

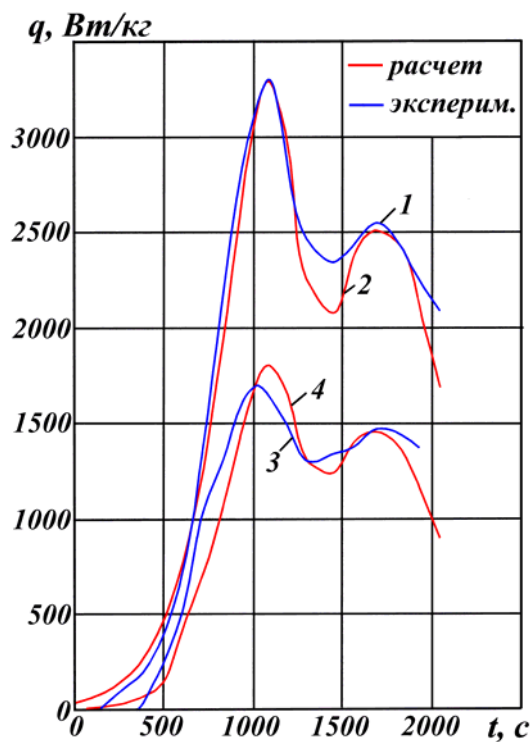
THERMAL EQUIPMENT IN PILOT PRODUCTION LINE OF CARBON FIBRES

Carbon high-strength bundles of strength 3600-5000 MPa at modulus of elasticity 210-230 GPa and high-modulus carbon bundles at modulus 300-500 GPa with strength 2000-3000 MPa and linear density from 33 up to 54,000 tex are required as an initial raw material for development and production of the modern non-metal composites (carbon phenolic, carbon-carbon, carbon-ceramic materials). Such bundles are: Vulon 320K at modulus of elasticity no less than 400 GPa and strength no less than 2 GPa with initial PAN-bundle of linear density 54,000 tex, which contains 320,000 elementary fibres, and Vulon-M on the basis of PAN thread 33.3 tex, its strength is half as large again the analog VMN-4M not produced in Russia now.

In 1992, KeRC took the initiative in starting the work on making a modern line of continuous production of high-strength and high-modulus carbon fibres of the indicated characteristics from polyacrylonitrile fibre (PAN- fibre). The most skilled and experienced organizations of Russia are involved to the development of the technology and separate assemblies of the line. Public corporation «TsK MPFG «Formash»» coordinates the work. NIIGraphit has developed the initial data on designing the line and the equipment for neutralization of exhaust. Development of documentation for the system of induction heating for furnace of grafitization and carpet ohmic heater for carbonization furnace is made by VNIETO. Development and manufacturing of high-temperature fans is committed to MOVEN. General layout of the line, transportation system, receivers of the finished products, line control system are developed by special design and technological bureau of machine building for production of the chemical fibres (SKTB MKhV).

Making the thermal equipment for the line to provide strict performance of the complex technological rules and uniformity of reaction space for processing of the fibres, and by that reducing the finished product characteristics variation requires the highly skilled experts in gas dynamics and thermal processes. So, development of thermal equipment (furnaces of oxidation, carbonization, graphitization and supporting systems) is committed to KeRC whose specialists have the highest authority in solving the analog tasks and great experience in rocketry and space engineering.

For the last years KeRC specialists have found the effective decisions of several complex tasks on equipment for production of artificial fibres. Thorough study of the main processes in all stages of thermal processing and determination of the required parameters and properties precede an issuing of documentation on the thermal equipment. Some characteristics of the fibres are given in Figs. 1, 2.



Determination of kinetic constants of the process

Fig. 1

Curves of heat release in PAN – fibres

$$\frac{E}{R} = \frac{T_1 T_2}{T_1 - T_2} \ln \left[\left(\frac{T_2}{T_1} \right)^2 \frac{a_1}{a_2} \right]$$

