Notice

DESCRIPTION CN120772003A

A method for enhancing the separation of iron/vanadium-titanium in vanadium-titanium magnetite by Joule thermal flash reduction and magnetic separation

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一种焦耳热闪速还原-磁选强化钒钛磁铁矿铁/钒钛分离的方法

[0001]

Technical Field

技术领域

[n0001]

This invention relates to a method for strengthening the separation of iron/vanadium-titanium in vanadium-titanium magnetite by Joule thermal flash reduction and magnetic separation, which belongs to the field of unconventional metallurgical technology.

本发明涉及一种焦耳热闪速还原-磁选强化钒钛磁铁矿铁/钒钛分离的方法，属于非常规冶金技术领域。

[0003]

Background Technology

背景技术

[n0002]

Vanadium-titanium magnetite is a polymetallic symbiotic mineral resource and is recognized worldwide as a strategic mineral resource.

钒钛磁铁矿是一种多金属共生的矿产资源，是世界公认的战略性矿产资源。

Vanadium, titanium, iron, and their associated metallic elements all play a vital role in the development of human society.

无论是钒、钛、铁还是其伴生的金属元素，对人类社会发展具有至关重要的作用。

my country has a wide distribution and abundant reserves of vanadium-titanium magnetite, with proven reserves exceeding 30 billion tons, ranking among the world's top.

我国钒钛磁铁矿资源分布广泛、储量丰富，已探明储量达300亿吨以上，居世界前列。

In recent years, with the rapid development of my country's economy, the demand for mineral resources such as vanadium, titanium, and iron has been increasing. Therefore, developing vanadium-titanium magnetite deposits with huge reserves is of great significance.

近年来，随着我国经济的飞速发展，对钒、钛、铁等矿产资源需求量日益增加。 因此，开发储量巨大的钒钛磁铁矿意义重大。

[n0003]

The current smelting processes for vanadium-titanium magnetite mainly include the blast furnace method, the pre-reduction-electric furnace melting method, and the direct reduction-magnetic separation method.

当前钒钛磁铁矿的冶炼工艺主要包括高炉法、预还原-电炉熔分法和直接还原-磁选法。

The blast furnace method for smelting vanadium-titanium magnetite has the advantages of large processing capacity and effective recovery of iron and vanadium, but it also has problems such as long process, high energy consumption, high pollution and ineffective recovery of titanium. The pre-reduction-electric furnace melting method can recover iron and vanadium, but the smelting temperature is high and the titanium slag has a high grade, but there is no mature titanium recovery process yet. Direct reduction-magnetic separation can retain the activity of vanadium and titanium components while reducing iron oxides by metallization, which provides the possibility for further processing and utilization of vanadium and titanium components. Therefore, it has become a research hotspot for the processing and utilization of vanadium-titanium magnetite in recent years. However, since the main iron-bearing minerals in vanadium-titanium magnetite are magnetite and ilmenite, ilmenite is more difficult to reduce than magnetite. Furthermore, iron grain growth is difficult under solid-state reduction, resulting in poor subsequent iron/vanadium-titanium separation and low recovery rate, which greatly limits the application of direct reduction process.

高炉法冶炼钒钛磁铁矿具有处理量大，有效回收铁、钒，但存在流程长、能耗大、污染大和钛无法有效回收等问题。 预还原-电炉熔分法能够回收铁和钒，但冶炼温度高，钛渣品位高但尚未有成熟回收钛工艺。 直接还原-磁选可在金属化还原铁氧化物的基础上，保留钒、钛组分的活性，为后续钒、钛组分的进一步加工利用提供了可能，因此，近年来成为钒钛磁铁矿加工利用的研究热点。 但由于钒钛磁铁矿中含铁矿物的主要物相为磁铁矿和钛铁矿，相较于磁铁矿，钛铁矿难以被还原，且固态还原下铁晶粒生长困难，导致后续铁/钒钛分离效果差，且回收率低，极大地限制了直接还原工艺的应用。

[n0004]

Joule heating equipment is a technology that uses direct current to generate heat to directly heat the material to be heated. Due to its characteristics of rapid heating, high-temperature heat treatment and rapid quenching, it has attracted widespread research interest in the fields of material synthesis and metallurgical separation.

