THE PRESENT STATE AND THE FUTURE DEVELOPMENT OF SILICON METAL PRODUCED IN THE ME-

AND SMALL-SIZE ELECTRIC FURNACES.

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Abstract

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Abstract

The silicon metal production in China already has a history of more than 30 years. Since 1980's the productive capacity and the export of silicon have rapidly increased. Its present productive capacity already ranks first in the world, in 1987 the export of silicon metal to only Japan was 55,000t. The developed process, Technical present state and resource features of silicon metal production in the medium and small-size electric furnaces adopted widely in China are described. The reducing reagent resource expansion, silicon refining, fume clearing and dust utilization, as well as start-up of the electric furnace and researched results in the production of silicon metal are also described. The conjncture of the future development is briefly described.

Introduction

The silicon metal production in China began in 1957. Before 1970's, the silicon metal was produced by several leading enterprises, it fulfilled domestic demand. Since 1870's because of invigorating the domestic economy and opening to the world, the Chinese silicon metal has begun to enter into the international market. Since 1980's our silicon metal has welcomed by several countries, especially Japan, the export increased gradually. According to the statistics of the Japanese custom house, the exports of our silicon metal to Japan during 1980-1987 were respectively: 1980:183t, 1981:9722t,1982: 13333t, 1983: 17883t, 1984:14313t. 1985:2322ot, 1986: 23220t, 1987: 55000t.

With the increasing gradually domestic demand and foreign exports, since 1980's the silicon metal production in China has rapidly developed, in the same time that the large scacle leading enterprises continuously develop, there rapidly set up and put them into operation a lot of local medium and small-size enterprises. These enterprises mainly used the electric furnaces 1800KVA, 2500KVA and 1300KVA. This is different from the electric furnaces with capacity of 10000KVA widely used abroad. This paper has emphatically discussed the resource feature and technical present state of silicon metal production in medium and small-size electric furnaces.

1. Development feature

(1) General condition of silica and electric power resources in China.

China is abundant in quartz with high silica and silica mineral deposit, and they spread over wide areas. The high-grade mineral with Sio2 is almost found in each provice and district in China. The deposit of may ore bodies is over million tons. the structure of the mineral with Sio2 is compact without obiously bisible fissure, the rock lager is thick, easy to mine, impurities are only a few, and easy to treat. Its thermal stability at high temperature is good, so it's suitable for silicon metal production.

China is one of the richese countries in energy sources in the world. According to literature, the geological resources of coal mine in China are over 500 billion tons. the theoretical resources are 0.68 billion KW, of which 0.38 billion KW can be developed.

The spread of coal resources in China is not balanced, the coal resources in some provinces are very abundant, each is over 10 million, but in some provices there is a limitation in transportation, the mined coal can not be carried wholly to other places, the calorific value of

some coal is relative low, it can only be used in generation of electric power locally.

At the present the phydrenergy source in China is utilized about 4%, there set up a lot of hydraulic power stations in some provinces and districts, but they are affected by geographical conditions and some other reasons, some of the set up small hydraulic power stations are not connected to the big network, others are runoff tyoe power stations without regulation, in Spring and Summer, when the load can not reach the installed capacity, the hydraulic power station can not generate leectricity at full load, thus the generation set must be stopped and discharged water, the residual electricity during the period of rich in water can not be utilized.

(2) Set up of the medium and small size electric furnace for industrial silicon production.

The medium and small-size electric furnaces in China mostly set up under the conditions of the spread and features of the mineral sources and energy resource in China. Of recent years, in the dis-

trics where have a lot of hydraulic power and coal sources, especially in the districs where have abundant reasonal hydraulic power, dispersedly set up many medium and small size electric furnaces, which spreads in many provinces and districts, thus can use local materials, the investment is low, the economic effect will be obtained quickly. Some medium and small-size enterprises have set up one electric furnace 6300KVA, from construction to commissioning only took 8 months, made an investment of 1.5m yuan, after less than a year the whole investment was recovered.

The blow-out and blow-in electric furnaces of medium and small-size are convenient, the loss due to blow-out and blow-in electric furnace is relatively low, efficiently utilized seasonal hydraulic power and some disposed residual electric power.

The medium and small-size electric furnances produce silicon metal, ferro-silicium and calcium carbide, these products can be remelted to each other, and the objective need can be quickly suited.

Of recent years, in the construction of the medium and small-size electric furnances, some enterprises in China have jointly operated with domestic and foreign capital and operated by way of compensation trade, absorbed foreign capital. Some silicon metal enterprises have set up their own power station or the power plant has set up silicon metal furnaces, the generation has combined with silicon metal production, thus the energy sources deveopment whould be facilitated and pushed on.

