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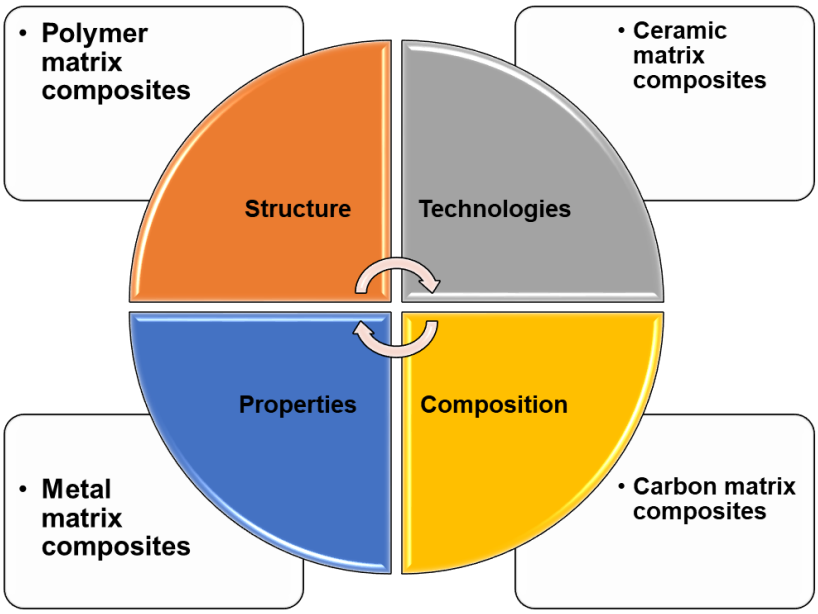
Polymer Composites for Automotive Sustainability. Polymer Bearing Solutions for Lubricated Applications.



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Creation of high-tech equipment, a significant acceleration of progress made by science and technology and the implementation of resource-saving technologies require the development of new materials in the parts of machines working with slip friction and have a low coefficient of friction. The monograph presents the results of theoretical and experimental studies of polymer composite materials (PCM) on the basis of polytetrafluoroethylene (PTFE). Polytetrafluoroethylene has been studied with fillers of different chemical nature in order to form a perfect structure and the required level of operational properties of fluoroplastic composites. An important aspect here is the objective assessment and analysis of the influence of fillers on the structure and physical and mechanical properties of PCM. The development of composite models and prediction of operating characteristics of antifriction materials using PTFE on their basis was studied. Promising in this respect are polymer composite materials (PCM) based on polytetrafluoroethylene (PTFE) due to its unique operational properties - the lowest coefficient of friction among polymers, high chemical inertia, thermal and cold resistance. However, low wear and thermal conductivity, high coefficient of thermal expansion and creep limit the possibilities of its application in its pure form. The technical progress leads to the complication of the use of PCM, in which they no longer meet the necessary requirements. This causes the need for new macromolecular substances or the modification of already existing polymers. First, it requires large material costs (for the synthesis of new polymers and the creation of new technological productions). The second is more economical and promising. Technically, it can be implemented by modifying polymers. In the case of PTFE it is advisable to modify the polymer by mechanical activation, which is related to the low energy and metal capacity of the equipment, the simplicity and safety of the process, as well as the possibility of introducing the corresponding functional fillers. The influence of modes of mechanoactivation processes in the technology of preparation of ingredients on the structure and properties of composites is insufficient. The problem of increasing the efficiency of composite sealing elements of friction units and increasing the life of their operation remains unresolved.

Therefore, the study of the specific features of the activation and modification of the matrix and fillers, the development of the principles of obtaining tribo-technical composites based on PTFE is an actual task of the technology of polymer and composite materials, which is an important scientific and technical problem.

The information provided may also be useful to engineers and technical staff in technical practice organizations that are producers of ensuring series production and production of spare parts in the automotive and other demanding industries. Monograph is also based on its own experience and discussions with various companies and organizations, such as Poltava-GasVydobuvannya Gas Production Division (GPD) (Poltava, Ukraine), “Sumy NPO” PJSC (Sumy, Ukraine), Concern «NICMAS» (Sumy, Ukraine) and so on.

The monograph provides a comprehensive presentation of information from data collection to assess them and issuitable and useful also for university teachers, students of technical faculties who are interested in new approaches and trends in this area. The monograph was supported by grant KEGA.