焦耳热设备是使用直流电生热直接加热待受热材料的技术，因其具有快速升温、高温热处理和快速淬冷的特点，在材料合成、冶金分离等领域引起了广泛的研究兴趣。

Joule heating and carbon thermal shock can achieve rapid reduction of vanadium-titanium magnetite and good growth of metallic iron grains, thus laying a good foundation for efficient iron/vanadium-titanium separation. Therefore, the idea of using Joule thermal carbothermal reduction of vanadium-titanium magnetite to strengthen iron/vanadium-titanium is highly innovative.

采用焦耳热碳热冲击可以实现钒钛磁铁矿的快速还原以及金属铁晶粒的良好生长，从而为铁/钒钛的高效分离奠定了良好的工艺矿物学条件。 因此，本发明提出采用焦耳热碳热还原钒钛磁铁矿强化铁/钒钛的思路是十分具有创新性的。

[0007]

Summary of the Invention

发明内容

[n0005]

The present invention aims to provide a method for strengthening the separation of iron /vanadium-titanium in vanadium-titanium magnetite by Joule thermal flash reduction and magnetic separation.

本发明旨在提供一种焦耳热闪速还原-磁选强化钒钛磁铁矿铁/钒钛分离的方法。

Vanadium-titanium magnetite powder and a certain amount of carbon source are mixed and then placed in a Joule heating device for flash reduction. During the reduction process, iron oxides are reduced to metallic iron, and vanadium and titanium components exist in the form of oxides.

将钒钛磁铁矿矿粉和一定质量的碳源进行混合后置于焦耳热设备中进行闪速还原，还原过程中铁氧化物被还原为金属铁，钒、钛组分以氧化物形式存在。

Roasted ore can be ground and magnetically separated to obtain direct reduced iron powder and vanadium-titanium concentrate. Direct reduced iron powder is used as a raw material for short-process steelmaking, and vanadium-titanium concentrate can be separated from titanium by acid leaching. Because the Joule heating equipment can reach 3000°C in 1 second and cool down rapidly, it can achieve flash reduction of iron oxides and growth of metallic iron grains. This solves the problems of low reduction efficiency, slow kinetics, and poor iron /vanadium-titanium separation in the traditional direct reduction process of vanadium-titanium magnetite. It has the advantages of low energy consumption, good iron/vanadium-titanium separation effect, and high recovery rate.

焙烧矿经磨矿-磁选可以分别获得直接还原铁粉和钒钛富集物，直接还原铁粉用作短流程炼钢的原料，钒钛富集物经酸浸可实现钒、钛的分离。 由于焦耳热设备可以在1s内升至3000°C并快速冷却，

可以实现铁氧化物的闪速还原以及金属铁晶粒的生长，解决了传统钒钛磁铁矿直接还原过程铁氧化物还原效率低、动力学缓慢以及铁/钒钛分离效果差的问题，具有能耗低、铁/钒钛分离效果好、回收率高的优点。

[n0006]

A method for separating iron/vanadium-titanium in vanadium-titanium magnetite using Joule thermal flash reduction-magnetic separation enhancement includes the following steps:

一种焦耳热闪速还原-磁选强化钒钛磁铁矿铁/钒钛分离的方法，包括以下步骤：

[n0007]

Step 1: Mix vanadium-titanium magnetite powder and carbon source in a certain proportion and then place them in a flash Joule heating device for thermal shock flash reduction;

步骤1：将钒钛磁铁矿矿粉和碳源按比例进行混合后置于闪蒸焦耳热设备中进行热冲击闪速还原；

[n0008]

Step 2: Grind the product obtained in Step 1 in a ball mill according to a certain liquid-solid ratio to obtain a slurry;

步骤2：将步骤1所得产物按照一定的液固比置于球磨机中磨矿，得矿浆；

[n0009]

Step 3: The grinding slurry is separated by magnetic separation to obtain magnetic concentrate and tailings.

