Research on the Titaniferous Slag Smelting Process and Furnace

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Abstract: The article mainly introduces the raw material of the titaniferous slag smelting and the conventional and new metallurgical process of the titaniferous slag smelting. Through analyzing the different fuctions of the furnaces in the two smelting process, the article summarized the advantage of new process compared with the conventional one.

1. Introduction

The titaniferous slags are divided into high titanium type and low grade titanium type, and the high titanium slags which are produced by using titanium concentrates are industrial materials containing TiO₂ (75% or higher). On the other hand, the low grade titanium slags contain TiO₂ (45%~50%) which are produced by using vanadium titanium magnetite. The main production equipments are the arc furnaces which are normally divided into circular type and rectangular type. According to the different furnace sealed types, the arc furnace can also be divided into three types: airtight, half closed and open types.

The titaniferous slags are the main material to produce titanium dioxide, titanium sponge and electrode which have a very wide range of applications. The titanium dioxide product can be widely used in coatings, plastic, papermaking, printing ink, chemical fiber, rubber, cosmetics, food and other industries [1].

2. The Raw Material of the Titaniferous Slag Smelting

The raw material of smelting titaniferous slag are mainly mineral aggregates and reducing agents.

2.1. The Mineral Aggregates

There are mainly three kinds of mineral aggregates, which are titanium concentrates, rutile and titanium iron ores. Among them the rutile and titanium concentrates contain more TiO₂, and the titanium iron ores contains less TiO₂. There are almost 965 million tons of titanium concentrates reserved in our country which mainly located in Sichuan, Hainan, Hebei, Yunnan, Guangdong and Guangxi province. 97% of titanium concentrates are rock ores which are 837.85 million tons. And 3% of titanium concentrates are placer which are 22.51 million tons. The composition of the typical titanium concentrates and titanium iron ores are shown in table 1. The titanium slags contain different TiO₂ because of using the ore materials with different TiO₂ grades. The common product acid dissolved titanium slags containing TiO₂ 73% - 77% demand that the titanium concentrate materials contain 46.5% TiO₂ or higher.
Table 1: The main composition of the titanium concentrates and titanium iron ores

| Items           | TFe  | TiO₂ | V₂O₅ | S   | SiO₂  | Al₂O₃ | MgO  | CaO  |
|-----------------|------|------|------|-----|-------|-------|------|------|
| Titanium concentrates | 33.59 | 47.20 | 0.25 | 0.015 | 1.56  | 0.43  | 1.20 | 0.20 |
| Titanium iron ores      | 56.74 | 11.84 | 0.60 | 0.08 | 3.35  | 3.0   | 1.40 | 0.08 |

2.2. The Reducing Agents

The main types of the reducing agents are gas, charcoal, anthracite, coke and etc. The reactivity and resistivity of the charcoal is very good, but its price is high because of the lack of resources. The charcoal is not used widely because of the high volatile flux and ash content. The reactivity and resistivity of the gas and anthracite is lower than the charcoal, also they have large-scale reserves, but they are not widely used due to the high volatile flux content and difficulty control in arc furnace smelting process. The coke has low reducibility but it is used widely in titanium slag smelting because of the low conductivity, large-scale reserves, a high carbon and low volatile flux content. In conclusion, the best reductant of the titanium slag smelting is the coke.

3. The Process and Furnace of the Titaniferous Slag Smelting

Number The conventional titanium slag smelting usually choose the titanium concentrates as raw material. The main furnace of the conventional smelting process shown in figure 1 is circular or rectangle arc furnace equipment.

![Figure 1](image.png)

**Figure 1:** The conventional titaniferous slag smelting process.

The titanium concentrates are beneficiated from the titanium magnetite, so the conventional titanium slag smelting process need beneficiating operation and the request to feedstock is more rigorous. In recent years, many domestic mining companies research and test new technology process which use directly vanadium titanium magnetite as raw material. The famous titaniferous slag producing company in Panzhihua city has a new technology process proved by the practice which adopt the new arc furnaces. It is shown in figure 2.
In this new process, the vanadium titanium magnetites are directly reduced by rotary hearth furnace, then the DRI are added into the submerged arc furnace. The function of the titaniferous slag arc furnace is mainly melting DRI and separating titaniferous slag. As a result, the furnace output a lot of hot metal containing vanadium and titanium slags. The new process compared to conventional titanium concentrate smelting process has the following features: 1) the power consumption per ton of slags gets 500-600 kwh lower than the power consumption in the conventional process. The new process also decreases the electrode consumption and reduces production cost. 2) The products of the submerged arc furnace are mainly hot metal containing vanadium and titanium slags, but the titanium slags have 20%-50% TiO$_2$. Compared with the conventional process of which titanium slags have more than 75% TiO$_2$. So in the new process the titaniferous slags need deep processing and further enrichment of TiO$_2$.

The new smelting process can also change the types of smelting equipment to adapt to different scales of production. For the large-scale smelting, the shaft furnace or rotary kiln can be used instead of the rotary hearth furnace to product the direct reduced iron[2], and in the follow-up process the large rectangle submerged arc furnace can be used instead of conventional circular arc furnace to product the titanium slag and the liquid iron. Such the melting process is adopted by one New Zealand steel company of which the annual output are 700,000 tons of liquid iron and 700,000 tons of titanium slag contained 35% TiO$_2$. Its process flow is shown in figure 3.
The main smelting equipments of the New Zealand steel company are 4 sets of 4.6 x 65 m rotary kiln and 2 sets of 42 MW rectangular submerged arc furnace. In the rectangular arc furnace, the action is mainly melting process of DRI and separating process of titaniferous slag. The smelting process of the New Zealand steel company increases the rate of vanadium reduction and decreases the rate of titanium reduction with controlling MFe in the slag which has obtained more vanadium in the hot metal and more titanium in the slag.

4. Conclusions
By comparison between the new smelting process and the conventional process, conclusions are drawn as below.

1) The raw material of smelting titaniferous slag are mainly the titanium concentrates and the titanium magnetites, which are used in different technological processes. The coke is commonly chosen as the main reducing agent.

2) In the new technological process of smelting titanium slag which chooses the titanium magnetites as the raw material, the submerged arc furnace mainly smelt DRI and separate the titaniferous slag, of which the process are deep reduction reactions. The key factors are controlling less MFe content in the slag and reducing more vanadium into the liquid iron.

3) The power consumption per ton of slags in the new process gets 500-600 kwh lower than the power consumption in the conventional process.

4) The new smelting process could obtain more vanadium in the hot metal and more titanium in the slag compared with the conventional process.

5. References
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