2. Technical present state

The medium and small-size electric furnaces with capacity of less than 6300KVA compared with those of over 10000 KVA, their thermal stability is poorer, the operation and management are more difficult. But because of adopting some measures for several medium and small-size electric furnaces, the index of the economic effect and the specific consumption of material and electric energy are still better. The technical present state is briefly described in several aspects as below.

(1) Use variety of carbonaceous mamterials as reducing agent

In the later stage of 1950's when our country began to produce silicon metal, mainly used charcoal as reductant, produc-ec one ton silicon metal consumed over 1.5 tons charcoal. In the middle stage of 1960's, began to use the mixed reductant composed of charcoal, petroleum coke and bituminous coal. Since 1970's, in order to suit easures to local conditions and to use materials locally for some medium and small-size electric furnaces, the test on using the conncob, wood chip(partially instead of charcoal) as reductant and wholly using petroleum coke as reductant for smelting silicon was carried out, and the better effect was obtained.

a single-phase 2-electode furnace 5000KVA produced 1 ton silicon metal consumming reductant: bituminous coal 346KG, petroleum coke 350kg, charcoal 998kg, and specific energy consumption was 11757KW.H/ton Si.

A 3-phase 3-electrode electric furnace 5000KVA produced ! ton silicon metal consuming reductant: petroleum coke 1280kg, wood flour 610kg, and specific energy consumption was 13200 KW,H/ton Si.

The practice of production of silicon metal using wholly petroleum coke as reductant had shown that the industrial production could be carried out in such a way, and the quality of product could be also raised. The problems existed were: the permeability of the furnace charge was poor, the pound of the furnace was dif-

ficult, energy consumption was higher. A 3-phase,3-electrode furnace 5000KVA produced 1 ton silicon metal using wholly petroleum coke as reductant, the petroleum coke consumption was 1450 kg, the specific energy consumption was 15721 KW-h/tons silicon metal.

(2) Strictly control and in time adjust mixture ratio

Thelevel of mechanization and automation in production of silicon metal by medium and small-size electric furnaces in China is low, the manpower consumption in the operation and management is much more. To bring the operations and managers into full play is the important aspect of better production of the silicon metal. In the process of smelting silicon metal, on the one hand the electric and geometric parameters of the electric furnace must be well chosen, on the other hand depends on the stric observation and careful operation of the real operators who are at their posts around the electric furnace, thus makes them in time adjust the material and mixture ratio according to variation of the furnace condition and moisture content and size of the furnace charge, often maintain the size

the charge entered the furnace and ratio onto the suitable level. Thus can guarantee the furnace charge has relative big coefficient of resistance, the more silicon carbide might be deeply submerged. So can use relative high working voltage in the furnace, make the output comparative high, energy consumption can be reduced. When the electric furnace 1800KVA can be done is such a way, its working voltage can be maintained at 90-92v. Under the conditions of that the diameter of electrode is 350mm, the diameter of the furnace chamber is 2700mm, the depth of the furnace chamber is 1600mm, the electrode can often be maintained at that level the distance between its bond and furnace bottom is 300-350mm, silicon metal produced in each furnace is 100 tons/month, the specific energy consumption reaches 12800KW-h/t Si.

(3) The improvement of the lining and start up of cold furnace

As to the fining of the furnace in China usually use the baked carbon brick for the bottom, the gragitized carbon brick for the side wall, the refractory clay brick for the rest. When lining the several medium and small-size electric furnaces, in order to use material locall7 and reduce the material cost, we use self-baked carbon brick mainly made by the materials composed of metallurgical coke, petroleum coke, high quality anthracife natural earthy graphite and coal-tar, but the above mentioned material should be crushed, mixed and blended, mould pressed and vibration formed. Comparing with baked carbon brick and graphited carbon brick, the raw material sources for self-baked carbon brick is wide, technique of production is simple, low cost. The practice has shown that the self-baked carbon brick has progrties such as high-temperature-resistant, antioxidation, corrosion-resistant, the themal stability at high temperature is goodm and its integrity is strong, because use self-baked carbon brick to line the furnace, the composition of the binding material used in the cracks is the same as that of carbon brick. Its baking process is simultaneous withthe procedure in production, so the carboneous lining formed is solid, compact and inegral. Originally when use baked carbon brick lining, the strength at the joints leakage would be improved.

besides, the self-baked carbon brick is still easy to make into various forms according to real need of the electric furnace, so the amount of working in the process of laying furnace may be reduced.

