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TECHNOLOGY FOR MANUFACTURING CATHODES FOR ALUMINIUM REDUCTION IN CHINA

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Abstract

More than 20 manufacturers producing cathode blocks used in aluminum smelters exist in China. The total annual production capacity for the cathodes reaches up to 300 kt, most of which are semi-graphitic cathode blocks and some graphitized cathode blocks as well.

The types and quality of the Chinese cathode products and the manufacturing technology for both semi-graphitic and graphitized cathode blocks in China are reviewed in this paper.

An energy saving manufacturing technology developed in China for the graphitized cathode block production is also revealed.

Introduction

There exists more than 20 cathode block producers for aluminum reduction in China with annual production of 300 kt. The major product type is the so-called semi-graphitic cathodes with 30-50% aggregate graphite composition and a small quantity of graphitized cathodes is produced by a few manufacturers based on customer requirements.

High amperage cell technology of more than 400 kA has been applied in all the newly built smelters in China since 2008 and a potline with 500 kA cells has been put into operation. The capacity of the larger cells with more than 300 kA occupies 40 % of primary aluminum output in China.

This application of high amperage cell technology brings about new and strict requirements to the specifications and quality of cathodes and anodes. It is now required for the cathodes used in high amperage cells to have excellent properties, such as better heat and electrical conductivity and homogeneous quality. Their specifications and configurations have to meet the demands of the high amperage cell design.

The new structure cell technology has been developed in Chalco in recent years and applied in more than 1000 cells with a great achievement of energy saving of about 1000 kWh per ton of primary aluminum. Nevertheless, the configurations of the cathodes used in the new structure cells are quite different from the traditional cells and so there are some difficulties to manufacture such complicated configuration cathode blocks.

Power consumption has a great impact on operating cost of graphite products due to the very high electricity price. A new energy saving technology for the graphitization furnace has been developed in China for reducing electricity consumption during the graphitization process and has obtained commercial application.

The status of the manufacturing and technology used in Chinese cathode industry is analyzed and reviewed in this paper.

Status of Cathode Manufacturing in China

Most of the cathode producers in China are located in Shanxi Province where about 60 % of total production in China is represented. Provinces such as Ningxia, Guizhou, Yunnan, Gansu, Henan and Hebei have 1 to 2 cathode manufacturers respectively. The total annual output in China is about 300 kt of cathodes. The location distribution of the major cathode manufacturers is shown in Figure 1.

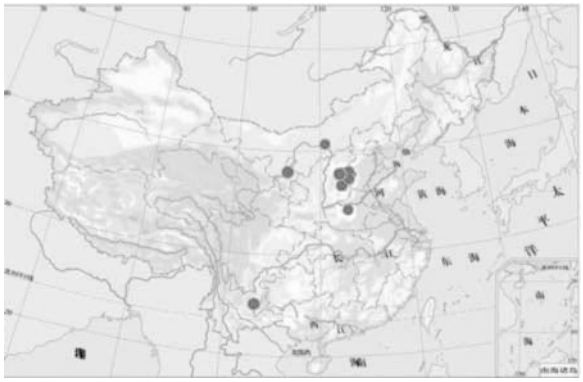

Figure 1: Locations of the major Chinese cathode manufacturers

Table 1 on the following page shows the cathode production of the major Chinese cathode manufacturers.

There are two types of production technologies used in Chinese cathode manufacturer. The first type used applys advanced processes and equipment introduced from overseas with higher levels of automatic control. This type of manufactureing generally requires higher capital investment and greater production scale and usually owns their own electrically calcined anthracite facility, extrusion or vibration forming machines, ring baking furnace with cover and sophisticated machines etc. The other type of cathode manufacturer has been developed gradually, most of which have no electrically calcined anthracite furnace and therefore purchase it from the market. They apply domestic vibration forming machines, open ring baking furnaces and the level of automation and process control sophistication is lower so that less investment is needed.