步骤3：磨矿矿浆经磁选分离获得磁精矿和尾矿。

[n0010]

In step 1, the particle size of the vanadium-titanium magnetite powder is 90% less than 74 μm.

步骤1中，所述的钒钛磁铁矿矿粉的粒度90%小于74μm。

[n0011]

In step 1, the carbon source used is one of lignite, bituminous coal, coal tar pitch, coke, or biomass carbon, with lignite or bituminous coal being the preferred carbon source.

步骤1中，所用的碳源为褐煤、烟煤、煤沥青、焦炭、生物质碳中的一种，优选的碳源为褐煤或烟煤。

[n0012]

In step 1, the mass ratio of carbon source to vanadium-titanium magnetite is 0.1 to 1:1, preferably 0.3 to 0.7:1.

步骤1中，碳源和钒钛磁铁矿的质量比为0.1～1:1，优选为0.3～0.7:1。

[n0013]

In step 1, the current intensity applied by the flash Joule heating device is 40-150A, the current application time is 0.1-10s, the peak temperature is 1200-2500°C, and the number of cycles is 1-50; preferably, the current intensity is 50-120A, the application time is 1-5s, and the number of cycles is 10-20.

步骤1中，闪蒸焦耳热设备所施加的电流强度为40～150A，施加电流时间为0.1～10s，峰值温度为1200-2500°C，循环次数为1-50次；优选的电流强度为50-120A，施加时间为1～5s，循环次数为10-20次。

[n0014]

In step 2, the grinding particle size is 80% less than 45μm, and the slurry concentration is 10% -80%;

步骤2中，磨矿粒度为80%小于45μm，矿浆浓度为10%-80%；

[n0015]

The preferred grinding particle size is 90% less than 45 μm, and the preferred slurry concentration is 40-60%.

优选的磨矿粒度为90%小于45μm，优选的矿浆浓度为40～60%。

[n0016]

In step 3, the magnetic field strength is 300-1800 Gs, preferably 600-1200 Gs.

步骤3中，磁场强度为300-1800Gs，优选的磁场强度为600-1200Gs。

[n0017]

The main chemical reaction equations of this invention are as follows:

本发明的主要化学反应方程式如下:

[n0018]

Fe₃O₄(s)+C(s)=3FeO(s)+CO₂(g)

Fe₃O₄(s)+C(s)＝3FeO(s)+CO₂(g)

[n0019]

FeO(s)+C(s)=Fe(s)+CO₂(g)

FeO(s)+C(s)＝Fe(s)+CO₂(g)

[n0020]

FeTiO₃(s)+C(s)=Fe(s)+TiO₂(s)+CO(g)

FeTiO₃(s)+C(s)＝Fe(s)+TiO₂(s)+CO(g)

[n0021]

Fe₂TiO₅(s)+3C(s)=2Fe(s)+TiO₂(s)+3CO(g)

Fe₂TiO₅(s)+3C(s)＝2Fe(s)+TiO₂(s)+3CO(g)

[n0022]

The working principle of this invention is as follows:

本发明的作用原理在于：

[n0023]

After vanadium-titanium magnetite and carbon powder are mixed, they are heated in a Joule heating device. During the heating process, carbon selectively reduces iron oxides to metallic iron, while the vanadium-titanium components still exist in the form of oxides.

钒钛磁铁矿和碳粉进行混合后置于焦耳热设备中进行加热，加热过程中碳将铁氧化物选择性地还原为金属铁，钒钛组分依旧以氧化物的形式存在。

Roasted ore was ground and then magnetically separated to obtain metallic iron powder and vanadium-titanium concentrates, respectively.

焙烧矿经磨矿-磁选分别获得金属铁粉和钒钛富集物。

[n0024]

The beneficial effects of this invention are as follows:

本发明的有益效果为：

[n0025]

This invention utilizes the rapid heating characteristic of Joule heating equipment to reduce vanadium-titanium magnetite. It features a simple process flow, good iron/vanadium-titanium separation effect, and high recovery rate, providing a feasible approach for the efficient utilization of vanadium-titanium magnetite in my country and has a very broad prospect for promotion and application.