When use self-backed carbon brick for lining the furnace, due to its baking is completed in the process of bake and later in the continuous production, so a

set of baking furnace system suited to it is needed.

A lot of silicon metal furnaces had been set up for utilization of seasonal hydraulic power and some dispersed residual electric power, so that times of limit electricity and blow-out of furnace were relatively more. As to short time service interrmption, the furnace hearth was heated by carbonaceous reductant, thus the temperature would be raised rapidly after power transmission. As to start up of cold furnace after long time semice interruption, it was different from the start up of new lined furnace, the temparature was not raisedslowly, to the bottom of electrode added a certain quantity of silicon and carbonaceous reductant, the lumpt of silicon was melted after power transmission, the conductivity was strengthened, the gemperature of furnace was raised quickly. Thus the normal prodiction was returned to quickly.

When the cold furnace start up, the higher working voltage was adopted usually, as to electric furnace 6300 KVA, the secondary voltage during starting up was 125-130V, the secondary voltage during starting up of cold furnace 1800KVA was 90-95V. Thus during the time from the beginning of start-

up to normal production, the relative big crucible and discharge zone could be formed, returning to normal production stage was guaranteed successfuly.

(4) Measures for raising the quality of product

Strict acceptance and finely selecting raw material. In many medium and small enterprises established the organization of special check combined with mass check. With the exception of a person specially assigned for checking on the raw material entered the factory and on every links in the preduction chain, the daily check was carried out by the production workmen organized, the poor raw material found which instantly stopped to use.

strictly control the enteming of the iron into the raw material. The raw maerial should be concentrated by dressing, besides, in the industrial process the iron rod used for poring the furnace was strictly forbidden, the iron fool in the operation should be made by friction-resistant alloy steel.

work out the norm of the enterprise, At the present time the sate norm adopting widely at every factory is waiting for conection. In order to quarantee and raise the product quality, beside the state norm, worked out the inner controlled norm in the enterprise, and according to such inner controlled norm worked out optimum technologic working instruction.

Use gas for refining. The process of entering gas in molten Si for refining has adopted for many years in our country. This process of removing Ca and Al from Si had obviously effect. The problem existed was environment pollution. In order to prevent environment from pollution at the furnace taphole and refining installation added efficient gas collecting hoods.

Use flux for refining. Added flux of Na2-SiO2 system on $Na2CO^3$-SiO^2 system into molten Si. In the experimental stage, these two kinds of flux had an obvious effect on removing AL and Ca, Ca content reduced to 9% (combined with the rest method), Al content reduced to 30%. In actual production in the silicon metal furnace 1800KVA, the si refining carried out with the flux containing Na^2o and SiO^2 was adopted, the reduction of AL was 20%, the reduction of Ca was 40%.

(5) Fume cleaning and dust recovering and utilization the large amount of fume generated in industrial Si smelting, after which exhausted from the furnace, seriously polluted the environment.

In our country since 1970's the test on composition of fume and dust recovery in silicon metal production in the medium and small-size furnaces had been carried out, and adopted cleaning technique of high tension electrostatic precipitators and bag-type collectors on the electric furnaces 2700KVA, 3200KVA and 5000KVA.

The fust from medium and small-size silicon metal furnaces is fine and light, good viscosity, not easy to settle, poor hygroscopicity, strong adhesion to the surface of metal or fabric. Beside the minor carbon powder and crystallized Sio 2. (2)

Specific surface and size distribution of the dust are shown in the following table.

Specific surface and size distribution of the dust

Chemical composition of the dust, % :						
Sio2	Al_2O_3	Fe_2o_3	Mgo	Cao	So_3	Lo_1
93.7	0.5	0.6	0.7	0.4	0.4	3.6

The counter-blow positive pressure glass fibre filter adopted on the silicon metal furnace 2700 KVA has already operated for several years. The dust removing system erected on the stack of the fume discharging hood of the original electric furnace, shut off by means of the value, made the dust-laden gas press into the ash chamber of the dust collector through change of valve by the fan, the dust after the bag filter adhered to the wall of bag filter, the gas after cleaning discharged through the upper shuttle of the filtering chamber into the atmosphere (2).