Table 1: Major Chinese cathode manufacturers and their production

No.	Company	Locations	Graphitic, kt	Graphitized, kt	Total, kt
1	Chalco Guizhou	Guizhou	22		22
2	Chalco Qinghai	Qinghai	23		23
3	Shanxi Pingyao Fengyan Carbon Co.	Pingyao, Shanxi	40	10	50
4	Liangyu Carbon Co.	Pingyao, Shanxi	50		50
5	Shanxi Danyuan Carbon Co.	Shanxi	20	15	35
6	Shanxi Jinyang Carbon Co.	Lingshi, Shanxi	30		30
7	Shanxi UC RusAl Carbon Co.	Shanxi	30		30
8	Shanxi Sanjin Carbon Co.	Taigu, Shanxi	25	10	35
9	Shanxi Qixian Yutong Carbon Co.	Qixian, Shanxi	25	5	30
10	Yunnan Wancheng Carbon Co., Ltd.	Yunnan	25		25
11	Shandong Yankuang Carbon Co.	Shandong	20		20
12	Ningxia Qingtongxia Aluminium Co.	Qingtongxia, Ningxia	20	20	40
13	Ningxia Ningping Carbon Co. Ltd	Ningxia	18		18
14	Henan Wanji	Xinan, Henan		50	50
15	Baotou Aluminum Co. Ltd	Baotou, Neimenggu	20		20

Types and Quality of Cathode Products

With the development of the Chinese aluminum industry and more requirements from the domestic market the major cathode products are the semi-graphitic cathodes with 30-50% graphite, which occupies more than 80% of total production and the rest, 20%, is the high graphitic cathodes with more than 50% graphite content or graphitized cathodes.

Table 2 below shows the quality comparison between domestic and overseas cathode products.

The study results show that the electrical and thermal conductivity will be enhanced with the graphite content increasing in the cathodes, while the sodium expansion and compressive strength will be reduced.

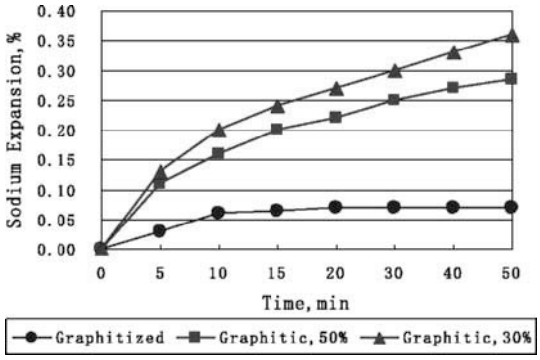

Figure 2: Sodium expansion of different types of cathodes

Table 2. Quality comparison between domestic and overseas cathode products

Overseas companies	Graphite content	ash %	Electrical resistance μΩ·m	Compressive strength Mpa	Bulk density g/cm^3	Real density g/cm^3	Porosity %	Sodium expansion %	Thermal conductivity w/(m·k)
Company 1	30%	4	37	30	1.58	1.92	17.7		12
	50%	4	28	28	1.58	1.93	18.1		18
Company 2	30%	2.1	30	26	1.55	1.94	20.1	0.4	13
	50%	1.6	24	25	1.56	2.01	22.4	0.35	18
Company 3	30%	4.0	30	27	1.58	1.95	19.0		16
	50%	2.5	25	24	1.59	1.97	19.3		17
Company 4	10%	5	35	35.7	1.55	1.89	18.0	0.9	10
	30%	4	28	28.6	1.58	1.95	19.0	0.7	14
	50%	3.5	23		1.58	2.02	21.8	0.6	18
Domestic, 30%		3.5	31.4	30	1.58	1.94	18.6	0.64	15.6
Domestic, 50%		2.8	25.2	27.6	1.57	1.98	20.7	0.53	21.8
Chinese Standard		≤7	≤40	≥32	≥1.56	≥1.90		≤1.0	

As shown by the test results in Figure 2 the sodium expansion of the semi-graphitic cathodes with 50% graphite and graphitized cathodes is only 75% and 20% of the graphitic cathodes with 30% graphite respectively. And the sodium corrosion resistance becomes obviously better with the increase graphitic content.

The results of industrial application show that the cell voltage of high amperage cells is reduced greatly and the cell operation becomes more stable with higher current efficiency by using the cathodes with higher graphite content.

Demand for high quality cathodes on the international market is growing , which promotes the cathode manufacturers to develop and produce new cathode products.

Based on incomplete statistics data about 50 kt of cathodes are exported from China every year. The aluminum reduction technology transfer from China also provides opportunities to develop the international market for the high quality cathode blocks for export.

The domestic demand for graphitized cathodes in China is very limited because almost all the Chinese smelters use the graphitic cathodes instead of the graphitized cathodes due to the consideration for lower capital cost and higher cell life In recent years there appears to be only five to six cathode manufacturers who have started manufacturing graphitized cathode blocks to meet the international demand.

