Light Metals 2013 *Edited by: Barry Sadler*
TMS (The Minerals, Metals & Materials Society), 2013

COMPARISON OF MIXING PROCESS METHODS IN PREBAKED ANODE PRODUCTION

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Keywords: Prebaked anode， Mixing process, Continuous method, Interval method

Abstract

The continuous, batch, and semi-continuous mixing processes are mainly used for prebaked anode production in China. In recent years, the semi-continuous mixing process is very popular in China. There are three kinds of mixing processes, which are different in construction, equipment configuration, yield, product quality and also varying investment, operation and maintenance cost. Considerations for selecting a mixing process include environment, automation level, staff ability requirement, and adaptability with different raw materials. For a new green anode plant project, the clients always focus on the investment, profit, product quality, operational efficiency, energy consumption and environmental standard, and then choose the proper mixing process method. The three kinds of mixing processes have different advantages according to the project scale, investment, automation level and product quality, and they will all be presented in this paper.

Introduction

It is well known that the paste mixing process is the key step for anode production. It kneads dry aggregate (calcined coke, butts, green scrap) with liquid pitch to get high quality paste for forming.

The kneading temperature, time and power are mainly crucial factors for paste quality. Usually, the continuous, batch, and semi-continuous mixing processes are mainly used for prebaked anode production in China. In recent years, semi-continuous mixing process is also popular in China because of project investment, operation and maintenance cost, and stringent environmental standards. The high efficiency, energy saving, environmental protection, low power consumption, security and high quality anode are basic requirements for any prebaked anode project. Therefore, it is necessary to understand the advantage or disadvantage for the three kinds of mixing process in operation, such as process and equipment configuration, paste quality and yields, annual availability, construction investment and construction period, operating and maintenance costs, environmental emissions, automation level, staff ability, and adaptability for different raw materials.

Introduction of mixing process

The continuous mixer or kneader is the main equipment for the continuous process. The batch mixer is for the intermittent process and the double layer batch mixer is for semi-continuous process which is widely used in recent prebaked anode projects in China. In the intermittent process, dry aggregate is preheated by electricity and this process is applied for the production of graphite electrodes and aluminum cathode. The intermittent process is not suitable for anode production because of the smaller capacity.

Continuous kneading

The continuous mixer or kneader is the main equipment for the continuous process. This equipment is divided into two kinds, the horizontal and vertical type. Horizontal kneaders are represented by Swiss BUSS and USA B&P Company, the vertical are represented by kneading machines of German EIRICH Company [1].

Horizontal continuous kneader

The Horizontal continuous kneader has used biaxial shafts in the past. In recent years, most of them use a single shaft. Figure 1 shows a picture of a single shaft horizontal continuous kneader.

Figure 1: Picture of horizontal continuous kneader.

The Horizontal continuous kneader operates as follows: the dry aggregate materials and liquid pitch are mixed and kneaded by the rotating and reciprocating moving of the shaft. Its main feature is that with the force produced by the moving between moving blade on the shaft and fixed blade on the shell of the machine, a good kneading function to the paste can be obtained by this movement.

The kneading effect and quality of paste is claimed to be better than the vertical continuous kneader. The paste temperature at the outlet of the machine ranges between 180~190°C. In the shaft and shell of the kneader, HTM is used to heat the paste to a target temperature. This type of kneader has a block gate and uses the gate opening to control the power of the machine and therefore get a uniform paste quality. It also has a large production capacity rate.

The volatile matters of the pitch are collected by the fume treatment system that allows the work room to have a good environment. It is widely used all over world. In recent years, this equipment is used in mostly in lines that produce over 200,000 tons/year. The diameter of the cavity is more than 600mm and can produce up to 40~55t/h paste capacity.

Vertical continuous mixer

The vertical continuous kneader working mechanism uses the interacting force between high speed mixing blades (beaters) and reverse rotating shell to make the paste have a floating state. Under this condition, the dry aggregate and pitch have a good

mixing function. Figure 2 shows a picture of a vertical continuous kneader.

Due to the high rotating speed of the beaters, the vertical continuous kneader can get a good mixing effect on the paste. This makes a very homogeneous paste quality, but not as good kneading function to the paste. In order to have good penetration of the liquid pitch, vertical continuous kneaders need a higher paste temperature (190~200℃). As this machine does not have the HTM to heat the paste, the dry aggregate preheating temperature needs to be higher.

Figure 2: Picture of vertical continuous mixer

The vertical continuous kneader made by EIRICH company represents the development of new technologies in recent years, More than 10 sets of this machine have been put into operation in the world. China has four sets. The client of this machine mainly distributed in tropical and subtropical regions. Paste plants which use the vertical continuous mixer always have a capacity over 150,000 tons/year.

Intermittent kneading

The batch mixer is the main equipment for paste intermittent production line. Figure 3 shows a picture of a traditional horizontal biaxial batch mixer.

Figure 3: Picture of traditional horizontal biaxial batch mixer

Firstly, the traditional intermittent batch mixer (also called single-layer batch mixer) preheats dry aggregate material by HTM, then blend with liquid pitch to internally produce paste. Most single-layer batch mixers contain a double Z-intersecting mixing blade with same speed and the same horizontal plane arrangement, and HTM heating.