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Anton PANDA, Konstantin DYADYURA:

POLYMER COMPOSITES FOR AUTOMOTIVE SUSTAINABILITY. POLYMER BEARING SOLUTIONS FOR LUBRICATED APPLICATIONS

Abstract:

Creation of high-tech equipment, a significant acceleration of progress made by science and technology and the implementation of resource-saving technologies require the development of new materials in the parts of machines working with slip friction and have a low co-efficient of friction. The monograph presents the results of theoretical and experimental studies of polymer composite materials (PCM) on the basis of polytetrafluoroethylene (PTFE). Polytetrafluoroethylene has been studied with fillers of different chemical nature in order to form a perfect structure and the required level of operational properties of fluoro plastic composites. An important aspect here is the objective assessment and analysis of the influence of fillers on the structure and physical and mechanical properties of PCM. The development of composite models and prediction of operating characteristics of antifriction materials using PTFE on their basis was studied. Promising in this respect are polymer composite materials (PCM) based on polytetrafluoroethylene (PTFE) due to its unique operational properties - the lowest coefficient of friction among polymers, high chemical inertia, thermal and cold resistance. However, low wear and thermal conductivity, high coefficient of thermal expansion and creep limit the possibilities of its application in its pure form. The technical progress leads to the complication of the use of PCM, in which they no longer meet the necessary requirements. This causes the need for new macromolecular substances or the modification of al-ready existing polymers. First, it requires large material costs (for the synthesis of new polymers and the creation of new technological productions). The second is more economical and promising. Technically, it can be implemented by modifying polymers. In the case of PTFE it is advisable to modify the polymer by mechanical activation, which is related to the low energy and metal capacity of the equipment, the simplicity and safety of the process, as well as the possibility of introducing the corresponding functional fillers. The influence of modes of mechanoactivation processes in the technology of preparation of ingredients on the structure and properties of composites is insufficient. The problem of increasing the efficiency of composite sealing elements of friction units and increasing the life of their operation remains un-resolved. Therefore, the study of the specific features of the activation and modification of the matrix and fillers, the development of the principles of obtaining tribotechnical composites based on PTFE is an actual task of the technology of polymer and composite materials, which is an important scientific and technical problem. The information provided may also be useful to engineers and technical staff in technical practice organizations that are producers of ensuring series production and production of spare parts in the automotive and other demanding industries. Monograph is also based on its own experience and discussions with various companies and organizations.

CONTENTS

LIST OF USED SYMBOLS AND ABBREVIATIONS

CM – composite materials,
PMC − polymer matrix composites;
MMC – metal matrix composites;
CMC − ceramic matrix composites;
CAMCs – composite matrix composition of carbon;
PTFE – polytetrafluoroethylene;
ACN – artificial crystalline nuclei;
CF − carbon fibers;
I − intensity of wearing, 10^{-6} $mm^3/N \cdot m$;
V – material volume, m^3;
ρ - density, kg / m^3
c_n – concentration of the inclusions oriented in the n-direction, %;
σpp − tensile strength, MPa;
δ – elongation at fracture, %;
l – average fiber length;
d – diameter;
σ_{ij} - tensions;
e_{ij} - deformations;
ε_{ij} – deformation rate;
χ_n – indicator function;
u_i - shifts;
W – the functionality of the elastic energy of deformation;
μ, λ - Lamé parameters;
E – modul of elasticity;
c_s – volume content of dispersed particles;
c_f – volume content of fibers;
Q – the function of the geometrical fiber parameters;
Q_l – the function of elastic properties;
W* - the functionality of the elastic deformation energy dissipation;
k – the limit of the material plasticity;
η - the material viscosity;
H – the hardness of material;
τ – the criterion of coherence of macro-properties.
cc – cubic centimeter

INTRODUCTION

The automotive industry is a large and critical sector within the global economy. Modern development of the automobile industry is not possible without improving the tribological properties of materials of units of friction. Increasing the reliability of the units of friction of the car mechanisms is important for reducing the cost of maintenance and repair. The study of friction, wear, and lubrication is the main task of increasing the durability of automotive mechanisms [1, 2, 3]. Friction is a complex process of the interaction of coupled solids. This process is accompanied by the following phenomena:

- oxidation due to the interaction of the surface of the friction with the environment;
- selective mass transfer;
- structural and phase transformations;
- absorption decrease in the strength of the surface layer;
- stress distribution in conjugated surfaces and depreciation of the latter.

At the same time, under the influence of the accompanying friction of physical, chemical, electrochemical and mechanical influences of the properties of the material, its composition and structure in the surface layers of contact interaction are subjected to continuous changes. As a result, products of deterioration and secondary structures on the working surfaces may be formed, the chemical composition and structure of which differ in composition and structure of the starting materials of the friction pairs, which affects the wear resistance of the units of friction.

Units of friction of the car are exposed to adverse factors: high humidity, dustiness and others. The resistance of the material of the surface layer, the adhesion forces and the wear and tear mechanism are continuously changed under the influence of external factors.

Particularly active wear is subjected to plain bearings [4, 5]. Mostly wear parts of the car chassis.