During the counter-blow ash cleaning, the actuation of the exacutive mechanism of electromagnetic valve was self-controlled by the time differential-pressure controller, the air inlet was shut off by the change over valve, because of negative pressure draft in counter-aspiration channel, the air stream outside the door flew backwards, the air stream through shuttle from the outside of filtering bag penetrating it entered the inside, then the dust accumulated on the inner wall of the filtering bag

was shaken out into the chamber, the air stream after counter blow returned to negative pressure dust before the fan, which together with the dust-laden gas was pressed into the filtering bag chamber by the fan, and discharged after cleaning.
Process design parameters for dust removing system

Volume of fume from electric furnace, m^3/h	3,000
Fume temperature, °c	about 150 (with the change of air temperature
Concentration of dust-laden fume, g/ m^3	1
Filtering speed, m^3/min	0.34
Filtering bag, diameter 230mm,	length 5000 mm divided into 7
Counter-blow speed, m/min	chamber, 60 ps/ chamber
Air speed in dust-laden duct, m/s	0.7-1.0 10
Work cycle for ash cleaning	60 min time 40-42S

Of the late years the research results obtained by several units in China showed, the dust recovered might be used in many aspects.

The dust (is called silica fines for short) contained a great amount of silica recovered from the fume, added into the common cement, sand, stone and superplasticizer, thus could produce high strength concret. This high strength concrete added with silica fines has features such as small contraction, low hydration heat, good anti-permeability, high tensile strength, wear-resistance, corrosion-resistance, oil-proofing. The silica fines used as concret additive was already adopted in the diversion tunnel work at the hydraulic power station.

As additive, the silica fines can be used as anti-corrosive material in water work. The mortar of silica fines prepared by silica fines additive already used in repairing the water gate of the dam, the result showed that silica fines mortar has shock resistance which, compared with the cement No. 600 raised by 60 -150%, its hydroscopicity, compared with that of common cement, reduced by 20 -30%, the compressive strength, compared withthat of common cement, raised by 45 -66%, the tensile strength raised by 7-20%.

The microporous light refractory made by silica fines has small volume density, good thermal insulation, a certain compressive strength at normal temperature, good machinability, easy to cut and lay, at 850 -950 °c, it has resistance to Al and electrolytic fouling, and suitable for lining of AL reduction cell.

From now on, except that the part of local medium and small-size enterprises in China which must be adjusted according to supply of energy sources and raw material, a big part of the enterprises must be further perfected and raised. The conjectures of the main technical development are: (1)Reduce the use of charcoal and widen use of the coal. At present though many medium and small-size enterprises far and wide adopt mixed reductant composed by 2 or 3 kinds of materials such as charcoal, petroleum coke, clip, corncob, bituminous coal, but as a whole the most still use charcoal, the specific weight of charcoal used in some enterprises is relative big. The amount of bituminous coal used is not big. China is rich in coal, some coal mines have non-binding lump coal with good property, the ash content in coal of whole mine layer is only of 3-5 %, and good activity, high specific resistance, low degree of graphitization at high temperature. (3) The study on the property and feature of this coal, widen its application in the reductant, has a development future.

(2) Use Self-backed electrode or carbon electrode

At present on medium and small-size silicon metal furnaces mostly adopt graphitized electrode. The electrode contains less impurities, can guarantee the quality of product, but its cost is high, the resource is difficult, thus the expansion of the furnace capacity is limited. In order to solve these problems, the study on new structure of self-backed electrode or combined type of carbon eletrode. At the same time solve the problem of formulation of electrode paste, as far as possible reduce the impurities entered the furnaces.

(3) Use short hood and further solve the problem of gas cleaning

On the silicon metal furnace 1800 KVA and 6,000KVA, we use short hood. The practice showed that the short hood on the furnace can better solve the problem of insulation of radiant heat, improve operating environment, short network of

flexible bushar can erect on the furnace hood, reduce the effect of high temperature in the furnace, improve conductivity, prolong the service life; use short hood, reduce the mixed gas from the hood, can clean the fume and recover the waste heat. From now on, the short hood will be spreaded and adopted on the medium and small-size industrial silicon furnces,

and further solve the problem of gas cleaning.

(4) Study and use new technique of direct current furnace

The furnace with direct current has features of reduction in concumption of electrode and noise. We have adopted monoelectrode for power supply with direct current on the silicon metal furnace 8000 KVA. This test is carried out now.

Conclusion

The local medium and small-size silicon metalenterprises in China have set up since 1980, now they already became an important power of industrial silicon production in China. Of late years, these local medium and small-size enterprises brought the utilization of dispered residual pwer and development and utilization of energy sources, mine sources and man power sources into active place. From now on these enterprises need further to consolidate, perfect and improve. We will provide much more good quality and cheaper silicon metal, for many countries of the world. at the same time we also hope to introduce fond and technique from every country.

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