本发明利用焦耳热设备快速升温的特点来还原钒钛磁铁矿，具有工艺流程简单、铁/钒钛分离效果好、回收率高等特点，为我国钒钛磁铁矿的高效利用提供了可行途径，有着十分广阔的推广应用前景。

[0029]

Detailed Implementation

具体实施方式

[n0026]

The present invention will be further described in detail below with reference to specific embodiments.

下面结合具体实施例对本发明做进一步的详细说明。

[n0027]

Comparative Example 1:

对比例1：

[n0028]

1g of vanadium-titanium magnetite powder and 1g of lignite were mixed and then subjected to reduction roasting in a muffle furnace at a roasting temperature of 1000°C for 60min. The resulting roasted ore was then ground in a ball mill with a slurry concentration of 50%, a grinding particle size of 90% less than 45μm, and a magnetic field strength of 1000Gs.

将1g钒钛磁铁矿矿粉和1g褐煤混合后在马弗炉中进行还原焙烧，焙烧温度为1000℃，焙烧时间为60min；得到的焙烧矿在球磨机中进行磨矿，矿浆浓度为50%，磨矿粒度为90%小于45μm，磁场强度为1000Gs。

In Comparative Example 1, the iron grade of the magnetic concentrate was 45.28%, the iron recovery rate was 52.17%, and the recovery rates of vanadium and titanium in the tailings were 49.32% and 55.61%, respectively.

对比例1中磁选精矿的铁品位为45.28%，铁回收率为52.17%，尾矿中钒、钛的回收率分别为49.32%和55.61%。

[n0029]

Comparative Example 2:

对比例2：

[n0030]

1g of vanadium-titanium magnetite powder and 1g of lignite were mixed and then subjected to reduction roasting in a muffle furnace at a roasting temperature of 1100°C for 120min. The resulting roasted ore was then ground in a ball mill with a slurry concentration of 50%, a grinding particle size of 90% less than 45μm, and a magnetic field strength of 1000Gs.

将1g钒钛磁铁矿矿粉和1g褐煤混合后在马弗炉中进行还原焙烧，焙烧温度为1100℃，焙烧时间为120min；得到的焙烧矿在球磨机中进行磨矿，矿浆浓度为50%，磨矿粒度为90%小于45μm，磁场强度为1000Gs。

In Comparative Example 2, the iron grade of the magnetic concentrate was 58.19%, the iron recovery rate was 70.03%, and the recovery rates of vanadium and titanium in the tailings were 66.38% and 73.26%, respectively.

对比例2中磁选精矿的铁品位为58.19%，铁回收率为70.03%，尾矿中钒、钛的回收率分别为66.38%和73.26%。

[n0031]

Comparative Example 3:

对比例3：

[n0032]

1g of vanadium-titanium magnetite powder and 1g of lignite were mixed and then subjected to reduction roasting in a muffle furnace at a roasting temperature of 1150°C for 180min. The resulting roasted ore was then ground in a ball mill with a slurry concentration of 50%, a grinding particle size of 90% less than 45μm, and a magnetic field strength of 1000Gs.

将1g钒钛磁铁矿矿粉和1g褐煤混合后在马弗炉中进行还原焙烧，焙烧温度为1150°C，焙烧时间为180min；得到的焙烧矿在球磨机中进行磨矿，矿浆浓度为50%，磨矿粒度为90%小于45μm，磁场强度为1000Gs。

In Comparative Example 3, the iron grade of the magnetic concentrate was 78.32%, the iron recovery rate was 86.39%, and the recovery rates of vanadium and titanium in the tailings were 80.36% and 85.47%, respectively.

对比例3中磁选精矿的铁品位为78.32%，铁回收率为86.39%，尾矿中钒、钛的回收率分别为80.36%和85.47%。

[n0033]

Comparative Example 4:

对比例4：

[n0034]

1g of vanadium-titanium magnetite powder and 1g of lignite were mixed and then subjected to reduction roasting in a muffle furnace at a roasting temperature of 1200°C for 180min. The resulting roasted ore was then ground in a ball mill with a slurry concentration of 50%, a grinding particle size of 90% less than 45μm, and a magnetic field strength of 1000Gs.

