.3~8%
  - dolomite: 0~8%
  - limestone/calcium lime: 4~35%.

Wherein, in an embodiment, only sintered ore blocks in particulate diameter of 10-60 mm, coke, limestone/cal-
cium lime, dolomite and fluorite are added as metallurgical raw material in smelting steps.

[0011] Wherein the main component of the nickel oxide ore and the weight ratio of its own are:

Nickel: 0.5–4.5%;

Chrome: 0.3–12%;

Iron: 38–55%.

[0012] Wherein the preferable weight ratio of the additives to the sintered ore is:

- Fluorite: 0.3–5%
- Dolomite: 0.5–5%
- Limestone/calcium lime: 8–15%.

[0013] Wherein the content of CaO in limestone is greater than 50%, while that of CaO in calcium lime is greater than 80%; the content of Mg in the dolomite is higher than 10% and that of CaF₂ in morite is bigger than 80%.

[0014] Compared with the prior art, furnace temperature can reach up to about 1700 °C in the conventional blast-furnace smelting technology, chrome contained in nickel oxide ore mainly exists in the form of Cr₂O₃ whose melting point is about 2300 °C, consequently, the reduction degree of chrome in nickel oxide ore is limited to cause bad fluidity of the obtained molten iron and easily to produce phenomenon of frozen furnace, and even result in accidents. In metallurgical method of ferronickel by smelting nickel and chrome iron ore provided by the present invention, the addition of fluorite can lower the influence of chrome on furnace temperature effectively and raise the fluidity of molten iron, meanwhile, because the addition quantity of fluorite in metallurgical method provided by the present invention is strictly calculated, the accidents, such as burnout of the crucible, caused by too high addition quantity of fluorite, can be effectively avoided. In the metallurgical method provided by the present invention, meanwhile, magnesium contained in dolomite may also be helpful to solve the problem on bad fluidity of molten iron caused by chrome in nickel and chrome ores. Limestone can not only provide alkalinity, but also can balance the above two additives. The metallurgical method of one-step blast-furnace smelting provided by the present invention is characterized by short technical process, high yield of continuous production, total extraction of nickel, chrome and iron in laterite nickel ore once for all, high ratio of resource utilization. The slag obtained by smelting is an excellent raw material to produce concrete, except the exhaustion of a given mass of CO₂ gas, no other solid or liquid wastes are produced and there is no pollution.

[0015] By contrast, the metallurgical technology of blast-furnace smelting provided by the present invention has some advantages, for example low cost. Blast furnace in the technology provided by the present invention can consume 150-200 kilowatt-hours per ton iron, while the conventional ore smelting technology need consume 2000-4000 kilowatt-hours and cokе of 0.5 ton per ton iron; For example economic resources, high yield, namely the mean yield of blast furnace is bigger than that of ore-smelting furnace; such as little pollution, little dust, high recovery rate of the raw materials which are respectively 97–98% for iron, 99% for nickel and 40–50% for chrome.

Specific embodiment:

[0016] The present invention can further be explained and described in combination with specific examples below. The following examples are not intended to limit the scope of the present invention and all the modifications and rearrangements based on the spirits of the present invention are without departing from scope of the present invention.

[0017] Crushing and sieving raw ores, wherein the raw ore block in particulate diameter of 10-60mm is used as raw material for blast furnace smelting and mixing the feed of ore powder in grain diameter smaller than 10mm thereof with coke powder, calcium lime/limestone and sintering to obtain sintered ore blocks;

[0018] Crushing and sieving the sintered ore blocks, wherein the sintered ore block in particulate diameter of 10-50mm is used as raw material for blast furnace smelting and sintering the ore powder in particulate diameter smaller than 10mm again.

[0019] Mixing sintered ore block, raw ore block, coke, limestone/calcium lime, dolomite and fluorite and blast-furnace smelting to obtain ferronickel.

