BIO Web of Conferences **105**, 06011 (2024) https://doi.org/10.1051/bioconf/202410506011
AEGISD-IV 2024

Study of the influence of ultrasound on the wear resistance of coatings made of composite polymer materials for the shape of architectural and artistic reinforced concrete products

Muzaffar B. Mukhitdinov*, *Farrukh* A. Dadakhanov, and *Zhasur* D. Nuritdinov

Namangan Engineering and Construction Institute, Namangan, Uzbekistan

Abstract. This paper investigates the impact of ultrasound on the physical-mechanical properties and wear resistance of polymeric composite materials and coatings used in architectural-artistic concrete products. The study is motivated by the frequent failure of polymer coatings on the working surfaces of technological equipment. The research focuses on the development of effective thermosetting epoxy polymeric materials with high adhesion and wear resistance properties for use in the working surfaces of architectural-artistic concrete products. The study examines the effect of ultrasonic treatment on the wear resistance of epoxy polymeric composites in contact with concrete. The investigation uses two types of base compositions of the binder. The compositions are filled with various industrial dispersed and fibrous fillers, including graphite, carbon fibers, soot, iron powder, cement, talc, kaolin, glass fiber, PTFE, and high-density polyethylene. The study is significant as it provides insights into the development of effective thermosetting epoxy polymeric materials with high adhesion and wear resistance properties for use in the working surfaces of architectural-artistic concrete products. The results of the study can help improve the efficiency and durability of metal equipment used in the production of concrete products.

1 Introduction

It is known that coatings made of polymer materials on the working surface of technological equipment often fail during operation. The reasons for this are the destruction of the surface of the equipment as a result of wear or peeling of the polymer coating during repeated exposure to the concrete mixture during the molding stage [1-8].

At the stage of development of such compositions, researchers focused on the anti-adhesive properties of the polymer with concrete and the effect of temperature and humidity of the concrete mixture on the adhesive strength of the polymer itself with the substrate. On a global scale, to increase the efficiency and performance of metal tooling for the manufacture of

* Corresponding author: I.axmedov0588@gmail.com

reinforced concrete products, it is relevant and necessary to create effective tribotechnical modified composite thermosetting epoxy polymer materials to produce coatings with high adhesive properties and wear resistance. In this aspect, it is relevant and necessary to increase the adhesive strength and wear resistance of composite thermosetting epoxy polymer materials and coatings based on them with high physical and mechanical properties for use on the working surfaces of architectural and artistic reinforced concrete products.

In this aspect, this article presents the results of studies on the effect of ultrasonic treatment on the wear resistance of composite epoxy polymer materials working in contact with concrete

2 Materials and methods

The study employs two types of the main composition (OS) of the binder, consisting of 100 parts by weight (mass) of ED-16 epoxy resin, 12 parts by mass of polyethylene polyamine hardener, and 20 parts by mass of dibutyl phthalate plasticizer (OS-1), and 100 parts by mass of ED-16 epoxy resin, 7 parts by mass of piperidine hardener, and 20 parts by mass of aliphatic low molecular weight epoxy resin (OS-2). The selection of the binder based on ED-16 is due to its ease of use, relatively high physical and mechanical properties and heat resistance, and the ability to produce coatings with both cold and hot curing.

For filling epoxy compositions, industrially produced dispersed and fibrous fillers of organic, inorganic, synthetic, and mineral origin were chosen, including granular and lamellar graphite, carbon fibers, carbon black, iron powder, cement, talc, kaolin, fiberglass, fluoroplastic, and high-density polyethylene. The use of these fillers allows for the development of epoxy compositions with tailored properties for specific applications. [9-13].

When developing such compositions, both binders were used, because each has its own advantages and disadvantages, which is of both scientific and practical interest. For example, OS-1 is more wear-resistant and has relatively lower adhesive strength with concrete, while OS-2 has good adhesion to steel.

The development of such compositions was carried out mainly for the following purposes:

- adhesive (to concrete) wear-resistant epoxy composition - ABIEK;
- particularly wear-resistant epoxy composition - OIEC;
- adhesive (to steel) wear-resistant epoxy composition - ASIEK.

This conditional division of the composition according to functionally important properties allows us to more expediently resolve the issue of rational choice of components in the composition.

The study used mainly standard installation methods. Thus, adhesive strength according to GOST 14-760-69, bending strength according to GOST 4648-71. The wear-resistant properties of composite thermosetting epoxy polymer materials when interacting with concrete were studied using a disk tribometer UzDST3330:2018.

For ultrasonic treatment of polymer compositions, we used an LP-250W unit with a frequency of 1 MHz, which allows us to vary the power of ultrasonic vibrations from 80 to 250 W. The choice of installation is due to the fact that ultrasonic vibrations, especially with a frequency of 600-1000 kHz, accelerate the polymerization reaction, the processes of oxidation of substances, dispersion of ingredients, ensure the intensity of mixing, and the uniformity of the composition. All these processes are important for obtaining high-quality composite polymer materials and coatings.

