Influence of modification by nanodispersed powders on layered composite aerospace hulls and protective shields

A S Chermoshentseva¹, A M Pokrovskiy¹, L A Bokhoeva², A B Baldanov², V E Rogov³

¹ Bauman Moscow State Technical University, 5/1, 2nd Baumanskaya Street, Moscow, 105005, Russia
² East Siberia State University of Technology and Management, 40v, Klyuchevskaya Street, Ulan-Ude, 670042, Russia
³ Baikal Institute of Nature Management Siberian Branch of the Russian Academy of Sciences, 6, Sakhiyanova Street, Ulan-Ude, 670047, Russia

E-mail: asch-13@ya.ru

Abstract. The paper presents data on the influence of nanopowder on the structure of layered composites. Different quantities of the nanomodifier, based on the nanodispersed silicon dioxide powder, were added to the composite. The experimental research has shown that modification of a small amount of silicon dioxide powder (mass fraction of concentration 0.3 wt. %) is effective for using the layered composite aerospace hulls and protective shields.

1. Introduction

In the aerospace area a significant number of details are fabricated from composite materials. These details should possess high strength characteristics (aerospace hulls, protective shields). In order to enhance strength characteristics, various nano additives are introduced into these materials. However, the hidden defects in the structure of layers composite materials reduce strength significantly [1-4].

At present one of the modern trends of enhancing the strength properties of such composites is alloying them with nanodispersed powders. Introduction of their small amount into the binder before manufacturing aerospace hulls and protective shields allows increasing strength properties of details. But a mechanism of interaction with nanodispersed powders, as well as the process regularities of such nanomodification with composite materials, is not researched profoundly. However, such nanomodification of structural elements is promising from several points of view [5-7].

This paper presents the experimental research of the influence of the silicon dioxide powder “Tarkosil T-20” (T-20) on the structure of layered composites with defects.

2. Materials and methods

The glass-reinforced plastic of the T-25 (VM) TU 6-11-380-76 grade (Russian grade abbreviation) with nanopowder was used as a material for experimental research. This glass-reinforced plastic contains a matrix with a reinforcing material inside it. The powder-modifier was introduced into the matrix. The content of the nanopowder was 0; 0.1; 0.3 and 0.5 wt. %. Figure 1 shows photos of the layered composites specimens with nanodispersed silicon dioxide powder and without modifier addition. All specimens have artificial defects.
The layered composites specimens with the nanodispersed silicon dioxide powder “Tarkosil T-20” with defects.

The samples were fabricated of ten layers (fiberglass). We used the unidirectional fiberglass. As nanomodifying additives we chose the nanodispersed silicon dioxide powder “Tarkosil T-20” (T-20). The average particle size of 20 nm. Filler was added to the preheated resin, stirring it evenly, and then a hardener was added to the mixture. For the purpose of consolidation polyethylenepolyamine (PEPA) (1 part per 6 parts of resin) was added into the resin. To break up the agglomerates and more uniform distribution in the resin of filler particles used ultrasonic disperser UZG 13-0.1/22. After mixing, the mixture was used as a binder for composite materials. A thin strip of teflon film (10-100 μm thick) simulates the defect. We tested 24 specimens on the testing machine Instron 5982 [8,9]. We compared the experimental results of samples with concentrations ranging from 0 wt. % to 0.5 wt. %.

3. Experimental results
As a result of mixing of a resin with the nanodispersed silicon dioxide powder “Tarkosil T-20” and the hardener “polyethylenepolyamine” (PEPA) we obtained higher results than in case of using only a resin for the manufacture of composite materials. Reasoning from literature review, the main consequence of nanopowder introduction into the matrix is the nanosize of the particles. The nanoparticles should be a barrier for defects. The main role of a filler consists in prevention of growth of a crack as a result of changing its direction [10]. This testifies to formation of links of the nanoparticles “Tarkosil T-20” with the hardener “polyethylenepolyamine” and the epoxy resin. In particular, hardener can form a chemical bond with OH-groups. An experiment testifies that we can consider such a sequence of mixing as a modification of nanoparticles by the hardener molecules, which increases the chemical activity of the particles in a resin.

Figure 2 shows photos of the nanodispersed silicon dioxide powder “Tarkosil T-20”.

Figure 3 shows that when introducing a small amount (0.3 wt. %) of the silicon dioxide powder, this results in changing of the strength of composite materials based on it. When increasing the content of silicon dioxide powder, the effect is reduced. For successful testing, the modifier distribution must
be homogeneous enough.

Figure 4 shows experimental research of the layered composites specimens with the nanodispersed silicon dioxide powder and without modifier addition, and the process of destruction of specimens from glass-reinforced plastic. Stress is proportional to strain. A increase in stress will cause the same increase in strain.

![Graphs showing critical load vs. nanopowder concentration for different specimen sets.](image)

**Figure 3.** Graph of nanopowder concentration (%) versus critical load (N) for 1-24 specimens.
Figure 4. Experimental research

4. Conclusion
The qualitative analysis of the experimental research shows that we have succeeded in obtaining a positive effect under concentration 0.3 wt. % of the modifier. When introducing a small amount of the silicon dioxide powder, the powder particles become a barrier for defects. Introduction of the large quantity of the nanopowder leads to its reduction of its influence on the material structure.

Application of composites in industries has led to the need to take into account new factors, which affect their performance characteristics [11-13]. The research results are relevant for aerospace industry, namely for the manufacture of aerospace hulls and protective shields made of composite materials.

Acknowledgments
The reported study was funded by the Russian Foundation for Basic Research (RFBR) according to research project No. 18-29-18050/18 mk.

References
[1] Alfutov N A, Zinoviev P A and Popov B G 1984 Calculation of multilayer plates and shells of composite materials (Moscow: Mashinostroenie) p 264
[2] Pobedry B E 1984 Mechanics of composite materials (Moscow: Moscow State University) p 336
[3] Ambartsumyan S A 1974 General theory of anisotropic shells (Moscow: Science) p 448
[4] Alfutov N A 1991 Fundamentals of calculation on the stability of elastic systems (Moscow: Mashinostroenie) p 311
[5] Bardakhanov S P, Lygdenov V T, Goverdovskiy V N, Lee C M and Lee O C 2017 Advances in materials science and engineering 2017 2397238
[6] Syzrantshev V V, Vikulina L S, Nomaev A V, Kopanitsa N O, Abzaev Y A, Demyanenko O V, Kopanitsa G D and Bardakhanov S P 2018 Solid state phenomena 271 124-132
[7] Lee C M, Goverdovskiy V N, Lygdenov V T and Bardakhanov S P 2016 The 11 International forum on strategic technology (IFOST-2016) 1 124-127
[8] Chermoshentseva A S, Pokrovskiy A M, and Bokhoeva L A 2016 IOP Conf. Series: Materials Science and Engineering 116 (2016) 012005
[9] Chermoshentseva A S, Bokhoeva L A, Rogov V E 2018 International Conference "Aviamechanical engineering and transport" (AVENT 2018) 158 49-53
[10] Adamenko N A, Fetisov A V and Agafonov G V 2010 Constructional polymeric composites (Volgograd: VolgGTU) p 104
[11] Zarubin V S and Sergeeva E S 2018 Mathematical models and computer simulations 10 288-298
[12] Zarubin V S, Kuvyrkin G N and Savelyeva I Y 2017 Mechanics of composite materials 53 497-504
[13] Zarubin V S, Sergeeva E S and Magnitskiy I V 2018 Iutam symposium on mechanical design and analysis for am technologies 1 92-94