Promising materials for the manufacture of sliding bearings are polymer composites. The use of polymers can significantly reduce the cost of expensive materials and reduce energy consumption. The polymer matrix-based composites have high antifriction properties and are suitable for use at medium loads and slip rates. An urgent issue is the use of self-lubricating polymer-composite materials in units of friction, where undesirable or impossible external lubrication [6, 7].

Composites are one of the most widely used materials because of their adaptability to different situations and the relative ease of combination with other materials used to serve specific purposes and to exhibit desirable properties. Contemporary tribotechnical industry requires production of new polymer-composite materials (PCM) with high level of operational characteristics [6, 8].

In particular, the inclusion of polytetrafluoroethylene (PTFE) into oxide layers on aluminium can considerably improve practically all their properties, such as hydrophobic, antifriction and anticorrosion ones that enables the use of them in components working in friction junctions and production of anti-icing coatings [9, 10, 11].

The optimization of technological regimes of producing and converting PTFE-composites and coatings on their basis allows to provide optimal combination of deformation-durable and tribotechnical characteristics of the product as well as technical-and-economical and techno

logical parameters, to start the production of materials adapted to concrete industrial conditions and practical application.

The intensity of PCM wear depends greatly on mechanical properties, nature, structure and sizes of particles of matrix and fillers, composite material structure, its hardness, toughness, elasticity, level of the external force effect on the contact "composite – counterbody". The abrasive composite wear depends on the fact how effectively the composite material mi

crostructure can resist different processes of the material separation during the deformation. The main contribution into the amount of wear is made by the chain of plastic deformations and break in the thin surface layer. The distribution of the energy absorbed by the active layer determines the kinetics of accumulating damages and breaks and change of friction processes.

The perspective direction to improve the mechanical properties and increase the life service of such materials is a modification of the structure using the external physical fields. Thus an important aspect is the development of the technology of formation and improvement of technological properties of the components that determine the technical and economic efficiency of application of the developed composite materials and provides forecasting of PCM operational characteristics. The wide use of composite materials based on polymeric matrixes in tribotechnical engineering is conditioned by savings of high-value composites based on nonferrous metals, low-density products and comparatively low energy expenses connected with parts production.

The experience of many theoretical and practical works concerning the technology of formation of polymer composites has been analyzed and systematized.

The development of composite materials production based on thermoplastic or reaction able polymers should be grounded on scientific principles of polymers technology, applied materials science and physical and chemical mechanics of composite structures. Selecting the type of polymer matrix is conditioned by tribo-units operating conditions, loading and high-speed modes that further determine the technological principles of formation of polymer composites structure. Differences in technology for obtaining polymer composites are mainly conditioned by the structure of macromolecular chains of the polymer matrix and by the formation of links between the segments of macromolecules. Substantiated mode parameters of matrix and fillers preparation process and formation of filled composition affect the level of physical, mechanical and tribotechnical characteristics of polymer composites. Replacement of traditional tribomaterials in friction units of industrial equipment mainly consists in developing carbon fiber reinforced polymer (CFRP) on the basis of polytetrafluoroethylene containing modified fillers or epoxy composite materials containing powder products based on copper.

For a long time, the growth of PCM development technologies was based primarily on empirical researches, that were connected with the complexity of interphase interactions in multicomponent polymer systems and with their determining influence on the properties of polymer composites. The combination of theoretical studies of structural and phase transformations with experimental researches allows formulating the scientifically grounded approach to the forecasting and targeted adjustment of polymer composite properties [11, 12].

Identifying the influence regularities of fillers, chemical and technological factors on the formation processes of composites with deepening the scientific ideas about the formation

structure, studying their physical, mechanical and tribotechnical characteristics, allows control of the properties of polymer composites, that is one of the important problems of contemporary polymer materials science. The implementation of matrix and fillers modification methods and application of composites formation technology on the basis of polymers under the influence of external physical fields solves the important scientific and technical problem of polymer composites development and it defines the relevance of this research direction.

The aim of this work is to generalize the results of studies of the impact of technological factors on physical, mechanical and operating properties of polymer composite materials and to optimize technological process parameters. The results of the scientifically grounded solution of these tasks allow creating controlled technology for obtaining polymer composite materials and they provide consumers with the forecasted properties of composite materials on the best world analogues level.

PTFE-based (polytetrafluoroethylene) plain bearings are a cost-effective alternative for many industrial and automotive applications [12, 13].

Design and creation of new structures of three-component antifriction composite materials are based on the researches modeling their behavior in the conditions of tension. In the presented models the uniform approach based on the variation principles of mechanics of a solid body and allowing formulating boundary value problems in the form of a condition of minimality of functionality is used. The multifactoriality of the dependence of abrasive wear of a composite on its elasticity, viscoplasticity and durability is considered. Macroscopic characteristics of composite material are directly connected with its structure which is characterized by spatial distribution of components and their properties.