The single layer batch mixer kneads and separates the paste at the same time. Normally, two mixing blades are in opposite rotation and the paste is repeatedly blended and kneaded. When the paste is thrown back into the bottom of the mixing chamber it is split into two parts - one part of paste is departed from the original mixing blade and taken away by the other mixing blade. This step is so called paste separation. Due to two blades in continuous rotation, the paste is blended, extruded, split and kneaded, so as to achieve the purpose of the uniform paste.

The single layer batch mixer is still widely used for old, low capacity anode plants. Firstly dry aggregate materials are blended and preheated to 150℃ using HTM during 20 minutes, then mixed with 170℃ ~ 180℃liquid pitch. Wet mixing requires 40 to 50 minutes, so one mixing cycle of single layer batch mixer takes 60 to 70 minutes. The common problems with this technology are too long paste mixing time, small capacity, low paste quality (especially uneven paste quality for different batch mixer).

Semi-continuous mixing process

In recent years, one semi-continuous mixing process is adopted for a new anode project on the base of the single layer batch mixer in China. The body of the single layer batch mixer is divided into two parts. It is so called the double layer batch mixer. The dry aggregate materials are blended and heated by HTM in the upper part of body, and when temperature of the dry aggregate materials is suitable, the sliding valve is opened and material falls into the lower part of body. The preheated dry materials are mixed with liquid pitch. This kind of batch mixer heats dry aggregate materials in the upper body and mixes them with liquid pitch in the lower body at the same time; usually one cycle of paste preparation takes 40 to 45 minutes. Several Double Layer Batch mixers are normally connected together to achieve the so called semi continuous kneading process..

Figure 4: Picture of double layer batch mixer

Comparing with imported continuous mixers or kneader, the double layer batch mixer is less capital investment (only about 1/8 of imported products) for the same production capacity, lower injected paste quantity, flexible carbon production and capacity adjustment. Comparing with the single layer batch mixer, it is larger capacity with lower energy consumption. Energy saving is nearly 50% and the investment is 50% less for the same production capacity.

In recent years, this kind of semi-continuous mixing process is widely adopted in some large and medium scale anode plants and mineral furnaces for carbon electrodes enterprise in China. At present, more than 150 sets of double layer batch mixers (total anode production capacity of three million ton/year) are operating at the capacity of 3000 l/h, 4000 l/h. Several sets are operating at the capacity of 5000 l/h, 6000 l/h. The capacity of 7000 l/h is erected already, and the capacity of 8000l/h is developed.

The comparison of several mixing process

Paste Quality

The most important process parameters of mixing process are kneading temperature, time and power.

It is generally believed that the kneading temperature should be 50 to 70℃ higher than the pitch softening point. If the kneading temperature could not meet the requirements, the viscosity of the pitch will be high; pitch will have poor penetration to dry aggregates materials which will cause uneven kneading, and a very 'plastic-like' paste. This paste is not conducive to molding, which easily leads to the loose structure of the raw products and low bulk density of anode. The kneading temperature should also not be too high. Too high kneading temperature causes the emission of the light components of the pitch volatile, heavy component oxidation results in poly-condensation which cause the pitch aging. That also make pitch aggregate wetting deteriorate, deterioration of the paste, and therefore generation of more reject paste.

The key to improving the quality of paste and reducing the kneading time is to improve the preheating temperature of dry materials, which makes the pitch penetrate quickly and thoroughly infiltrating the coke particles. The continuous mixing process, with high kneading power, shortens the kneading time (4 to 5 minutes) and improves production efficiency. However, the less kneading time also influences the paste quality. After a continuous mixer or kneader, normally a powerful paste cooler is installed, and the high temperature paste is cooled to a suitable temperature target for forming. Cooling time is approximately four minutes and mixing power input are about 3 to 4 kWh / t.

For the intermittent and semi-continuous mixing process, the kneading time and temperature are the important factors which determine the kneading quality. The kneading time and temperature depend on the softening point of pitch, aggregate formulations, kneading power and other factors. The kneading time of paste is controlled between 30 to 35 minutes to ensure the high paste quality.

The two kinds of mixing processes require a large power input per unit (8-10 kWh/t) due to their long kneading time. It could be suitable to feed paste for former continuously, if there is a reasonable kneading capacity to match with forming capacity. It can eliminate the influence of temperature fluctuations caused by intermittent feeding to paste quality, to ensure the stability of the product quality. The intermittent and semi-continuous mixing processes produce anode blocks using many batch mixers, and the stability of the paste quality is said to be worse than that of continuous mixing process. Table 1 shows the comparison of green anode quality between batch mixing process and continuous mixing process. The paste samples are taken by the same production process conditions in the laboratory.