Cathodes with Complicated Configuration for "New Structure Cells"

The new structure cell technology is a key energy saving aluminum reduction technology developed in China recently. The core technology of which this technology is based on is the cathode configuration optimization and design. The stability of the metal pad in the cells can be greatly improved by changing the cathode configuration and collector bars. This results in reduced ACD and cell voltage for energy saving.

Compared with the traditional cells the configuration and shape of the cathodes used in the new structure cell are quite irregular and difficult to process. Ordinary cathodes have a regular cuboid shape and a smooth working surface. The collector bars are installed in the cathode bottom. Even though in the different amperage traditional cells the sizes and numbers of the cathodes used are not the same and the cell bottom surface always appears horizontal. A schematic diagram of a traditional cathode is shown in Figure 3.

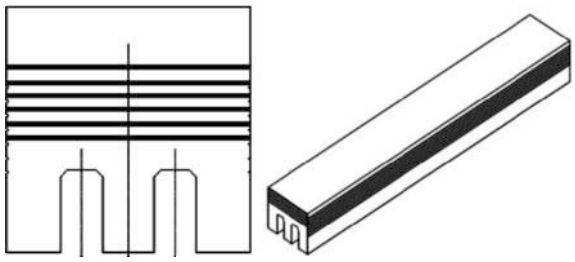

Figure 3: Schematic diagram of the traditional cathode

The cathodes with grooves on the surface in the new structure cells are processed from the ordinary cathodes by mechanical fabrication machines. Figure 4 is the typical cathode with grooves on its surface.

Figure 4: The typical cathode with grooves

There are a number of disadvantages for processing the cathodes with grooves by mechanical machines:

(1) More fabrication loss and lower qualification rate. For a cathode block with a specification size 3200mm × 520mm × 515mm and bulk density of 1.58g/cm^3 approximately 0.23 ton will be cut off and the mass of the processed cathode is reduced by 17.4% due to the processing, which also increases the production cost.

(2) More difficult processing and lower productivity. Usually it is difficult to process cathodes to a special shape because the machines have to be retrofitted and the cathode position on the machine has to be changed for processing in the different directions. These results in complicated operation, higher production cost and higher waste product rate.

(3) The mechanical fabrication technology can not satisfy the requirement for producing the wetted cathodes with a very thin composite surface layer for reducing production cost.

A new technology to produce the cathodes with special grooves has been developed by Chalco since 2008 for a wide application of the new structure cell technology in its smelters. The technology is based on direct vibration forming. The groves on the cathodes are formed during vibration forming process directly.

Based on the simulations of stress distribution, the configurations and shapes of the mould in the forming machine are specially designed in order to form the desired shape. The groove edges are changed to a rounded shape for reducing the structural stress and improving the strength and qualification rate.

A production line with annual capacity of 10 kt of the cathodes blocks with grooves by direct vibration forming has been put into operation at Baotou Aluminum Corporation. The high quality cathodes with complicated configuration produced in the company are applied widely in the energy saving new structure cells.

Energy Saving Graphitization Technology in China

The graphitized electrode production for steel making in China was about 675 kt in 2011, of which approximately 200 kt were common power electrodes, 250 kt were high power electrodes and 220 kt were ultra-high power (UHP) electrodes. The production of UHP electrodes is increasing now. The major manufacturers for electrodes in China are Jilin Carbon of China Iron & Steel Group, Fangda Carbon in Lanzhou and Juyuan Carbon in Jiexiu, Shanxi.

Graphitization technology in China was developed from the Acheson technology. Indirect heating technology is used in an Acheson furnace which is not so easy to control. A longitudinal graphitization technology was then introduced for energy saving and better control by use of direct heating and computer control system.

About 80% of the graphitized electrodes now produced in China use longitudinal graphitization technology with a lower electricity consumption compared with the Acheson furnace.

The schematic diagram of the longitudinal graphitization furnace, which is also called as U type furnace, is shown in Figure 5.