$$k = \frac{E \cdot a_1}{R \cdot T_1^2} \cdot e^{E/(RT_1)}$$

$$E_1 = 146.5 \cdot 10^6 \text{ J/kmole,}$$

$$k_1 = 7.3 \cdot 10^{11} \text{ 1/s,}$$

$$Q_1 = 1.2 \cdot 10^6 \text{ J/kg,}$$

$$E_2 = 83.7 \cdot 10^6 \text{ J/kmole,}$$

$$k_2 = 5.6 \cdot 10^4 \text{ 1/s,}$$

$$Q_2 = 2 \cdot 10^6 \text{ J/kg}$$

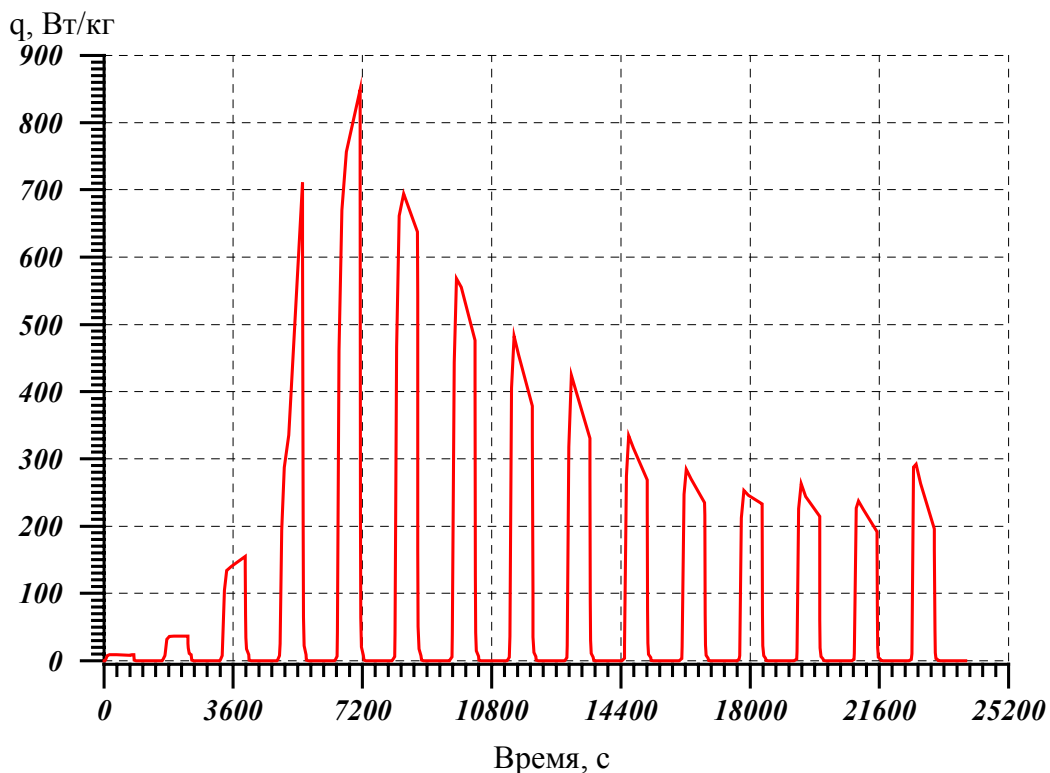


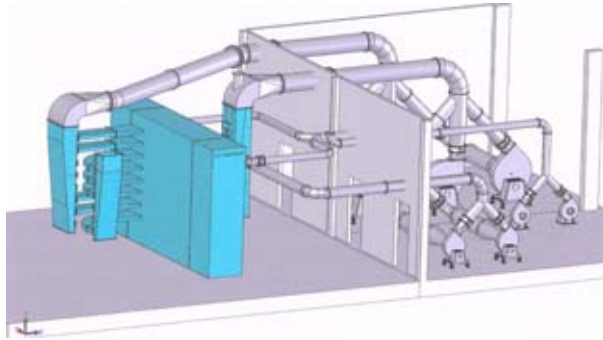
Fig.2. Heat release in budles as their processing advances in oxidation furnace. The most complex systems and assemblies have been experimentally validated on full-scale experimental models.

Presently KeRC has completely finished the autonomous testing of:

- heater of carpet type;
- gasdynamic gates;

- nitrogen heaters of temperature 800°C at flow rate 0.256 g/s ;
- systems of automatic keeping the small pressure drops and other systems of new development.

Such system of making the complex equipment allows one not only provide high quality of documentation but within the shortest terms to soundly eliminate the faults revealed in the process of starting-up and adjustment work.



As an example, Fig. 3 shows the view of oxidation furnace with circulation system.

Fig.3

Important peculiarities of the developed equipment are:

- variation spectrum of the main parameters of manufacturing process, if necessary:
 - velocity of the bundles transportation 22.5 m/hour ($15\dots90\text{ m/hour}$);
 - maximum temperature at oxidation up to 300°C ;
 - maximum air flow rate by 100% of the nominal value;
 - volume of purified gases by 100% of the nominal value;
 - fibre tension at oxidation $\pm 50\%$ of the nominal value;
 - maximum temperature at carbonation $+ 25\%$;
 - nitrogen flow rate at the required temperature up to 50% of the nominal value;
 - graphitization temperature within $1400\dots2700^{\circ}\text{C}$;
 - corresponding regulation of the other concurrent parameters;
- control and providing the set parameters of the technological rules in the production process;
- minimization of energy consumption at manufacturing of the products that is reached by:
 - strict determination of the required and adequate flow rate of air, nitrogen and other materials;
 - regulation of the processing at manufacturing of the different products;
 - sequential use of full heat content on subsequent transitions on temperature;
 - regeneration of heat released by the equipment for neutralization, it is proportional to the content of the products giving off at oxidation of PAN-fibre that is reached by multiple use of gas-air mixture before neutralization in its turn.