The transition from iron and steel to polymeric composite materials (PCM) has been taking place at a rapid tempo during the last 15-20 years in the technically developed countries, capacity in melting up steel has been curtailed and the manufacture of CM has been accelerated, and regions of application of these have been expanded [1-6]. PCM permit one to greatly reduce volumes of metal and the weight of articles and to ensure the necessary strength and resistance to corrosion, to reduce material and labor expenditures in the manufacture and repair of articles, and to organize waste-free technologies.

Materials technologists have convincingly shown that the 21st century will be the century of composite materials. Thus, by the year 2000 or 2005, both for the USA and for Western Europe, it is expected that the output for the annual demand for composites will be 2.5-3.0 million tons. The proportion of these among other materials will reach 30-40%, and in Japan even 50%.

The high level of information and new forms of organizing manufacturing operations including material on worker-free technology with computer control [5] are assisting in the rapid progress of composites.

In our country, in recent years the manufacture of composite materials for construction purposes has developed very rapidly, including carbon-fibre filled plastics and aramide plastics. However, the cost of the latter is high [6], and they are not suitable for mass consumption. In the 13th 5-year period, an annual rise in chemical production of 5% is contemplated; the increase in manufacture of PCM for broad purposes is planned to be 18% per year.

Developments and studies in the chemical engineering department of the Saratovskii Polytechnic Institute are pursuing the objective of developing new forms of bulk PCM, of increasing the level of technology, and a broader application of these. In the present review, we examined developments on developing hybrid PCM. The term "hybrid" usually characterizes composite materials containing more than one type of filler. The purpose of developing hybrids is to develop a new material which will preserve the advantages of the component substances but is free of their defects. An advantageous deviation of a definite property of the material from the additive value is characterized by the term "hybrid effect."

The basic principle in these developments was to use for the PCM readily available cheap starting components which are put out on a very large industrial scale. These are such materials as phenolic- and melamine-formaldehyde resins, epoxy and polyester resins, and some man-made fibres (MF): Kapron, Nitron, Lavsan, viscose, polypropylene, and polyvinyl chloride fibres.

Characteristic features of the structure formation in PCM which have been formed with reinforcement by thermoreactive CF resins are the following [7-9]:

- a mutual effect of the polymeric binder and the polymeric fibre on the structure and properties of one another, both during the process of formation and also in the finished material under the action of external factors;
- the formation, as a result of this mutual effect, of an interfacial layer, which differs in structure and properties from the component PCM polymeric components, which determines to a considerable extent the properties of the material obtained.

The strengthening and elasticizing action of fibres is connected with their effect on the orientation of macromolecules in the layers of the polymeric binder, and on their ability to interact with the binder. The thinner this layer between fibres, the more strongly is the effect of the fibre displayed.
The optimum in properties is obtained at a content of 40-60% by weight of fibre in the PCM, where the thickness of the layers is 3-5 \( \mu \text{m} \) [7]. This shows up favorably in preventing the formation of cracks in the material, since the fibres change the mechanism of failure of the material, primarily as a result of the effect on formation of the structure of the interfacial layer, which is the source of cracks in PCM.

Depending on their nature and structure, fibres differently affect the formation of the topological structure of the polymer matrix (frequency of cross-links, packing density, and so forth). They retard or activate hardening of the binder; an inversion of the effect is also possible, which is observable on changing the pressure and temperature of hardening, or the content and geometry of the fibres [10].

The activity of fibres is caused by a number of physical and chemical processes on the interfacial boundary between the fibre and the binder in preparing the PCM. In particular, fibres have different sorptive powers with respect to the components of the binder. For example, with respect to sorptive activity toward polyethylene polyamine in a system involving an epoxy binder, fibres fall into the following series: viscose > Kapron > Lavsan > Nitron. Here the magnitude of the sorption may be regulated not only by the chemical nature of the fibre, but also by the proportion of the amorphous part and the degree of orientation of the structural elements [7].

As a result of diffusion of resin macromolecules or parts of them into the amorphous and defective regions of the surface layer of the fibre, the interfacial boundary is not always sharply expressed (Fig. 1). On the whole, however, during the process of forming the structure of a PCM, a mutual diffusion penetration of the components of the binder into the surface layers of the fibre and of low-molecular-weight compounds from the fibre into the polymeric matrix takes place, plus interaction of these with each other. In the end, this is accompanied by the formation of various levels of structural organization in the PCM with various molecular mobilities.

Thus, according to the evidence of [11], the temperature dependence of the mechanical loss coefficient (by the method of relaxation spectroscopy) indicates that \( \alpha_1 \) corresponds to the volume of matrix which is far from the surface of the fibre — a relaxation process; \( \alpha_2 \) — a relaxation process — corresponds to the structure of the matrix layer at the surface of the fibre, which has been formed as a result of physical and chemical interaction of the components. The third level of relaxation, \( \alpha_3 \), is connected with the surface layer of the fibre, in which components of the binder have diffused; and the fourth level, \( \alpha_4 \), a relaxation process, corresponds to the structure of the core of the fibre itself.

In the formation of PCM, the fibres are subjected to the action of elevated temperatures, and active media, which cause swelling and plasticizing. During treatments, the fibres may be either under tension (stretching, or relaxation under a load) or in the free state (relaxation without tension, or with shrinkage), which leads to a change in the cross-sectional profile (from round to elliptical or multifacial), to structural rearrangements (change in three-dimensional order and orientation), or to a change in their properties (strength, elasticity, or elastic modulus) [7, 12, 13]. An understanding of the mechanism of the mutual effect of the CF and the polymeric binder on the structure and properties of each other has made it possible to select ways for seeking and attaining hybrid effects in PCM.