The nanostate factor in the technology of polymer nanocomposites

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Abstract: *Methodological approaches to the implementation of the nanostate phenomenon in the formation of the optimal structure of composite materials and metal-polymer systems at different levels of organization have been developed. The concept of energy and technological compliance of functional composite materials and systems components, which determines the optimal parameters of stress-strain, adhesion and tribological properties under technological influences on the components in the process of obtaining composite and its processing, is proposed.*
KEYWORDS: *NANOPARTICLE, NANOSTATE, METHODOLOGICAL PRINCIPLES, STRUCTURE, ENERGY AND TECHNOLOGICAL COMPLIANCE*

1. Introduction

Modern scientific views on the structure of multicomponent materials (plastics, composites, alloys), products and constructions made on its basis have its foundations in the understanding them as systems whose parameters of characteristics (stress-strain, tribological, thermophysical, adhesive, etc.) depend on the intensity interphase interactions, characterized by the flow of certain physical and chemical processes at a given rate and leading to the formation of boundary (separating) layers with certain composition and structure [1–3]. These processes lead to the transformation of the initial state of the system components and determine the parameters of its performance characteristics.

2. Discussion

In the interfacial region of a multicomponent system, a complex of physical and physicochemical reactions occurs simultaneously with the dominant of one or several, for which the most favorable conditions are realized, determined by the value of the activation energy parameter (Fig. 1). This dominant reaction in the interfacial region, the kinetics of which corresponds to the conditions of formation and operation of the system, determines the resistance of an element made of a composite or a structure to the influence of technological or operational factors.