[0020] Sintered ore and other raw materials can be mixed and smelted, wherein the sintered ore and raw ore may be combined in any proportions and also used in total sintered ore or total raw ore. When raw ore is used in total quantity, the ratio of ore stone to coke is 1.9-2.1:1, when sintered ore is used as the total, that ratio of ore to coke is 2.2-2.4:1.

[0021] The main component in used nickel and chrome iron ore and its content (wt.%) are:
The main component in obtained sintered ore and its content (wt.%) are:

<table>
<thead>
<tr>
<th>Component</th>
<th>Fe</th>
<th>Ni</th>
<th>Cr</th>
<th>Ca</th>
<th>Si</th>
<th>Mg</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series code</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>38.18</td>
<td>4.49</td>
<td>11.92</td>
<td>4.52</td>
<td>3.24</td>
<td>1.67</td>
<td>3.14</td>
</tr>
<tr>
<td>2</td>
<td>40.12</td>
<td>2.97</td>
<td>10.07</td>
<td>4.01</td>
<td>3.12</td>
<td>1.55</td>
<td>3.01</td>
</tr>
<tr>
<td>3</td>
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<td>1.76</td>
<td>9.03</td>
<td>3.45</td>
<td>3.01</td>
<td>1.47</td>
<td>2.88</td>
</tr>
<tr>
<td>4</td>
<td>47.21</td>
<td>1.35</td>
<td>7.48</td>
<td>3.06</td>
<td>2.88</td>
<td>1.20</td>
<td>2.51</td>
</tr>
<tr>
<td>5</td>
<td>50.39</td>
<td>0.087</td>
<td>5.48</td>
<td>2.97</td>
<td>2.56</td>
<td>1.07</td>
<td>2.34</td>
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<tr>
<td>6</td>
<td>54.87</td>
<td>0.53</td>
<td>3.13</td>
<td>2.07</td>
<td>2.15</td>
<td>1.03</td>
<td>2.07</td>
</tr>
</tbody>
</table>

Constitution of the furnace materials (Weight: Kg) is shown in following table.

<table>
<thead>
<tr>
<th>Component</th>
<th>Raw ore</th>
<th>Sintered ore</th>
<th>Coke</th>
<th>Fluorite</th>
<th>Dolomite</th>
<th>Limestone/calcium lime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series code</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
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<td>1000</td>
<td>1000</td>
<td>455</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td>500</td>
<td>1000</td>
<td>415</td>
<td>70</td>
<td>70</td>
<td>70</td>
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<td>3</td>
<td>500</td>
<td>1500</td>
<td>680</td>
<td>60</td>
<td>90</td>
<td>90</td>
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<tr>
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<td>—</td>
<td>1500</td>
<td>625</td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>5</td>
<td>—</td>
<td>2000</td>
<td>920</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>—</td>
<td>2000</td>
<td>830</td>
<td>6</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Metallurgical technology parameters of the blast furnace:
The main component in the obtained nickel iron by smelting and its content (wt.%) are:

<table>
<thead>
<tr>
<th>Component</th>
<th>Fe</th>
<th>Ni</th>
<th>Cr</th>
<th>S</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series code 1</td>
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<td>33.11</td>
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<tr>
<td>Series code 2</td>
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<td>10.59</td>
<td>23.10</td>
<td>0.059</td>
<td>0.061</td>
</tr>
<tr>
<td>Series code 3</td>
<td>64.58</td>
<td>8.32</td>
<td>22.38</td>
<td>0.059</td>
<td>0.059</td>
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<tr>
<td>Series code 4</td>
<td>75.51</td>
<td>5.98</td>
<td>13.36</td>
<td>0.060</td>
<td>0.058</td>
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<tr>
<td>Series code 5</td>
<td>85.29</td>
<td>3.24</td>
<td>7.09</td>
<td>0.058</td>
<td>0.057</td>
</tr>
<tr>
<td>Series code 6</td>
<td>93.46</td>
<td>0.92</td>
<td>0.63</td>
<td>0.057</td>
<td>0.060</td>
</tr>
</tbody>
</table>

