The physical approach to the fracture of solids, including composites, is characterized by the endeavor to determine what processes develop in a body under the action of a load, from the moment the load is applied to the moment of final fracture, and to give a detailed description of the sequence of events leading to the accumulation of damage at all levels, from atomic to macroscopic.

Clarification of the nature of the fracture process in composites calls for both a phenomenological study of the macroscopic characteristics of the fracture kinetics and, in particular, a study of the temperature-stress dependence of the rupture life, together with direct experiments to provide information on the mechanical stress field in the system and the laws of damage accumulation after application of the load. For this purpose it is necessary to employ the entire arsenal of techniques used in modern solid-state physics and the physics of strength and plasticity.

Research into the structure and mechanical properties of composites, including their fracture mechanism, the results of which have appeared in a series of monographs [1-19] and journal articles, has produced a rich store of information on the physics of strength of this class of materials. As examples of such research, physical both in its formulation of the problem and its treatment of the results, it is possible to mention [20, 21] and many other investigations. However, at the suggestion of the board of editors, this review will be confined to presenting the results of systematic research on the physics of strength of composites carried out in recent years at the A. F. Ioffe Physicotechnical Institute, Academy of Sciences of the USSR, Leningrad. The main objectives of this research and certain initial results have already been described in review articles [22-28] and in a series of publications by colleagues at the Physicotechnical Institute [23-55], as well as in the proceedings of two seminars on the physics of strength of composites held in 1977 and 1978 [56]. It is a feature of this research that it is all based on the ideas of the kinetic theory of strength expounded in [57]. According to this theory, fracture should be regarded as a thermoactivated process of damage accumulation that develops in a body from the moment of application of the load. Hence it is essential to investigate and provide a detailed description of the damage accumulation kinetics. The rate of damage accumulation and its reciprocal integral, the rupture life, are the principal characteristics of the fracture process.

It is natural that research on the fracture of composites should parallel that on the fracture of homogeneous solids [57], by combining phenomenological studies of the temperature-stress dependence of the rupture life with the direct investigation of the internal stress field and the kinetics of damage accumulation at all levels. It is, however, necessary to take into account the coarsely heterogeneous structure of composites and the presence of at least two different components (reinforcement and matrix), as well as the unique importance of the component interfaces. This distinguishes the study of the fracture process kinetics of composites from the
study of the corresponding phenomenon in homogeneous solids. Thus it is necessary to investigate and describe the kinetics of damage accumulation in the matrix, in the reinforcement and at the interfaces, and to determine the role of the matrix in developing the strength of the composite and the effect of the adhesion of the components on the strength properties of the system. Nevertheless, the general approach of the physics of strength of composites can be based on the same kinetic theory of the fracture of solids as was developed in connection with homogeneous materials. This review surveys the results of recent research on the physics of strength of composites carried out at the Physicotechnical Institute and discusses the prospects for further advances in the field.

**Temperature-Stress Dependence of the Rupture Life of Composites**

As with homogeneous materials, the study of the fracture kinetics of composites [22-40, 55, 58, 59] is based on the investigation of the temperature-stress dependence of their rupture life. In the case of homogeneous materials, the study of the dependence of the rupture life \( \tau \) on stress \( \sigma \) and temperature \( T \) led to the discovery of a general law applicable to all the materials investigated [57]:

\[
\tau = \tau_0 \exp \left( \frac{U_0 - \gamma \sigma}{kT} \right).
\]  

(1)

The form of relation (1) and an analysis of the properties of the coefficients \( \tau_0, U_0 \), and \( \gamma \) for different materials made it possible to establish the physical significance of the expression and its coefficients and hence to arrive at important conclusions concerning the nature of the fracture of solids, and to lay the foundations of a kinetic theory of strength.

In the case of composites it was also necessary to determine whether expression (1) holds and to attempt to extract from it information concerning the nature of the fracture process in composite materials.

So far, systematic research on the functional dependence of \( \tau \) on stress \( \sigma \) and temperature \( T \) for more than ten fiber-reinforced composites and certain laminates and particle-reinforced composites has shown that expression (1) holds on a certain limited interval of test conditions. For our present purposes the test data concerning exceptions to rule (1), lying outside this interval, can be disregarded.

To confirm the validity of expression (1) for composites, in Fig. 1 we have plotted test data on the temperature-stress dependence of the rupture life for three different fiber-reinforced materials: copper-tungsten...