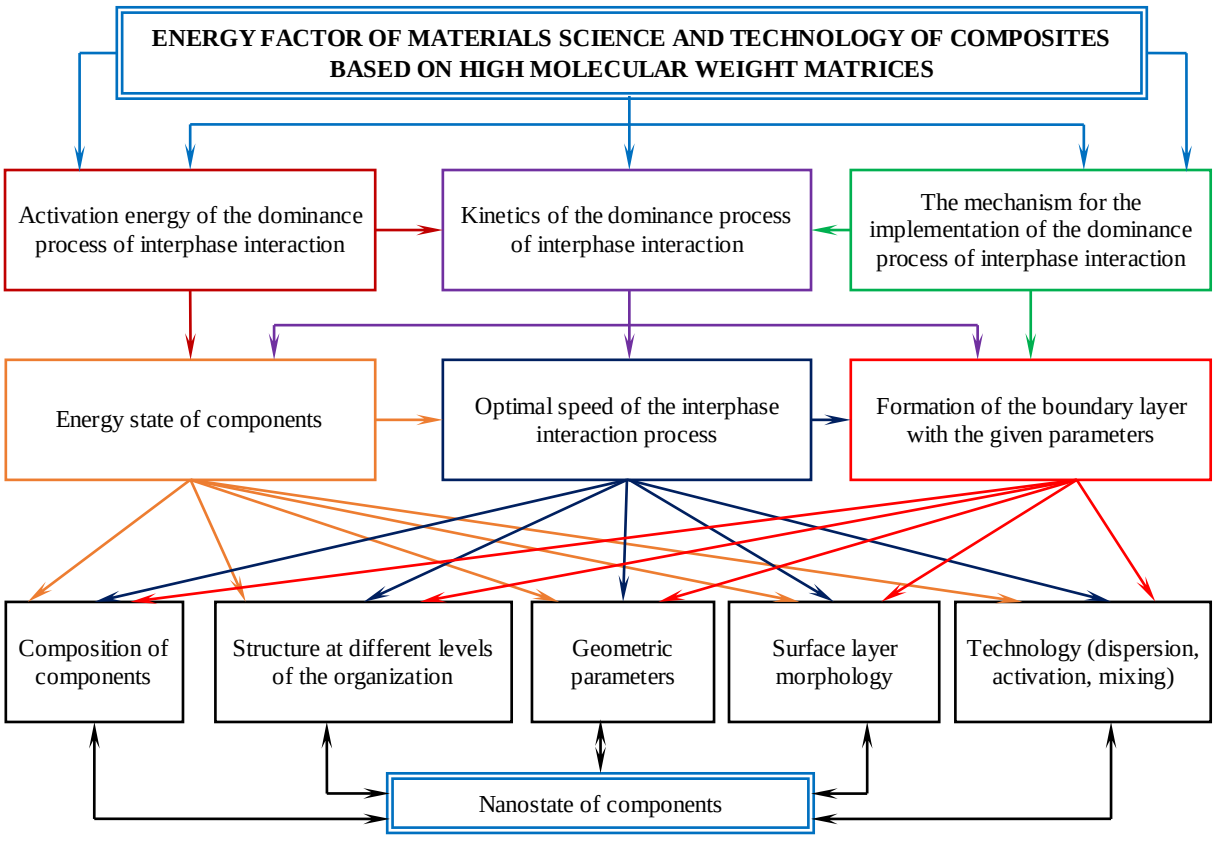

Fig 1. *Energy factor of materials science and technology of composites based on high molecular weight matrices*

Methodological approaches to the creation of composite materials based on polymer matrices in the presence of general regularities are characterized by a number of specific features determined by the modes of operation of the product, requirements for manufacturability and recycling, economic parameters that affect its competitiveness when compared with analogues.

In [4], the directions of targeted modification of polymer materials to improve the tribological characteristics are presented (Fig. 2).

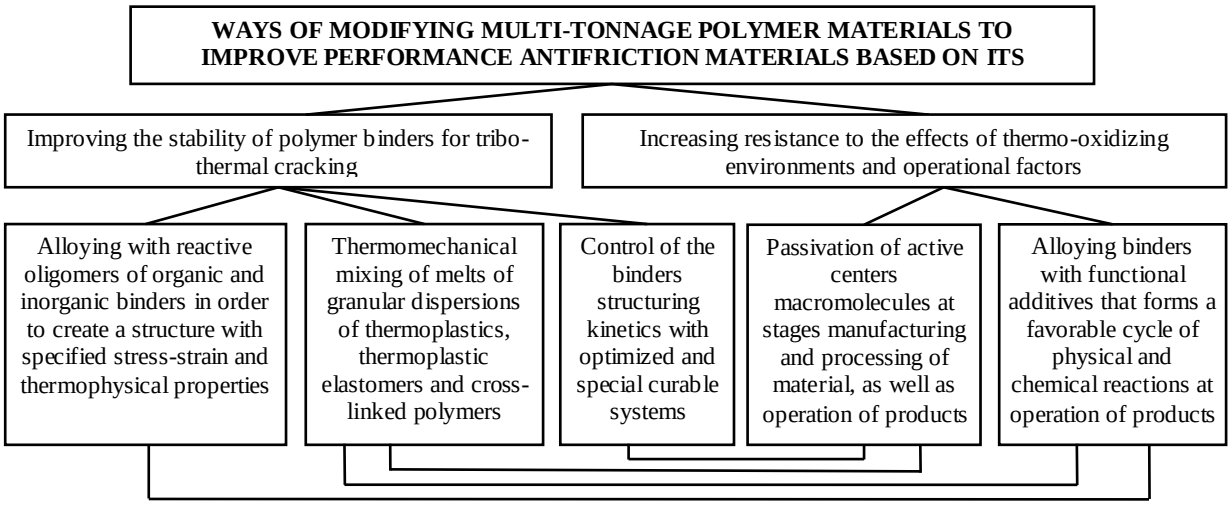

Fig 2. *Some directions of multi-tonnage modification produced polymer materials [4]*

It seems to us that the proposed modification methods are effective not only when creating tribological ("antifriction" according to [4]) materials, but also other types of composites for manufacturing products with specified performance parameters with appropriate adjustments to methodological approaches.

Analysis of numerous methods of targeted modification of high-molecular-weight matrices to obtain functional materials with specified parameters of characteristics, ensuring the effective use of products from them in the structures of machines, mechanisms of technological equipment, not only emphasizes their diversity, but also allows formulating methodological principles for the implementation of functional materials science in accordance with strategy of innovative development of various branches of the economic complex. When developing such principles (Fig. 3), we took into account the current trends in the development of the industrial sphere and the sphere of life support of social-minds of various levels, based on the permanent renewal of industrial products, increasing the level of its consumer characteristics, including ergonomic ones, in the concept of an ecological imperative in the process production and consumption of industrial products, the concepts of reasonable sufficiency and life cycle.