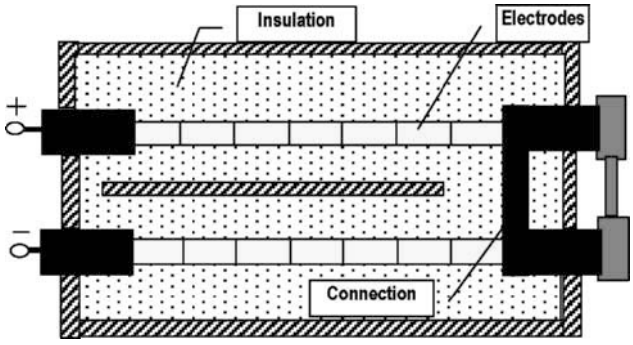

Figure 5: Schematic diagram of U type longitudinal graphitization furnace

The energy utilization status for both Acheson and longitudinal furnaces is compared in the Table 2.

Table 3: Comparison between Acheson and longitudinal furnaces

Energy Utilization status	Acheson furnace	longitudinal graphitizing furnace
Energy loss	77%	51%
in which: Power loss	24%	18.5%
Heat loss	22%	15%
Energy utilization rate	23%	49%

But the energy cost for the longitudinal graphitization technology is still too high.

On the basis of study results on U type furnaces a new kind of so-called straight line longitudinal graphitization technology has been developed by a Chinese company, Langfang Huanhui Carbon Technology Co. Ltd. for energy savings and now this technology is applied in China widely.

A great effort has been paid by Langfang Huanhui Carbon Technology Co. Ltd. for the innovation to the key technology and equipment, such as the transformer and rectiformer for the special longitudinal graphitization, electrical insulation graphitization furnace, mobile power supply facility and new electrical connections at a constant pressure.

The schematic diagram of the new type furnace for making graphitized cathode blocks for aluminum production is shown in Figure 6.

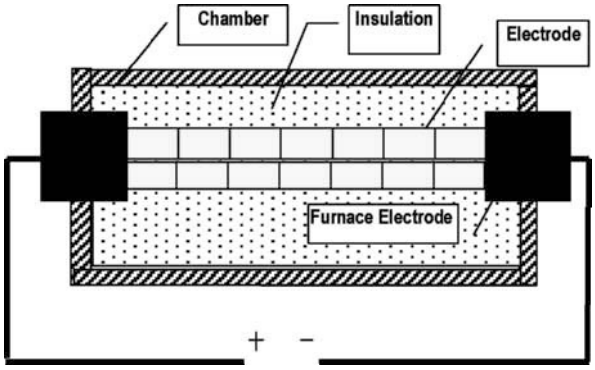

Figure. 6 Schematic diagram of straight line longitudinal furnace

Table 4: Comparison between Straight line and U type longitudinal furnaces

	Straight line longitudinal furnace	U type longitudinal furnace
Energy consumption, kWh/t	2900	4200
Annual Capacity, t	12000	6000
The largest loading, t	50	30
The highest amperage, kA	200 kA	130 kA
Investment	83.5%	100%

As shown in Table 4 the straight line longitudinal graphitization furnace has such advantages as higher power utilization rate and lower loss compared with the original U type furnace.

It is concluded from the industrial applications that for the straight line longitudinal furnace the graphitization energy consumption is about 300 kWh lower than the U type longitudinal furnace and the capital cost is reduced by 20%. Its core technology is that the electrode profile area is enlarged by a special technology for expanding production and the electromagnet interference is reduced to improve the furnace operation safety.

Many production lines using the straight line longitudinal furnace have been put into operation in China owing to its advantages mentioned above.

Conclusion

(1) More than 20 manufacturers producing cathode blocks used in aluminum smelters exist in China with an annual production of about 300 kt. The product types are semi-graphitic cathodes with 30-50% graphite and a small quantity of graphitized cathodes. About 50% of capacity is in Shanxi Province.

(2) The cathodes with complicated configuration are used in the New Structure Cells developed in China and processed by direct vibration-forming technology.

(3) The straight line longitudinal furnace technology has been developed for graphitized electrodes production in China with lower capital cost, higher capacity and energy consumption lower than 3000kWh/t.

References

[1] Liu Fengqin et al. Study on Cathode Property Changes During Aluminum Smelting, Light Metals 2007

[2] Liu Fengqin, Gu Songqing et al. Application of New Structure Reduction Cell Technology in Chalco's Smelters, Light Metals 2011 p.509-512

[3] Chinese patent: ZL200920108855.0 "Cathodes for the new structure cells"

[4] Liu Fengqin, Yang Hongjie, Yang Xiaopei "Manufacturing and applications of high quality cathodes in China" Carbon Technology (in Chinese) 2007, (4) p.36-41