FIBER THERMAL-INSULATION REFRACTORIES

L. A. Dergaputskaya

About 20 years have passed since the start of production in the former USSR of a new form of refractory thermal insulation — ceramic fibers. The technology, the fundamentals of which were developed by the All-Union Scientific-Research Institute for Fiber Glass-Reinforced Plastics and Fiberglass, was successfully introduced by the Ukrainian State Scientific-Research Institute for Refractories with participation of the Design Section of the Eastern Refractory Institute in Sukhoi Log Refractory Plant and Seversk Dolomite Combine. Since then, methods of production of various forms of mullite—silica fiber-base thermal insulation materials and parts, which are produced in accordance with the effective GOST 23619-79 and specifications, have been developed and introduced. Fiber parts are also produced by Pervoural'sk Dinas Plant and the Fiberglass Material Shop at Eastern Siberia Refractory Plant.

A large contribution to the development of methods and introduction of industrial production of refractory fiber materials and parts has been made by specialists of the refractory industry, including Doctor of Technical Sciences Professor N. V. Pitak, Candidate in Technical Sciences A. N. Gaodu, Candidate in Technical Sciences E. P. Saenko, Candidate in Technical Sciences V. V. Martynenko, Candidate in Technical Sciences I. G. Subochev, Candidate in Technical Sciences V. F. Kutukov, and Candidate in Technical Sciences N. P. Belyakova and also the personnel of Sukhoi Log Refractory Plant and Seversk Dolomite Combine. In 1984 the workers of these plants received the Prize of the Council of Ministers of the USSR for introduction of production of mullite—silica fiber materials.

Fiber refractory materials have found wise use in various branches of industry for lining of batch heating furnaces and heat-treatment, bell-type, and annealing furnaces, filling of temperature compensation joints, thermal insulation of the covers of soaking pits and the hearth tubes of batch furnaces, and heating of the top portion of ingots. In blast furnace production fiberglass materials and parts are used for insulation of the walls and domes of hot-blast stoves and the tops of blast furnaces and for making the compensation joints between the lining of the shaft and the shell.

As a result of their specific properties refractory fiber materials make it possible to develop basically new production operations and designs of heating equipment for such operations. Experience in the production, assembly, and service of furnaces in various branches of industry has shown that use of linings of fiber materials makes it possible to: reduce labor costs for assembly by two to three times; decrease material consumption for the structures of furnaces — the consumption of refractories by 10-12 times and the weight of the metal frameworks by 15-20%; reduce the consumption of fuel and electric power by 25-30% in batch furnaces and by 3-5% in continuous furnaces; increase the productivity of batch heating equipment by 15-20% as a result of more rapid heating and cooling and also the increase in working space.

In [1-3] a quite complete review of the production and use of refractory fiber materials and thermal insulation parts of them both abroad and in the former USSR is presented. An analysis of these materials shows that the properties of domestic products are at the level of foreign analogs.

In recent years the Ukrainian State Scientific-Research Institute for Refractories has solved the following basic problems in the direction of development of the production of thermal-insulation fiber materials: development of methods and organization of full-scale production of new forms of fiber materials and parts for the purpose of broadening the product range for various areas of use; development and improvement of equipment for production of refractory fibers and parts of them for the purpose of increasing product quality and mechanization of production operations.
The traditional chemical composition of aluminosilicate glass fibers (\(-50\% \text{ Al}_2\text{O}_3 + \sim 50\% \text{ SiO}_2\)) determines the temperature of their use, 1100-1200°C, above which the process of crystallization and embrittlement of the fibers related to this starts. Work done in the Ukrainian State Scientific-Research Institute for Refractories makes it possible to broaden the temperature range of use of fiberglass and explain the mechanisms of the physicochemical processes occurring in them. For example, fibers were developed for a service temperature of about 1300°C with additions of \text{Cr}_2\text{O}_3 and \text{ZrO}_2 and also with an increase in \text{Al}_2\text{O}_3 content to 57-62\% for service at 1400°C.

