“Fibrous polymer composite materials based on an epoxy matrix with two-phase reinforcement scheme”

Kosenko Ekaterina Aleksandrovna

Abstract. One of the promising areas for the development of composite materials science and the polymer composite materials (PCM) market is the expansion of the temperature range of operation of products. The creation of PCMs that are similar in structure to natural materials will make it possible to obtain composites in which defects do not accumulate during deformation, including during prolonged exposure to negative temperatures, which will ensure high reliability for structures made from such materials.

Thus, the development of a set of technological solutions aimed at creating a theoretical basis for the design and production of high-performance materials based on fibrous fillers and epoxy matrices, constructed on the principle of nature-like materials, and technologies for molding parts from them, is an actual cross-industry problem in the field of polymer composites processing technology, of great economic importance.

The purpose of this work is to develop scientific foundations and comprehensive solutions to technological problems aimed at creating PCM with a two-phase reinforcement scheme and technology for producing parts from them that are characterized by high durability under the action of static and dynamic loads, including at low negative temperatures.

To achieve this purpose, it is necessary to solve the following scientific and technical **tasks**:

1. Study the patterns of interaction between the epoxy binder and materials used as the liquid phase.

2. Investigate the influence of the amount of liquid phase material and its chemical nature on the strength characteristics of PCM with a two-phase reinforcement scheme under conditions of static and impact loads.

3. Investigate the influence of the reinforcement scheme with liquid phase material on the strength and adhesion characteristics of the epoxy material.

4. Develop a technique for multi-criteria optimization of liquid phase material in PCM.

5. Develop a model of PCM with a two-phase reinforcement scheme and study its stress-strain state.

6. Investigate the influence of the chemical nature of the liquid phase material on the long-term strength of PCM with a two-phase reinforcement scheme.

Scientific novelty. The scientific foundations for designing compositions of composite materials and technologies for producing products from them were developed. In addition to traditional fibrous materials, monomeric (oligomeric or elastomeric) material is used as the reinforcing composition in the structure of the extremely high anisotropy composite. This material forms an intermediate layer of reduced strength, which ensures a local change in the strength and deformation properties of PCM in the area of external loads, suppresses undesirable destruction mechanisms. This made it possible to create PCMs with adjustable rigidity, providing previously unattainable combinations of properties: high strength under impact and static loading under conditions of low negative temperatures, under long-term exposure to cyclic tensile and bending loads.

1. Hypotheses of destruction of PCM based on fibrous reinforcing materials and epoxy matrix were established, depending on the nature of loads and chemical nature of liquid phase material:

1.1. the use of triethylene glycol dimethacrylate and silicone sealant as liquid phase materials leads to a reduction in residual stresses, increases the relaxation properties of PCM and reduces the rigidity of the interphase boundary “elementary fiber-epoxy matrix”;

1.2. the use of synthetic wax as a liquid phase material leads to an increase in the rigidity of PCM under conditions of exposure to negative temperatures and does not improve its relaxation characteristics.

2. Rheokinetic dependencies were established between the epoxy binder, which contains liquid phase material, and its chemical nature, which made it possible to establish the complete absence of chemical and intermolecular interaction between the epoxy binder and the liquid phase materials: silicone sealant and triethylene glycol dimethacrylate.

3. Cause-and-effect relationships were established between the chemical nature, the amount of liquid phase material and the properties of PCM, which consists in the fact that the highest strength values are obtained with a low (5 parts by weight) content of liquid phase material.

4. Cause-and-effect relationships were established between the technology of reinforcement with liquid phase material and the properties of PCM, which consists in the fact that the highest strength values are obtained for those reinforcement schemes in which the liquid phase material is located at angles of 0 and +45° relative to the applied load.

Theoretical and practical significance.

Theoretical significance:

1. A multicriteria optimization technique was developed for determining the chemical composition of the liquid phase material, which made it possible to take into account the influence of temperature, static and dynamic loads.

2. A PCM model with a two-phase reinforcement scheme with liquid phase material was developed and a method for assessing its stress-strain state was proposed.

3. The hypothesis of damage accumulation in loaded PCM with a two-phase reinforcement scheme, including under the action of impact and cyclic loads was established, depending on the chemical composition and amount of liquid phase material.

4. The patterns of influence of the reinforcement scheme with liquid phase material on the mechanical characteristics of PCM under conditions of static and dynamic loading were established.

5. The theoretical foundations for controlling the structure and properties of PCM under conditions of long-term exposure to negative temperatures and dynamic loads were developed.

Practical significance:

1. Technological regulations was developed for molding parts from PCM with a two-phase reinforcement scheme using vacuum molding technology using triethylene glycol dimethacrylate as a liquid phase material. An invention patent was received for the developed technology.

2. The optimal composition of the liquid phase material was developed, taking into account the requirements for the static and dynamic strength of PCM.

3. Optimal schemes for reinforcement with liquid phase material under conditions of exposure to static and dynamic loads were developed.

4. The technique of identification of the quantity and distribution of the liquid phase material in the PCM was developed. An invention patent was received for the developed method.

5. Methods and techniques were developed for assessing the bending strength of PCM under conditions of static and dynamic loading. Invention patents were received for the developed methods.

6. The results of theoretical and experimental researches were implemented at CJSC «Universal-Aero» in the production of aviation and airfield equipment and in the educational process of the Moscow automobile and road construction state technical university (MADI).

Provisions to be defended:

1. Results of rheokinetic studies of an epoxy binder containing triethylene glycol dimethacrylate or silicone sealant as a liquid phase material.

2. Results of comprehensive experimental studies of the adhesive, mechanical and elastic properties of PCM with a two-phase reinforcement scheme under conditions of exposure at room temperature and low negative temperatures.

3. Results of multicriteria optimization of PCM composition with a two-phase reinforcement scheme.

4. Results of modeling the stress-strain state of carbon fiber reinforced plastics with a two-phase reinforcement scheme.

5. The principles of creating PCM with a two-phase reinforcement scheme and the technology of molding structures from them that are distinguished by high fatigue strength and a unique set of properties.