Some Understanding on PAN-based Carbon Fiber Carbonization Equipment

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Some Understanding on PAN-based Carbon Fiber Carbonization Equipment

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I. Brief description about the present status of development of carbon fiber carbonization equipment in China

China began the development of PAN-based carbon fiber in the mid 1960s, and in the early 1970s continuous production techniques had been achieved in the laboratory, which was a continuous pre-oxidation and low and high temperature carbonization experiment. At that time most of self-designed carbonization experiment was docking operating of low and high temperature carbonization furnace and in the form of interface exhaust.

In the process of development of carbon fiber, China achieved large scale production from small to large. Carbonization equipment has become industrial equipment able to carry out large-scale and industrialized production from experimental equipment. The core components have all been replaced with graphite compared with former Silicon carbide heating element and Corundum muff. And the equipment can not only meet the need of production, but assure the quality of carbon fiber.

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With the gradual maturity and perfection of carbon fiber techniques in China, people’s understanding towards carbonization equipment is improving step by step. The application of carbonization equipment on industrial production and feedbacks of its usage provide a good support on the improvement design and details.

At present, China already has the ability to design and produce kiloton carbon fiber and high-quality carbon fiber carbonization equipment independently.
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II. The function and classification of carbonization equipment in PAN-based carbon fiber producing process

During the entire process of manufacturing PAN-based carbon fiber, the fiber structure has two major changes from organic PAN-based raw material to inorganic carbon fiber containing over 92% of carbon. One change is from linear molecular chain of PAN-based raw material to heat resistant ladder structure of pre-oxidized fiber. The other is from heat resistant ladder structure of pre-oxidized fiber to turbostratic graphite structure of carbon fiber.

Carbonization equipment is the key to achieve a second fiber structure. In order to process the solid phase carbonization step by step and orderly control the structure transformation, there is a need of carbonization environment which can be controlled continuously and has temperature gradient. Under this condition, the carbonization equipment is divided into low temperature and high temperature carbonization furnaces.

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III. The focus of carbonization equipment

1. Non-contact sealing

2. Discharge of exhaust gas and tar

3. Graphite heater of high temperature carbonization equipment

4. Connective structure between graphite heater and metallic material

5. Gas replacement in the thermal insulation layer of high temperature carbonization equipment

6. Others

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1. Non-contact sealing:

Because of the need of inert atmosphere for pyrolysis and polycondensation during carbonization reaction, the equipment must provide relatively anaerobic temperature and environment. Non-contact sealing device is to prevent outside air from entering the carbonization equipment and to prevent the gas in the equipment from leaking to the outside of the apparatus, meanwhile, the device controls and regulates muffle’s atmosphere and working pressure.

Discharging mode and flow rate of Nitrogen in the non-contact sealing device directly influence the sealing effect, which can be intuitive phenomenon of changes from the content of trace oxygen in muffle and the working pressure. Sealing device can be provided with a structure capable of generating turbulence which should not only generate adequate turbulence to purge attached and entrained air in fiber, but keep the sealing effect of non-contact sealing device.

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2、Discharge of exhaust gas and tar:

In the carbonization process, in particular, the low-temperature carbonization will produce large amounts of gas which need to be discharged out of muffle as soon as possible. Pre-oxidized fiber, under the low-temperature carbonization, will produce the reaction of pyrolysis and polycondensation which may generate a lot of by-products—CO, CO2, H2O, HCN, NH3, H2, and a series of exhaust gas of high molecular weight. Under the low-temperature carbonization, the weightlessness of pre-oxidized fiber is about 43%, that is to say, there is 43% solid fiber changing to exhaust gas and tar, which we can imagine the reaction situation. The muffle is full of a high concentration of exhaust gas, which will pollute fiber if not discharging it immediately. If the residence time of the exhaust gas is too long, double bonds unsaturated alkenes in the exhaust gas will occur secondary polycondensation which producing the secondary by-product with greater molecular weight—probably tar.

The discharging position should be specifically based on the weightlessness curve of pre-oxidized fiber. The form of Exhaust outlet should be top discharging, side discharging, and end discharging, which should be determined by the structure of muffle, specifications of fiber, quantity of fiber, and other factors. The design principle is to protect smooth discharge of the exhaust gas and to prevent the production of tar under the low-temperature condensation. Once the tar produced, there should be measures to prevent backflow of tar which will pollute fiber.

At the same time, the smooth discharge of the exhaust gas can also be the protection to muffle, especially, prolong the service life of alloy muffle of low-temperature carbonization equipment.

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3. Graphite heater of high temperature carbonization equipment:

General operating temperature of high temperature carbonization equipment is from 1400°C to 1600°C, which varies depending on different requirement of fiber. Some users even reached the technological requirements of 1800°C. Thus graphite is the ideal material of the heater in high temperature carbonization equipment.

The high-quality graphite should be the priority choice, which is high strength, high density, high purity and excellent antioxidant properties to greatly extend the life of the heater.

