Electro-Aluminothermic Process for Ferrovanadium Production in Pangang

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Abstract

An advanced technology electro-aluminothermic process for ferrovanadium production with low investment and high-technology level and its process requirements are introduced in detail. Measures on how to increase vanadium recovery are presented as well.

Key word electro-aluminothermic process ferrovanadium production

1. Introduction

At present the main vanadium-producing countries in the world are South Africa, USA, Russia and China, etc. Great importance has been attached to the production of ferrovanadium since it is the form in which vanadium is added to steel and special alloys. Electro-silicothermic, aluminothermic and electro-aluminothermic processes are generally used for producing ferro-vanadium.

In 1991, a ferrovanadium (FeV80) line with annual production capacity of 300 to 600 tons was set up in Pangang. Electro-aluminothermic process was adopted, the main advantages being low investment in equipment, simple processing requirements, short smelting time and high quality product. Through revamping and technical innovations in recent years, the annual production capacity of FeV80 has expanded to 1500 tons with 95% V recovery. As the quality of the product is in accordance with DIN 17563 standard, the demand has kept exceeding supply since FeV entered the international market.

At present the existing ferrovanadium production process in Pangang is being optimized to increase V recovery, aiming at further expanding the production capacity. Not only is the process described in detail in this paper, but also measures on improving V recovery and preventing the furnace from leaking are introduced.

2. Electro-aluminothermic process

2.1 Raw materials

(1) Vanadium pentoxide: V_2O_5, brand No. 98, in accordance with GB 3283-87 standard, grain size 55×55×5mm

(2) Aluminum granules: Al>99.2%, Fe<0.13%, C<0.005%, Si<0.1%, P<0.05%, P<0.05%, S<0.0016%; particle size, 10~15 mm

(3) Lime: CaO>85%, MgO<5%, SiO_2<3.5%, S<0.15%, P<0.03%, ignition loss<7%

(4) Return slag: chemical composition listed in Table 1, grain size 5~10 mm

(5) Iron chips: C content<0.4%, grain size < 15 mm

Table 1 Composition of return slag

V_2O_5	Al_2O_3	CaO	MgO	SiO_2	ΣFe
1.8~2.5	85~88	1.0~1.5	3.5~6.0	0.37	1.0

2.2 Main equipment

(1) Electric heater: 125 kVA, rated current 4500A, diameter of electrode circle 500~600 mm, electrode

diameter 200 mm, secondary voltage 104,121,160, 180,210V

(2)Smelting furnace: outer diameter 1.8 m, height 1.75 mm

(3)Charging system: self-manufacture

(4)Dust collecting system: self-manufacture, first stage-atomizing dedusting cyclone, secondary stage-bag filter

The production equipment is shown in Fig. 1.

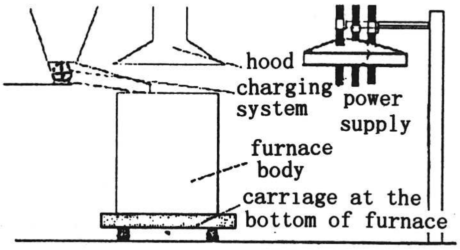

Fig.1 Schematic drawing of FeV production

2.3 Flow sheet

The flow sheet of electro-aluminothermic process for FeV80 production is shown in Fig. 2.

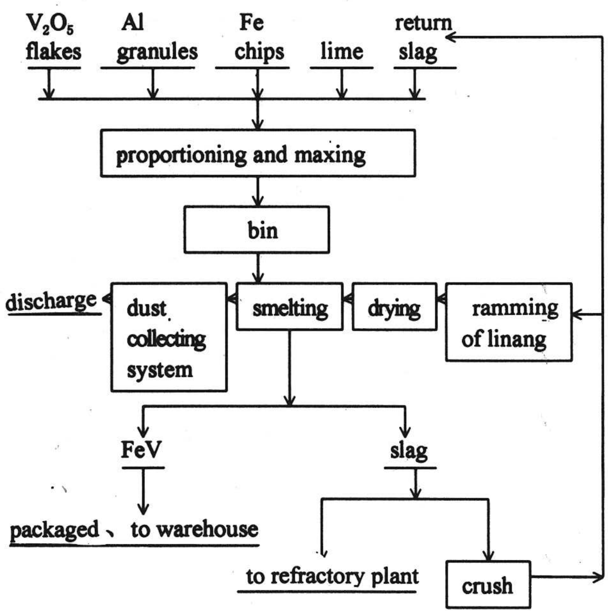

Fig.2 Flow process diagram of FeV melting

2.4 Operating practice

2.4.1 Preparation of burden

The optimal techincal condition of preparation of burden for smelting of FeV by the electro-aluminothermic process is that the heat of reaction per unit burden is 3140—3350KJ/Kg. Actually, the theoretical heat generated by Al addition excecds this value. In order to maintain this vales, return slag, line and rich slag (one contacting with slag) are added in the burden to eusure a stable reaction. Since the aluminothermic reaction procecds instantaneously and spontaneously once it is started and the short duration of reaction causes difficult control, the preparation of the burden directly influences the quality of the FeV product. Therefore, a thoroughly mixed burden with accurate proportioning and weighting is required to avoid the segregation of the burden.

