During the last decade, the leading engine manufacturers have been carrying out intensive studies for developing pistons reinforced with composite materials (CM) since at the present time, the possibilities of obtaining further improvements in the reliability and fuel economy and reducing the specific weight of engines incorporating pistons made from aluminum alloys are virtually exhausted. When developing composite materials, using new reinforcing agents that retain stability under severe service conditions and processing of highly heat resistant matrices have received much attention. Inorganic fibers having a combination of high levels of mechanical properties and thermal shock resistance meet the aforementioned requirements to the maximum extent.

One of the methods of producing pressure-impregnated CM is to obtain components having localized reinforcement, i.e., multicomponent products a part of which is made from a matrix alloy and a part made from a composite material such that the entire product is a nondetachable single piece. For example, it was suggested [1, 2] to produce pistons of automobile engines in which only the head and the zone adjoining the groove of the upper compression-ring are reinforced.

Similarly, a complex technology involving mixing of the fibers having a length of up to 6 mm with a matrix melt and subsequent hot pressing of the obtained preform is used. The preform is placed in a die having a porous ceramic insert at its base and is heated up to a temperature exceeding liquidus the of the matrix alloy by 50 K. This is followed by the application of pressure as a result of which the excess matrix alloy goes into the porous insert and the content of the fibers in CM increases. The specimens of the obtained CM have an ultimate compressive strength of 300 N/mm² and a modulus of elasticity of 150 kN/mm² at a fiber content of 20 vol. % [3].

When creating composite materials based on an aluminum alloy and a porous fibrous reinforcement, silica and aluminosilicate fibers, polycrystalline fibers of aluminum oxide, and filamentary crystals of silicon nitride are most frequently used.

The problems concerning the production of CM based on aluminum alloys are being studied at the enterprises of Japan, USA, UK, and Germany. The increasing number of publications indicates that starting from the early eighties, the interest in the composite materials increased abruptly. Zabolotskii [4] reviewed the literature published during the last ten years on the fiber reinforced composites and examined the methods of their production and properties. This paper reviews the investigations in which oxide and aluminosilicate refractory fibers were used for obtaining CM.

The ‘Insulite Babcock Refractories Company’ produces CM using an aluminosilicate material ‘Kaowool’ (Al₂O₃ 51% and SiO₂ 49%) that contains not more than 5% nonfibrous inclusions having a diameter >150 µm and approximately 15% mullite [5, 6]. In order to obtain CM, the reinforcing fibrous network is prepared in the form of specimens of a specific shape. The fibers are dispersed in colloidal silica that acts as a binder. Specimens are obtained according to the method of vacuum forming and are impregnated with molten aluminum at a pressure of 150 N/mm². The obtained composite material possesses superior wear resistance and a high ultimate bend strength.

The Japanese enterprise ‘Toyota Dzidosya’ uses short aluminosilicate fibers (5-40%) as a strengthening agent for obtaining CM; in this case, it is necessary to control the content of the nonfibrous particles in order to ensure high hardness, ultimate tensile strength, and ultimate bend strength of CM [7-9]. In order to improve the wear resistance and resistance to seizure of the diesel pistons, the enterprise started producing the upper portion of the pistons using a composite material
Fig. 1. Microstructure of the composite materials reinforced using aluminosilicate fibers containing nonfibrous inclusions (a) and polycrystalline Al₂O₃ fibers (b). ×1000.

Fig. 2. Dependence of the hardness HB of the composite material (I) on the volume fraction of the reinforcing mullite–silica fibers V; II) matrix alloy.

Fig. 3. Dependence of the tensile strength Rₜ of the matrix alloy (1) and the composite material (2) containing approximately 35 vol. % mullite–silica fibers on the test temperature.

reinforced with Al₂O₃·SiO₂ fibers or filamentary single crystals of SiC. Introducing 5% Al₂O₃·SiO₂ into an aluminum matrix increases the ultimate tensile strength by 4% and decreases the wear of the working surfaces in the zone of the piston rings by 100 times. It was reported that the enterprise manufactured more than 1 million pistons of this type over a period of 5 years [10, 11].