Claims

1. A metallurgical method of ferronickel production by blast-furnace smelting nickel oxide ore without crystal water, wherein the said method of blast furnace smelting mainly comprising the following steps:
   Crushing and sieving raw ores, separating raw ore block in particulate diameter of 10-60 mm and ore powder in grain diameter smaller than 10 mm, and mixing the feed of ore powder in grain diameter smaller than 10 mm with coke powder, calcium lime/limestone and sintering to obtain sintered ore blocks;
   Crushing and sieving the sintered ore blocks, separating sintered ore blocks in particulate diameter of 10-50 mm and ore powder in particulate diameter smaller than 10 mm, and sintering the ore powder in particulate diameter smaller than 10 mm again;
   Mixing sintered ore blocks in particulate diameter of 10-60 mm, raw ore block in particulate diameter of 10-50 mm, coke, limestone/calcium lime, dolomite and fluorite and blast-furnace smelting to obtain ferronickel, wherein the weight ratio of the following additives to sintered ore is:
   - fluorite 0.3–8%
   - dolomite 0–8%
   - limestone/calcium lime 4–35%.

2. The metallurgical method according to Claim 1, wherein main component of the said nickel oxide ore and the weight ratio of its own are: Nickel: 0.5–4.5%; Chrome: 0.3–12%; iron: 38–55%.
3. The metallurgical method according to Claim 1, wherein the raw are block may not added as metallurgical raw material in smelting steps.

4. The metallurgical method according to Claim 1 or 3, wherein the preferable weight ratio of the said additives to the sintered ore is:
   - fluorite 0.3–5%
   - dolomite 0.5–5%
   - limestone/calcium lime 8–15%.

5. The metallurgical method according to Claim 1 or 3, wherein the content of CaO in the limestone is greater than 50%, while that of CaO in calcium lime is greater than 80%.

6. The metallurgical method according to Claim 1 or 3, wherein the content of Mg in the dolomite is higher than 10%.

7. The metallurgical method according to Claim 1 or 3, wherein the content of CaF₂ in the fluorite is higher than 80%.

**Patentansprüche**

1. Metallurgisches Verfahren der Ferronickel-Produktion durch Verhüttung von Nickeloxid-Erzer ohne Kristallwasser im Hochofen, worin das Verfahren des Verhüttens im Hochofen hauptsächlich die folgenden Schritte umfaßt:

   Zerkleinern und Sieben von Roherzen, Trennen von Roherz-Blöcken mit einem Teilchen-Durchmesser von 10 bis 60 mm und Erz-Pulver mit einem Korn-Durchmesser von kleiner als 10 mm und Mischen der Beschickung von Erz-Pulver mit einem Korn-Durchmesser von kleiner als 10 mm mit Koks-Pulver, Calciumoxid/Kalkstein und Sintern unter Erhalt gesinterter Erz-Blöcke;

   Zerkleinern und Sieben der gesinterten Erz-Blöcke, Trennen der gesinterten Erz-Blöcke mit einem Teilchen-Durchmesser von 10 bis 50 mm und Erz-Pulver mit einem Teilchen-Durchmesser von kleiner als 10 mm und erneutes Sintern des Erz-Pulvers mit einem Teilchen-Durchmesser von kleiner als 10 mm;

   Mischen von gesinterten Erz-Blöcken mit einem Teilchen-Durchmesser von 10 bis 60 mm, Roherz-Blöcken mit einem Teilchen-Durchmesser von 10 bis 50 mm, Koks, Kalkstein/Calciumoxid, Dolomit und Fluorit und Verhüttung im Hochofen unter Erhalt von Ferronickel, worin der Gewichtsanteil der folgenden Additive zu gesintertem Erz wie folgt ist:

   - Fluorit: 0,3 bis ca. 8 %
   - Dolomit: 0 bis ca. 8 %
   - Kalkstein/Calciumoxid: 4 bis ca. 35 %.

2. Metallurgisches Verfahren nach Anspruch 1, worin die Haupt-Komponenten des Nickeloxid-Erzes und deren eigener Gewichtsanteil sind: Nickel: 0,5 bis ca. 4,5 %; Chrom: 0,3 bis ca. 12 %; Eisen: 38 bis ca. 55 %.