In addition, the various raw materials should be dried completely to avoid splashing during smelting.

2.4.2 Smelting

Smelting of FeV is carried out in a drum-type furnace which is prepared prior to smelting in three steps-lining, ramming and baking. During smelting, the furnace is first lifted onto the carriagefor bed charge. Then the carriage is delivered into the smelting chamber, and finally ignition is started in the lower part of the furnace. After ignited by the ignitor, all of the burden is gradually charged according to the condition of reaction from the upper part at a proper speed so as to ensure a stable reaction as well as to minimize splashing. The carriage is delivered to the furnace position for electric heating as soon as the aluminothermic reaction is completed. After the electric heating has completed, alloy ingot will not be removed until it has been self-cooled for 48 hours. The chemical composition are listed in Table 2 from the production data of 71 consecutive heats of furnace No. 970480-970550.

Table 2 Composition of FeV produced, %

P	S	V	C	Si	Al	Mn
0.026-0.036	0.009-0.018	78.10-81.30	0.07-0.12	0.70-1.09	0.20-1.49	0.25-0.33

2.5 Handling of the product

After removal from the furnace, the alloy ingot undergoes a series of treatment including water-quenching, surface finishing, breaking, crushing, screening, packing and finally stored in the warehouse. The slag is delivered to a crushing system. After treatment, a part of it is used as return slag, a part for rammed lining and the rest sold to refractory plant.

3 Methods for increasing V recovery

3.1 Reasonable Al charging ratio

In general, to increase the Al amount in the aluminothermic reaction will result in a complete and full reaction with high V recovery attained. However, when Al amount exceeds a certain limit, the surplus Al will go into the alloy which fails to meet the quality requirement. On the other hand, the alloy will acquire a lighter specific gravity because of the high Al content, affecting the settling rate in the slag. Consequently, the alloy included in the slag increases and the V recovery decreases. Meanwhile, the increased Al consumption will result in a higher production cost and unfavorable economic results. Through practice over the years, the relation among Al/V ratio in burden, V recovery and Al content in FeV80 has been found and calculated, as shown in Fig. 3.

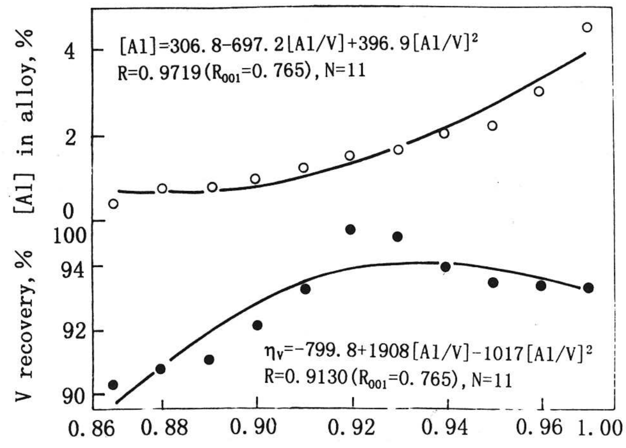

Fig. 3 Relationship between Al proportioning and [Al] in alloy and V recovery

3.2 Process control of aluminothermic reaction

In order to separate satisfactorily the alloy from the slag after smelting, a high smelting temperature must be attained. According to $\Delta G^\circ \sim T$ relation of reduction of V oxide ΔG° increases with the rise of temperature and the reaction toward right will decline with an incomplete reduction. In addition, excessively high temperature will place stringent demand on furnace lining as well as electric and mechanic equipment. Therefore, the reaction temperature should be controlled within a proper range. The thermal effect of reaction per unit burden and its feeding speed are also the main factors affecting reaction temperature. It has been shown from practice that the optimal thermal effect of reaction per unit burden for the smelting of FeV is 3140~3350 kJ/kg.

A fast reaction resulting from fast charging speed will cause the furnace temperature rise rapidly, leading to serious splashing and thus V and Al losses. On the contrary, a slow reaction from slow charging speed will result in a low smelting temperature at which the slag will easily become viscous with an incomplete separation of alloy from slag and low V recovery. Experience from operating practice has shown that the charging speed of 160~200kg/m^2. min would be appropriate.

3.3 Parameter control of power supply

Three-phase electric heater is used for FeV80 production in Pangang. The relation between voltage supply and V recovery has been noted. Under the condition of unchanged Al/V ratio (0.90), current (3000A) and electric heating time (40minutes), the effect of power supply on V recovery is shown in Fig. 4. A too high voltage will result in high power consumption. Usually, 121 V is adequate for obtaining a good recovery.

3.4 Electric heating time

Normally, the molten slag will solidify rapidly after the completion of the aluminothermic reaction. Electrically heating the slag will keep it in liquid state so that the reaction between slag and alloy continues. In addition, elevated temperature and lowered viscosity of the slag will result in complete sedimentation of metal particles, thus further increasing V recovery.

