Salaev R.A., Zhukova Yu.V.**Method for carbon tapes strengthening by modified nanotubes based on ultrasound resonators***Ulyanovsk State Technical University
(Russia, Ulyanovsk)**doi: 10.18411/lj-04-2019-240**idsp: ljournal-04-2019-240***Аннотация**

Разработан новый метод упрочнения углеродных лент модифицированными нанотрубками на основе ультразвуковых резонаторов. Установлено, что использование ультразвука для размешивания нанотрубок в связующем дает более равномерное их распределение по сравнению с существующими методами. Проведено сравнение предлагаемого метода упрочнения с применяемыми в настоящее время на производствах методами упрочнения. Предложен более эффективный метод упрочнения углеродных лент, путем внедрения углеродных нанотрубок ультразвуковым ветром в структуру углеродной ленты.

Ключевые слова: углеродные нанотрубки, связующее, углеродная лента, полимерно-композиционные материалы, повышение прочности, ультразвуковой ветер.

Abstract

A new method of carbon tapes strengthening with modified nanotubes based on ultrasonic resonators has been developed. It is established that the use of ultrasound for mixing nanotubes gives a more equal distribution compared to existing methods. A comparative analysis of the proposed strengthening method and the existing ones currently used in manufacturing has been conducted. A more efficient method for strengthening carbon tapes has been proposed by introducing carbon nanotubes with an ultrasonic wind into the carbon tape structure.

Keywords: carbon nanotubes, binder, carbon tape, polymer composite materials, increased strength, ultrasonic wind.

Currently, structures made of polymer-composite materials (PCM) are increasingly used in various technical fields including products that operate under high loads conditions. A number of exclusive properties that can be obtained in the production of these structures, the most important of which is the low specific weight makes the study of polymer-composite materials the most promising direction in modern materials science. Existing approaches to solving the problem of increasing the strength of PCM products have a number of problematic issues.

At the moment, the most promising way to increase the strength of PCM is the addition of a small amount of carbon nanotubes (CNTs) into the binder that leads to strengthening, conductivity and radio absorbing properties [1]. However, to obtain such properties, an even distribution of CNTs in the binder and the formation of covalent bonds between the CNT and the binder is required. Without additional modification, CNTs tend to form agglomerates, i.e. to uneven distribution, which significantly reduces the effect of their addition. Creating a cheap and effective method to solve the above-mentioned problem is currently one of the most important tasks related to the use of CNT in composite materials.

When conducting a number of experiments on the introduction and distribution of CNTs in the volume of the binder, it was observed that the most even distribution can be obtained when a binder is exposed to with ultrasound.

Besides research on CNT addition into the binder, the author team has developed another method for strengthening the PCM which can be used both as an alternative to the introduction of CNT into the binder and together with it. The essence of the proposed method is the introduction of CNT into the carbon tape structure using an ultrasonic resonator the impregnation process by means of an ultrasonic wind. This method will significantly improve the strength characteristics of the tape with minimal investments in equipment and CNT.

Currently, the author team is conducting further research on the ultrasound application for mixing and the introduction of CNTs into the binder and carbon tape structure, the purpose of which is to establish tendency of the processes and to select optimal conditions, i.e. the intensity and power of the ultrasonic wind and the number of CNTs providing the greatest hardening of the tape and obtaining PCMs with the best properties in terms of further products life.

Experimental part

In this work, we used CNTs obtained by chemical deposition of CNTs from the vapor phase (MOCVD method) using mixtures of volatile organometallic compounds and hydrocarbon precursors in an inert gas stream at 650-900 [3]. For the introduction of CNT into the structure of non-impregnated carbon tape, an installation was used, the scheme of which is shown in Fig. 1.

Fig. 1. Installation scheme

In this installation, nanotubes are filled up in a small container 4, the number of which varies based on the speed of the conveyor and the thickness of the tape. Then, using the ultrasonic wind, which is created by the URSK-7N-22 3 ultrasonic resonator (Fig. 2), CNTs are added into the structure of carbon tape 1, which moves along the conveyor at a low speed throughout its volume until it is impregnated with a binder. This gives the most even distribution of CNTs in the structure of the material, thereby increasing its strength characteristics. Rubber insulators 2 are necessary to create a tight joint, to avoid increased material consumption and CNT penetration into the environment, since when CNTs are introduced by ultrasonic wind, they are scattered over a wide range. After the end of introducing CNT, the carbon tape is removed from the conveyor.

Fig. 2. Ultrasonic resonator URSK-7N-22

The next step is to manufacture binders with carbon nanotubes to impregnate the carbon fabric incorporated into the structure of CNTs.

For the preparation of the binder used:

- ED-20 epoxy resin – 89.9 mass fraction;
- Hardener TETTA – 10 mass fraction;
- Modified carbon nanotubes – 0.1 mass fraction.
- Laboratory scales MASSA-K VK-300.
- Specialized containers for the preparation of a binder.

Pre-weighed components are stirred in a special container using an ultrasonic unit, since when ultrasound mixing the binder with CNT, the most even distribution of CNT occurs in the binder composition. After preparation of the binder, the carbon fabric is further impregnated in a special container, where carbon fabric is laid out in several layers with carbon nanotubes applied to its surface, the container binder is applied, and then the fabric is impregnated with a roller. The finished product was laid out in layers and placed under a hydraulic press with heating for 24 hours.

The obtained samples (Fig. 3) are installed in the tensile-testing machine UME-10TM, where strength tests at different speed modes of rupture of samples are carried out.

At the same time to compare the strength characteristics sample tests without CNT, as well as samples with CNT added only to the binder were carried out. After conducting laboratory tests by means of a tensile-testing machine UME-10TM analysis of the results which is presented in Table 1 was held.

Fig. 3. The samples

Table 1

Sample test results

Samples	E, GPa	Breaking stress at stretching, MPa
The sample without the addition of CNTs	250	2000
The sample with the addition of CNTs in the binder	275	2200
The sample with the addition of CNTs in the binder and structure of the carbon tape	300	2400
E - Young's modulus, GPa – gigapascal; MPa - megapascal		

The results of experimental studies allow us to conclude that the addition of a small number of CNTs into carbon fabric using ultrasonic wind, as well as the addition of CNTs to the binder and their further impregnation of carbon tape increases the strength of PCM structures up to 20–30%. Taking into account the cheapness of CNTs and equipment for their application, the proposed method for increasing the strength of PCM products is economically beneficial and, after completing additional studies and establishing optimal processing modes can be recommended for the introduction of products into production, the strength of which is one of the most important operational properties.

1. AjayanP. M., TourJ. M. MaterialScience: nanotubecomposites// Nature. 2007. V. 447. P. 1066 – 1068.
2. Zhu R., Pan E., Roy A. K. Molecular dynamics study of stress – strain behavior of carbon – nanotube reinforced Epon 862 composites // Mater. Sci. Eng. 2007. V. A447. P. 51 – 57.