将1g钒钛磁铁矿矿粉和1g褐煤混合后在马弗炉中进行还原焙烧，焙烧温度为1200°C，焙烧时间为180min；得到的焙烧矿在球磨机中进行磨矿，矿浆浓度为50%，磨矿粒度为90%小于45μm，磁场强度为1000Gs。

In Comparative Example 4, the iron grade of the magnetic concentrate was 87.32%, the iron recovery rate was 92.64%, and the recovery rates of vanadium and titanium in the tailings were 89.47% and 91.36%, respectively.

对比例4中磁选精矿的铁品位为87.32%，铁回收率为92.64%，尾矿中钒、钛的回收率分别为89.47%和91.36%。

[n0035]

Example 1:

实施例1：

[n0036]

1g of vanadium-titanium magnetite powder and 1g of lignite were mixed and subjected to carbothermic shock in a Joule heating device. The peak current was 100A, the current application time was 1s, the peak temperature was 1800°C, and the number of cycles was 30. The resulting roasted ore was then ground in a ball mill with a slurry concentration of 50%, a grinding particle size of 90% less than 45μm, and a magnetic field strength of 1000Gs.

将1g钒钛磁铁矿矿粉和1g褐煤混合后在焦耳热设备中进行碳热冲击，施加电流峰值为100A，施加电流时间为1s，峰值温度为1800°C，循环次数为30次；得到的焙烧矿在球磨机中进行磨矿，矿浆浓度为50%，磨矿粒度为90%小于45μm，磁场强度为1000Gs。

In Example 1, the iron grade of the magnetic concentrate was 95.17%, the iron recovery rate was 96.67%, and the recovery rates of vanadium and titanium in the tailings were 93.48% and 98.36%, respectively.

实施例1中磁选精矿的铁品位为95.17%，铁回收率为96.67%，尾矿中钒、钛的回收率分别为93.48%和98.36%。

[n0037]

Example 2:

实施例2：

[n0038]

1g of vanadium-titanium magnetite powder and 0.8g of lignite were mixed and subjected to carbothermic shock in a Joule heating device. The peak current applied was 120A, the current application time was 1s, the peak temperature was 2000°C, and the number of cycles was 30. The resulting roasted ore was then ground in a ball mill with a slurry concentration of 50%, a grinding particle size of 90% less than 45μm, and a magnetic field strength of 1000Gs.

将1g钒钛磁铁矿矿粉和0.8g褐煤混合后在焦耳热设备中进行碳热冲击，施加电流峰值为120A，施加电流时间为1s，峰值温度为2000°C，循环次数为30次；得到的焙烧矿在球磨机中进行磨矿，矿浆浓度为50%，磨矿粒度为90%小于45μm，磁场强度为1000Gs。

In Example 2, the iron grade of the magnetic concentrate was 93.25%, the iron recovery rate was 95.54%, and the recovery rates of vanadium and titanium in the tailings were 93.55% and 96.32%, respectively.

实施例2中磁选精矿的铁品位为93.25%，铁回收率为95.54%，尾矿中钒、钛的回收率分别为93.55%和96.32%。

[n0039]

Example 3:

实施例3：

[n0040]

1g of vanadium-titanium magnetite powder and 0.5g of lignite were mixed and subjected to carbothermic shock in a Joule heating device. The peak current applied was 120A, the current application time was 1s, the peak temperature was 2000°C, and the number of cycles was 30. The resulting roasted ore was then ground in a ball mill with a slurry concentration of 50%, a grinding particle size of 90% less than 45μm, and a magnetic field strength of 1000Gs.

将1g钒钛磁铁矿矿粉和0.5g褐煤混合后在焦耳热设备中进行碳热冲击，施加电流峰值为120A，施加电流时间为1s，峰值温度为2000°C，循环次数为30次；得到的焙烧矿在球磨机中进行磨矿，矿浆浓度为50%，磨矿粒度为90%小于45μm，磁场强度为1000Gs。

In Example 3, the iron grade of the magnetic concentrate was 90.18%, the iron recovery rate was 92.54%, and the recovery rates of vanadium and titanium in the tailings were 88.45% and 91.65%, respectively.