Because graphite material has smaller resistivity, from $8 \times 10^{-6}$ to $12 \times 10^{-6}$, any unreasonable design and processing deviation will cause high local current on graphite heater, leading to seriously effect on service life and the formation of its good temperature field.

Therefore, strict material selection, reasonable structure design, precision machining are all preconditions assuring the service life of graphite heater and forming good temperature field.
Meanwhile, because of smaller resistivity of graphite, the carbon heater should be equipped with low voltage and high current power transformer. The design of transformer is based on accurate resistance calculation of graphite heater. Only with the exact resistance calculations, the output parameters of the transformer will be accurately matched, which can make the graphite heater and the transformer play a higher thermal efficiency and provide a longer service life.

The excellent performance of the graphite heater

Strict Selection on Material
Accurate Calculation
Reasonable Structure Design
Fine Processing

Graphite Heater

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4. Connective structure between graphite heater and metallic material:

Graphite heater and metal conductive device need to be connected to leads to the corresponding electrical connections with external equipment. Compared with metallic material, the graphite material is relatively low strength and smaller resistance, thus it is essential to connect the two structures. Rational connection structure design can not only overcome the problem of low intensity of graphite materials, but also ensure that the resistance issues between the two different materials.

Unreasonable design of the structure will have a greater resistance when the two materials contact, so that the contact surface may produce ignition and high temperature, causing that effective power can not be loaded on the graphite heater. Even it will damage more severely on connecting structure with serious equipment accidents.

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5. Gas replacement in the thermal insulation layer of high temperature carbonization equipment:

High-temperature carbonization equipment uses a lot of fibrous thermal insulation materials. There will be a lot of air infiltration after the initial installation and stopping working for a long-time. If the air in the thermal insulation layer can not be completely displaced, the air will result in the oxidation of the carbon heater, the graphite muffle, and the graphite support structure. Only with quick and thorough replacement of the air with nitrogen, the service life of temperature carbonization equipment can be guaranteed.

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6. Other related issues:

In addition to the above, there are also other relevant factors influencing the fiber quality and the service life of carbonization equipment, such as the precise measurement and control of temperature, the atmosphere control, micro-pressure control, and system automation and integration.

By optimizing thermal insulation materials, designing reasonably, and matching graphite heater and transformer, the service power of equipment will be reduced. By optimizing non-contact seal structure, the amount of nitrogen can be reduced, hence the reduction of the cost.

Carbon fiber production line

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IV. The present status of development of Xi’an Fu Ruida Technology Co., Ltd, China

Xi’an Fu Ruida Technology Co., Ltd in China, located in a historical city, Xi’an, is a high-tech company, which is professional at development and production on special equipment of carbon fiber and carbon / carbon material production, and relevant technical services.

At present, the company is able to provide the entire production line from test line, pilot line to small-scale production line on carbon fiber (PAN base, asphalt base and viscose base), which supply polymerization, spinning, oxidation, and carbonization. And the company also can provide low and high temperature carbonization furnace for industrial production (kt grade), carbon / carbon materials testing lines, and the equipment of industrial production lines, which all have complete independent intellectual property rights.

With the rapid development of Chinese carbon fiber industry, the company in just a few years has gained a good performance—supplying 7 line to users including oxidation and carbonization test lines, pilot line, and small-scale production line; 1 test line of polymerization and spinning; 5 high temperature carbonization furnaces for test using; 5 high-temperature graphitization furnaces; over 10 sets of low and high temperature carbonization furnace for industrial production; and 1 carbon / carbon materials testing line. Products are mainly distributed in Shaanxi, Shandong, Zhejiang, Henan, Liaoning, Jilin, Shanxi, Jiangsu and other places with high reputation and credibility.

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Sincerity and honesty are the foundation of our business.

Practicability and innovation are our responsibility.

Mutual improvement is our team ambition.

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V. Future planning about Xi’an Fu Ruida Technology Co., Ltd, China

Xi’an Fu Ruida Technology Co., Ltd in China is active to integrate and enhance technical team, and strengthen and improve the standard and ability of production. We will achieve the aim of becoming an engineering company which can undertake carbon fiber production. According to market position of users’ product, we will provide correspondingly entire production lines and overall technologies.

In line with innovation, meticulousness, flexibility, efficiency, and creating the brilliancy together, our company wholeheartedly devotes to the development and production of specialized equipment on carbon fiber and carbon/ carbon materials. We hope to strengthen communication with other companies and users, and to develop and grow with them together.

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1. Develop and produce low and high temperature carbonization equipment of industrial production line
2. Develop and produce oxidation and carbonization equipment of test line, pilot line, and small-scale production line
3. Develop and produce high temperature graphitization equipment
4. Develop and produce polymerization and spinning equipment of test line and pilot line
5. The destination: Becoming an engineering company which can undertake carbon fiber production

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Thank you very much!

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