The application of these trends in the practical functional materials science of composites for mechanical engineering made it possible to identify the main requirements, the implementation of which ensures the achievement of optimal technical and social effects:

– optimization of parameters of deformation and strength characteristics;

– increasing the parameters of tribological characteristics in the given operating conditions;

– increasing the parameters of protective characteristics in certain operating conditions.

The formed requirements mainly relate to the field of functional materials science for mechanical engineering and do not consider the features of special materials science, the objects of which are used in the field of housing and communal services, medicine, agricultural production, sports and other areas of the functioning of industrial and special structures.

In our opinion, the formed requirements for functional composite engineering materials based on thermoplastics can be ensured by implementing the basic methodological principles, which include:

– formation of a structure with optimal ordering at a certain level of the organization;

– increasing resistance to tribo-thermal cracking;

– increasing resistance to the effects of thermo-oxidizing and operating environments and aging.

The proposed principles are based on modern approaches to controlling the structural characteristics of composite materials at the molecular, supramolecular, intermolecular and interfacial levels using various materials science and technological solutions, which are systematized by directions:

– doping matrices with reactive components that form chemical bonds between macromolecules;

– introduction into the composition of dispersed, including nanoscale, components of a given composition, habit and energy state into the bulk or surface layers;

– thermomechanical mixing of melts of the matrix and alloying components during the preparation and processing of the composite material;

– mechanochemical mixing of matrix and alloying components during the preparation and processing of composites into a product;

– passivation of active centers of macromolecules in the process of creating and processing composites and the operation of products from its;

– introducing functional additives into the composites, contributing to the formation of favorable cycles of physicochemical, including tribochemical, reactions.

It is obvious that the choice of the direction for the implementation of the methodological principle of creating a functional material with certain parameters of consumer characteristics depends on the purpose and operating conditions of the product from it in the designs of a specific system.

A characteristic feature of the introduced above methodological principles of creating composite materials for products of a certain functional purpose is their direct or indirect relationship, which manifests itself in the simultaneous influence of the selected factor on the complex of structural and physicochemical processes that determine operation under given conditions. For example, the introduction of nanosized modifiers into the composition of the composite simultaneously affects the structural parameters due to the formation of supramolecular formations of a new type, leads to the passivation of the active centers of macromolecules due to the formation of adsorption bonds, and changes the physicochemical processes that determine the adhesion, tribological characteristics, resistance to the effects of thermo-oxidizing environments and aging. Therefore, it is of particular interest to searching for modifiers of the complex mechanism of action, the use of which will allow the implementation of synergistic effects, manifested in the simultaneous increase in the complex of parameters of service characteristics.

The direction of using nanosized particles as a component that passivates the active centers of macromolecules, which creates preconditions for the initiation and development of unfavorable processes of destruction, oxidation, crosslinking, etc., which lead to a qualitative change in the initial structure of the composite with optimal parameters operational characteristics. The development of this approach, previously considered in [4], will make it possible to develop machine-building materials with increased performance parameters based on thermoplastic matrices for large-scale production of the class of polyamides and polyolefins, including

regenerated ones, the use of which currently does not correspond to its requirements potential opportunities.

The developed methodological principles are implemented in practical applications in the form of functional nanomaterials based on industrial thermoplastics and technologies for their manufacture and processing into products [5–8].