Table 1: Green anode quality - Batch and Continuous process

No	Specification	Unit	Continuous mixing process	Batch mixing process
1	Bulk density	g/cm^3	1.569	1.591
2	Real density	g/cm^3	2.081	2.084
3	Porosity	%	24.6	23.7
4	Resistivity	μΩ·m	32	31.3
5	Compressive strength	MPa	34.2	34.6

Comprehensive Comparison

The comprehensive comparison between intermittent, semi-continuous and continuous mixing process are shown as Table 2 and Table 3, based on Current situation in China.

Table 2: Comprehensive comparison of typical mixing process

Item	Semi-continuous	Intermittent	Continuous	
Equipment	Double layer batch mixer	Single layer batch mixer	kneader	mixer
Investment	Low	Lower	Highest	Higher
Paste quality	Best plasticity	good plasticity	better plasticity	normal plasticity
	Poor uniformity	Poor uniformity	Good uniformity	Best uniformity
Kneading power	16-20 kWh/t	16-20 kWh/t	7-8 kWh/t	4-5 kWh/t
Pitch content	Higher	Higher	Low	Low
Waste paste	0.5%	0.5%	3～5%	3～5%
Qualify rate of baked anode	99%	99%	98%	98%
Equipment weight for capacity	Higher	Highest	Normal	Low
Environment	Better	Worse	Better	Better

Table 3: Comprehensive comparison of typical mixing process

Item	Semi-continuous	Intermittent	Continuous	
	Double layer batch mixer	**Single layer batch mixer**	**kneader**	**mixer**
Construction period (production)	15-18 months	15-18 months	24-30 months	20-30 months
Commission	15-30 days	15-30 days	180-300 days	180-300 days
Operating costs (Including spare parts)	Lowest	Low	High	High
Capacity	Larger	Small	Largest	Large
Availability	70-75%	70-75%	60-65%	60-65%
Anode scale suitable for Single line	Below 200,000 t/a	Below 150,000 t/a	Over 200,000 t/a	Over 150,000 t/a
Operator	When the Anode capacity is between 150,000-250,000 t/a, semi-continuous mixing process needs more 4 to 5 workers than continuous mixing process. However, it should employ high ability operator.			

Four kinds of mixing process are all adopted in China. Semi-continuous double layer batch mixer is suitable for medium and large scale prebaked anode plant or multi-size product, high-quality, low-cost anode plant. Semi-continuous mixing process has rapid development in recent years; the single process line capacity of it is approximately 200,000 tons per year. The traditional single batch mixer is usually in the small and medium-sized aluminum smelter or multi-size product, high-quality anode plant, the single process line capacity of it is approximately 150,000 tons per year. Continuous mixer or kneader is widely used in modern large aluminum plants. It is suitable for owner-occupied, single species, large scale of anode plant construction,

majority of key equipment is needed to import from overseas company. The proportion of continuous mixing process is the maximum. The largest single process line capacity of it is more than 250,000 tons per year.

Intermittent and continuous mixing process are both widely use in the world. Comparing with continuous mixing process, intermittent and semi-continuous mixing process have advantages of lower equipment investment, shorter erection and commissioning time, low operating and maintenance costs, less waste paste ratio, higher running availability, higher yield, and lower requirements for operation and maintenance ability of operator. On the other hand, it has too much devices for configuration, lower environmental standard, lower degree of automation, poor paste quality and higher labor cost. The advantages of continuous mixing process are a high degree of mechanization, better uniformity of the paste, higher production capacity and labor conditions.

Two main reasons cause the high ratio waste quantity for continuous mixing process. One is because the continuous mixer or kneader needs high filling rate to ensure high quality paste. The other is that since the mixers/kneaders are upstream of the process, any issues downstream (on vibrocompactors, for example), will require a purge of the paste in the system, causing waste paste. Continuous mixing process is suitable to the lower anode specification, large scale production.

For export-oriented anode enterprises, it is necessary to meet the variable product dimension requirements, higher product quality requirements, and other characteristics. The export-oriented anode enterprises in China, almost always choose intermittent mixing or semi-continuous mixing process.

Two-thirds of the anode enterprises in China adopted intermittent or semi-continuous mixing process, while one-third use continuous mixing technology, but mostly do not reach the expected results due to the instability and continuity of the process line. In this particular enterprise, equipment maintenance and process technique control are a challenge.

Conclusion

1. Comparing with continuous mixing process, intermittent and semi-continuous mixing process have the advantages of low equipment investment, construction period, commission time, low operating costs, good paste plasticity, less waste paste, high annual availability, high yield, low ability requirements of operator for operation and maintenance. There are also disadvantages of worse environment, low degree of automation, poor uniformity of the paste, high labor quota. Main advantages of the continuous mixing process are a high degree of mechanization, better uniformity of the paste, higher production capacity, labor conditions.
2. The high efficiency, energy saving, environmental protection, low power consumption, security and high quality anode are basic requirement for one prebaked anode project.
3. Continuous mixing process is the inevitable trend of technique for paste production. The crucial point is how to improve its stability and continuity in China. Batch mixing process couldn't be eliminated immediately, semi-continuous mixing process represented by double layer batch mixer basically replaces the intermittent mixing process for most new anode projects in China,. The market for this in China is very good, and will maybe one day find its way to other new anode projects throughout the world.

References

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