实施例3中磁选精矿的铁品位为90.18%，铁回收率为92.54%，尾矿中钒、钛的回收率分别为88.45%和91.65%。

[n0041]

Example 4:

实施例4：

[n0042]

1g of vanadium-titanium magnetite powder and 0.8g of vanadium-titanium magnetite powder were mixed and subjected to carbothermic shock in a Joule heating device. The peak current applied was 100A, the current application time was 1s, the peak temperature was 1800°C, and the number of cycles was 5. The resulting roasted ore was then ground in a ball mill with a slurry concentration of 50%, a grinding particle size of 90% less than 45μm, and a magnetic field strength of 1000Gs.

将1g钒钛磁铁矿矿粉和0.8g混合后在焦耳热设备中进行碳热冲击，施加电流峰值为100A，施加电流时间为1s，峰值温度为1800°C，循环次数为5次；得到的焙烧矿在球磨机中进行磨矿，矿浆浓度为50%，磨矿粒度为90%小于45μm，磁场强度为1000Gs。

In Example 4, the iron grade of the magnetic concentrate was 78.32%, the iron recovery rate was 83.32%, and the recovery rates of vanadium and titanium in the tailings were 79.35% and 83.36%, respectively.

实施例4中磁选精矿的铁品位为78.32%，铁回收率为83.32%，尾矿中钒、钛的回收率分别为79.35%和83.36%。

[n0043]

Example 5:

实施例5：

[n0044]

1g of vanadium-titanium magnetite powder and 0.8g of vanadium-titanium magnetite powder were mixed and subjected to carbothermic shock in a Joule heating device. The peak current applied was 130A, the current application time was 1s, the peak temperature was 2200°C, and the number of cycles was 20. The resulting roasted ore was then ground in a ball mill with a slurry concentration of 50%, a grinding particle size of 90% less than 45μm, and a magnetic field strength of 1000Gs.

将1g钒钛磁铁矿矿粉和0.8g混合后在焦耳热设备中进行碳热冲击，施加电流峰值为130A，施加电流时间为1s，峰值温度为2200℃，循坏次数为20次；得到的焙烧矿在球磨机中进行磨矿，矿浆浓度为50%，磨矿粒度为90%小于45μm，磁场强度为1000Gs。

In Example 5, the iron grade of the magnetic concentrate was 94.12%, the iron recovery rate was 96.38%, and the recovery rates of vanadium and titanium in the tailings were 94.25% and 97.54%, respectively.

实施例5中磁选精矿的铁品位为94.12%，铁回收率为96.38%，尾矿中钒、钛的回收率分别为94.25%和97.54%。

[n0045]

Example 6:

实施例6：

[n0046]

1g of vanadium-titanium magnetite powder and 0.8g of vanadium-titanium magnetite powder were mixed and subjected to carbothermic shock in a Joule heating device. The peak current applied was 120A, the current application time was 0.1s, the peak temperature was

2000°C, and the number of cycles was 30. The resulting roasted ore was then ground in a ball mill with a slurry concentration of 50%, a grinding particle size of 90% less than 45μm, and a magnetic field strength of 1000Gs.

将1g钒钛磁铁矿矿粉和0.8g混合后在焦耳热设备中进行碳热冲击，施加电流峰值为120A，施加电流时间为0.1s，峰值温度为2000°C，循环次数为30次；得到的焙烧矿在球磨机中进行磨矿，矿浆浓度为50%，磨矿粒度为90%小于45μm，磁场强度为1000Gs。

In Example 6, the iron grade of the magnetic concentrate was 81.15%, the iron recovery rate was 84.32%, and the recovery rates of vanadium and titanium in the tailings were 76.54% and 83.25%, respectively.

实施例6中磁选精矿的铁品位为81.15%，铁回收率为84.32%，尾矿中钒、钛的回收率分别为76.54%和83.25%。