3. Metallurgisches Verfahren nach Anspruch 1, worin der Roherz-Block nicht als metallurgisches Ausgangsmaterial in den Verhüttungsschritten zugesetzt zu werden braucht.

4. Metallurgisches Verfahren nach Anspruch 1 oder 3, worin der bevorzugte Gewichtsanteil der Additive zu dem gesinterten Erz wie folgt ist:

   - Fluorit: 0,3 bis ca. 5 %
   - Dolomit: 0,5 bis ca. 5 %
   - Kalkstein/Calciumoxid: 8 bis ca. 15 %.

5. Metallurgisches Verfahren nach Anspruch 1 oder 3, worin der Gehalt an CaO in dem Kalkstein größer ist als 50 %, während der Gehalt an CaO in dem Calciumoxid größer ist als 80 %.

6. Metallurgisches Verfahren nach Anspruch 1 oder 3, worin der Gehalt an Mg in dem Dolomit höher ist als 10 %.

7. Metallurgisches Verfahren nach Anspruch 1 oder 3, worin der Gehalt an CaF₂ in dem Fluorit höher ist als 80 %.
Revendications

1. Procédé métallurgique d'une production de ferronickel par fusion en haut-fourneau de minerai d'oxyde de nickel dépourvu d'eau cristalline, où ledit procédé de fusion en haut-fourneau comprend essentiellement les étapes suivantes :

broyer et tamiser des minerais bruts, séparer des blocs de minerais bruts en diamètres particulaires de 10-60 mm et la poudre de minerai en diamètre de grain inférieur à 10 mm, et mélanger l'amenée de poudre de minerai d'un diamètre de grain inférieur à 10 mm avec de la poudre de coke, de la chaux riche en calcium/calcaire et friter pour obtenir des blocs de minerai frittés ;
broyer et tamiser les blocs de minerai frittés, séparer les blocs de minerai frittés d'un diamètre particulaire de 10-50 mm et la poudre de minerai d'un diamètre particulaire inférieure à 10 mm et friter la poudre de minerai d'un diamètre particulaire inférieur à 10 mm à nouveau ;
mélanger les blocs de minerai frittés d'un diamètre particulaire de 10-60 mm, un bloc de minerai brut d'un diamètre particulaire de 10-50 mm, du coke, calcaire/chaux riche en calcium, dolomite et fluorite et faire fondre dans le haut-fourneau pour obtenir du ferronickel, où le rapport pondéral des additifs suivants au minerai fritté est :

- fluorite 0,3-8%
- dolomite 0-8%
- calcaire/chaux riche en calcium 4-35%.

2. Procédé métallurgique selon la revendication 1, dans lequel le composant principal dudit minerai d'oxyde de nickel et le rapport pondéral de lui-même sont : nickel : 0,5-4,5% ; chrome : 0,3-12% ; fer : 38-55%.

3. Procédé métallurgique selon la revendication 1, dans lequel le bloc de minerai brut peut ne pas être ajouté comme matériau brut métallurgique pendant les étapes de fusion.

4. Procédé métallurgique selon la revendication 1 ou 3, dans lequel le rapport pondéral préférable desdits additifs audit minerai fritté est :

- fluorite 0,3-5%
- dolomite 0,5-5%
- calcaire/chaux riche en calcium 8-15%.

5. Procédé métallurgique selon la revendication 1 ou 3, dans lequel la teneur en CaO dans le calcaire est supérieure à 50%, tandis que celle de CaO dans la chaux riche en calcium est supérieure à 80%.

6. Procédé métallurgique selon la revendication 1 ou 3, dans lequel la teneur en Mg dans la dolomite est supérieure à 10%.

7. Procédé métallurgique selon la revendication 1 ou 3, dans lequel la teneur en CaF₂ dans la fluorite est supérieure à 80%.
REFERENCES CITED IN THE DESCRIPTION

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