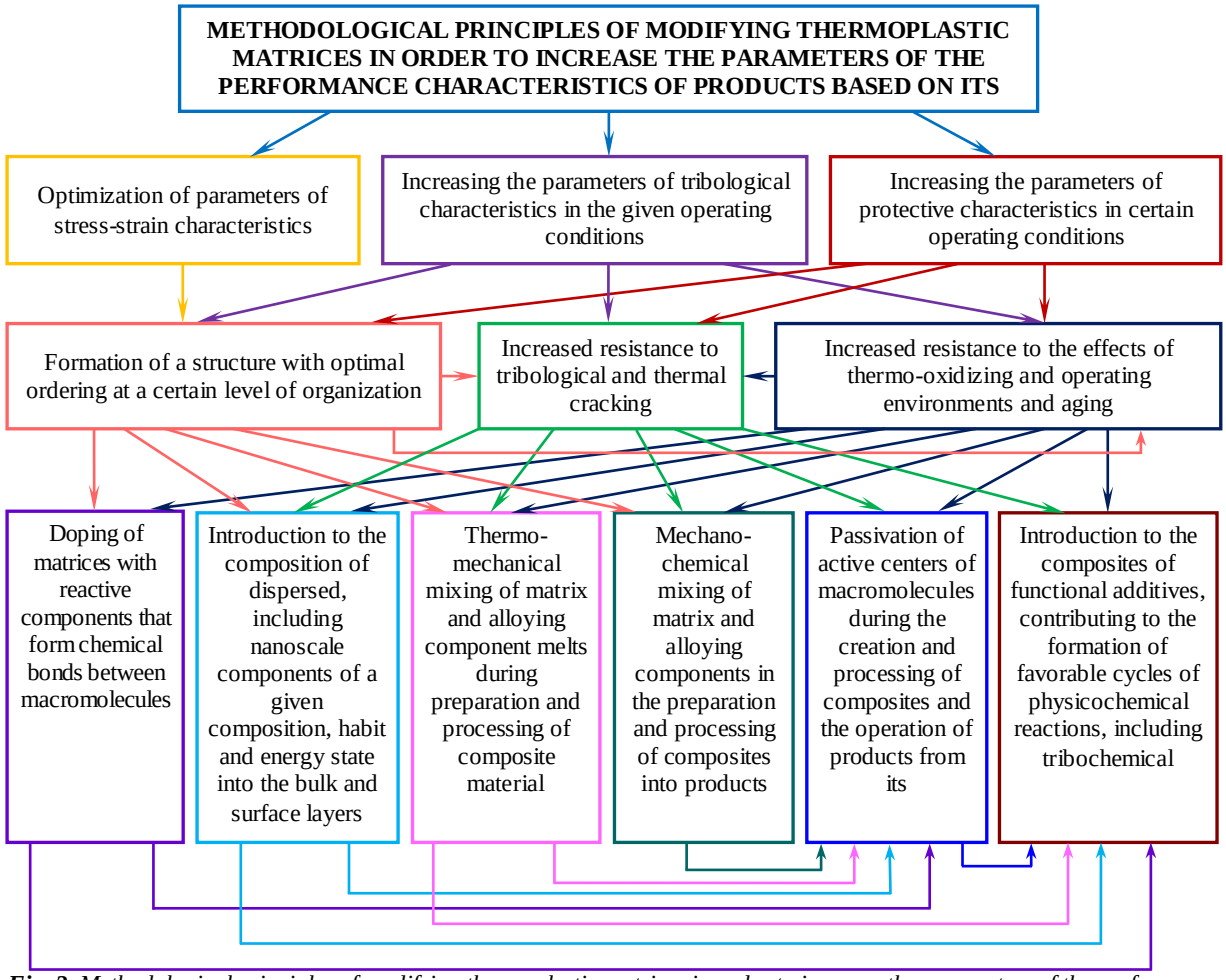

Fig. 3. *Methodological principles of modifying thermoplastic matrices in order to increase the parameters of the performance characteristics of products made from its*

3. Conclusion

Methodological approaches to the implementation of the nanostate phenomenon in the formation of the optimal structure of composite materials and metal-polymer systems at different levels of organization have been developed. The concept of energy and technological compliance of functional composite materials and systems components, which consists in ensuring the parameters of their energy characteristics are adequate to the value of the activation energy of the prevailing structural process is proposed. This concept determines the optimal parameters of stress-strain, adhesion and tribological properties under technological influences on the components in the process of obtaining composite and its processing. The concept was tested in the development of nanocomposites based on polymer matrices of industrial production, which surpass analogues in service characteristics.

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