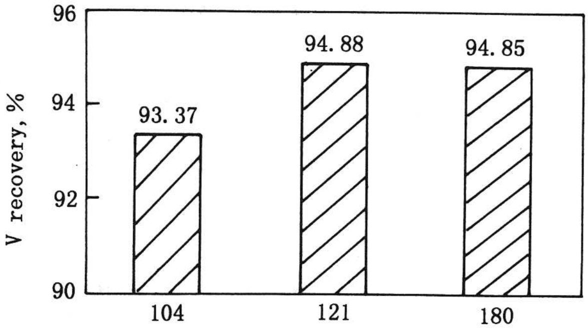

Fig. 4 Relationship between V recorvery and supply voltage

Electric heating time depends on the settling speed of metal particles from the molten slag. Analysis of micro-structure of FeV80 has shown that at the final stage of smelting most of the alloy particles are round ones with diameter of 5~175 mm, dispersing non-homogeneously in the slag, 80% of the particles having diameter of 5mm. When the furnace is in normal condition with smelting temperature of 1800℃, the theoretical settling speed of FeV particles can be calculated from Stokes formula:

$V=[2r^2_{metal}(\rho_{metal}-\rho_{slag})g][9\eta_{slag}]$

where r_{metal}---radius of alloy particle;

ρ_{metal}---density of alloy, g/cm^3;

ρ_{slag}---density of slag, g/cm^3.

g ---gravity acceleration, cm/sec^2;

η_{slag}---viscosity of slag, poise.

From measurement, density of FeV is 6.8~6.9 g/cm^3 and density of slag is 3.67 g/cm^3. When η_{slag} is 0.6 poise, the theoretical settling speed can be calculated as follows:

$V=[2\times 0.005^2\times(6.8-3.67)\times 980]/[9\times 0.6]$
$=0.0239$ cm/sec

If the thickness of slag layer is 80 cm, the theoretical time for FeV particles settling to the surface of alloy is:

$t=80/(0.0239\times 60)=52$ min

Under the condition of voltage of 120 V, current of 3000 A and Al/V ratio of 0.90, the experimental results of the relationship between V recovery and electric heating time is shown in Fig. 5. In practice, the electric heating time is generally controlled at above 52 minutes to warrant the quality of product and V recovery.

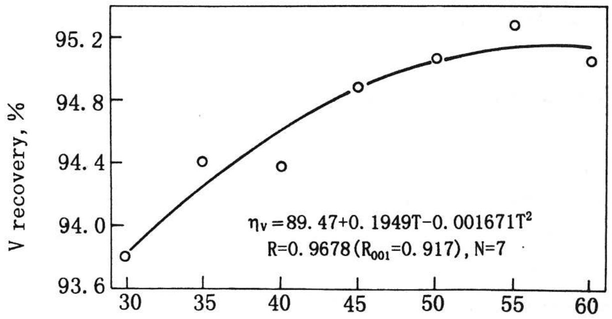

Fig. 5 Relationship between V recorvery and electric heating time

3.5 Charging of refined materials

For the purpose of increasing V recovery, crushed Al particles and iron oxide are added into the slag during electric heating to further react and evolve heat, thereby the resultant molten Fe-Al liquid drops being capable of reducing further the V oxide in the slag during its settling. In actual practice, V recovery can increase by about 2% due to the good separation of slag and alloy after the addition of refined materials. The amount of addition of refined materials depends on the V oxide content and the residual amount of Al in the slag.

4. Measures for preventing furnace from leaking

During the production of FeV, accidents of furnace leaking may sometimes happen causing hazardous effects. Preventive measures have been taken in Pangang as follows:

4. 1 Good lining and ramming

The furnace lining consists of a permanent layer and a temporary layer. The permanent layer is lined with magnesite bricks and high alumina bricks laid in three sections. The temporary layer is rammed with return slag. Owing to the inferior resistance to abrupt heating and cooling, the bricks can be easily damaged during dismantling of the furnace. Therefore, a good rammed lining is the key to prevent furnace from leaking. The strength of ramming should be adequate to avoid difficulties during dismantling of furnace. Meanwhile , the rammed layer at the furnace bottom is slightly thicker than that of the upper part. Besides, impurities with low melting point should not be mixed in the ramming materials and the joint between the hearth and the bottom should be tight.

4. 2 Good control of furnace condition

Firstly, the igniting flux should be distributed uniformly to avoid local explosion during ignition. Secondly, the burdens should be fed at a proper speed in order to maintain a reasonable temperature and to minimize the erosion of lining by slag.
During smelting, frequent observation of the furnace condition is required. No sooner has the outside shell of the furnace glowed red, than switching off the power or forced cooling down of the outside shell of the furnace with water spray is necessary .

5. Conclusions

(1). Electric-aluminothermic process used for FeV production in Pangang is an advanced technology characterized by low investment, easy process control, safe and reliable operation, high quality products and V recovery of more than 95%.

(2) It has been shown that the measures on preventing furnace from leaking are effective in eliminating accidents .

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