For the purpose of broadening the raw material base for production of aluminosilicate fiberglass, composite work was done on use of natural raw material — kyanite, chamotte, Arkalyk clay, Novoselitsa and Chalganov kaolin, and disthene—sillimanite concentrate, making it possible to replace scarce and expensive alumina in the method [4-6]. In addition, it should be taken into consideration that a significant portion of the refractory fiberglass materials produced are used at 800-1000°C, and therefore production of fibers from natural aluminosilicates is more desirable and economical.

The institute together with Khar'kov Aviation Institute has studied the mechanism of fiber formation and has improved the design of the fiber-forming device for production of mullite—silica fiber from molten material [7]. The new design made it possible to increase the effectiveness of controlling the stream of molten material, to equalize the field of velocities at the outlet from the flowing portion of the fiber-forming device, and to reduce steam consumption by 13\%. In this case fiber in which the total content of nonfiber inclusions dropped by 14\% to 35\% was obtained and the content of nonfiber inclusions larger than 0.5 mm decreased by 27\% to less than 1\%. The apparent density of the material was 102 kg/m³. The hourly capacity of the device was 650 kg of fiber.

With participation of the institute, Seversk Dolomite Combine has developed, built, and placed into service a machine for forming of thermal-insulation fiber plates and inserts by a mechanized method. The design of the forming machine has been patented. Its hourly capacity is 120 parts and the total installed power of the electric motors is 19 kW. The control panel of the forming machine provides for manual and automated operation. Specifications for production of this machine have been developed [8].

Refractory fiber crucibles with a temperature of one-time use of about 1600 °C and an apparent density up to 300 kg/m³ have been developed for casting of complex and especially complex critical parts in vacuum from measured blanks by the investment pattern method. The investment pattern casting method provides production from any casting alloy of castings of complex form, including impellers with curved blades weighing from several grams to tens of kilograms. This makes it possible to have a blank as close as possible to the finished part and in a number of cases to produce a cast part not requiring further machining before assembly. As a result of this there is a sharp reduction in the labor requirement and cost of parts and in the consumption of material and tools. Seversk Dolomite Combine has introduced the method of fiber crucibles for casting nickel-base high-temperature strength alloy turbocompressor turbine wheels.

The lack of effective domestic lining materials for operation under conditions of contact with molten aluminum has been responsible for a number of works in this direction. The methods developed for mullite—silica fiber- and alumino-calcium cement-base refractory thermal-insulation concretes and development of the optimum variations of the linings of furnaces for melting of aluminum and holding of molten aluminum have provided high technical and economic operating indices of Driver—Harris furnaces used in Khar'kov Bicycle Plant Production Union. The technical solutions proposed by the institute have made it possible to reduce labor costs for linings of melting and holding furnaces, to increase ecological indices in operation of them and metal quality, and to reduce the specific consumption of refractory materials. Thermal-insulation concretes have an apparent density of 0.8-1.0 g/cm³, a compressive strength of 2.1-2.9 N/mm², a thermal conductivity at an average temperature of 750°C of 0.21-0.24 W/(m·K), and a service temperature up to 1200°C [9].

One of the interesting directions in the area of fiber materials is research work on development of porous hardware for internal combustion engine metal composite pistons. The first work showed the promise of this direction and makes it possible to look forward to obtaining a metal composite with properties providing a significant increase in operating life of internal combustion engine pistons [10].

The institute has developed and introduced into Novolipetsk Metallurgical Combine a design of double-layer batch heating furnace hearth tubes. Type MKRR-130 roll fiber material and MKRV-200 felt are used as the thermal-insulation layer, and a set of shaped refractory parts is used for protection of them. Such a design is best recommended for insulation of vertical tubes and is somewhat poorer for insulation of transverse ones. The shaped parts with lock joints are made of type MLS-62 mullite compositions. The life of such insulation for a 2000 mill at temperatures of 1350-1370°C is as high as 1-1.5 years, and the consumption of reference fuel drops by 0.5 kg/ton of metal.