3 Results and discussion

The samples were processed in an ultrasonic field according to our chosen method [14, 15], at a constant ultrasonic vibration frequency of 1 MHz and a field intensity of 5 kW/m2.

The results of an experimental study of the dependence of the wear rate of epoxy compositions on the time of exposure to an ultrasonic field are presented in Figure 1.

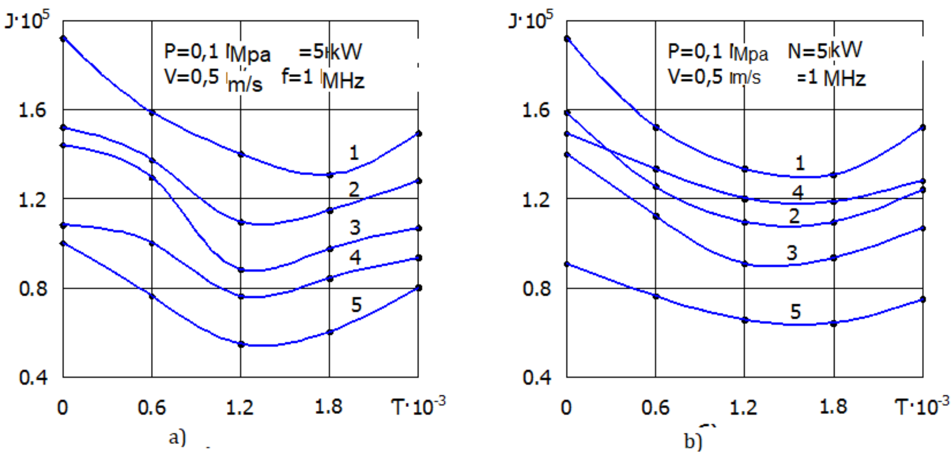

Fig. 1. Dependence of the wear rate of epoxy compositions ABIEK-3(1), OIEK-1(2), OIEK-3(3), OIEK-5(4), ASIEK-3(5) on concrete (a) and in the presence of moisture environment (b) on the duration of treatment in the ultrasonic field.

As depicted in the figure, the wear rate of epoxy compositions undergoes significant changes with increasing exposure time to the ultrasonic field, reaching a minimum within the duration range of 1200-2000 seconds. Furthermore, the location of this minimum varies depending on the composition type and binder. For instance, the minimum wear intensity value for OS-1 is 0.8 x 10^{-5}, observed at an ultrasonic field exposure time of 1000-1200 seconds, whereas for OS-2, the minimum wear rate is 0.95, corresponding to an ultrasonic treatment time of 900-1000 seconds.

The minimum value of the wear rate of filled compositions is observed with a relatively long time of exposure to the ultrasonic field, compared to unfilled ones, and differs significantly in value depending on the type of components. It should be noted that the highest wear rate, both in wet and dry environments, is observed for ABIEK-3 compositions, and its lowest value is for ASIEK-3 compositions. An overall increase in the wear resistance of the compositions by 30-50% is observed compared to compositions not treated in an ultrasonic field.

One of the advantages of ultrasonic processing of polymer materials, in our opinion, is a reduction in the heterogeneity of the polymer composition; the viscosity of the compositions is reduced by almost 2.5 times. This greatly contributes to improving the wettability of the composition with other bodies.

An equally important feature of ultrasonic treatment of polymer compositions before applying them to the surface of samples is that after ultrasonic treatment, the components of the composition, especially fillers, are distributed more evenly (see Fig. 2), aggregated particles of fillers are reduced and thus microdefects and heterogeneity in the volume of the polymer material are reduced to a minimum.

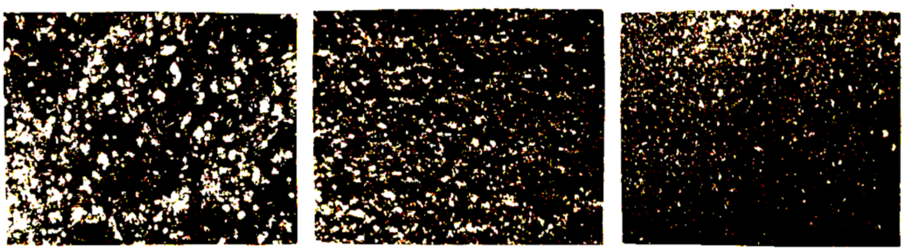

Fig. 2. Change in the surface structure of the composite epoxy coating made from OIEK-2 under the influence of an ultrasonic field.

One of the important factors determining the effectiveness of ultrasonic treatment is the presence of mechanochemical processes [5]. Thanks to this, the curing speed of thermosetting compositions increases almost 2 times. If at room temperature a composition based on ASIEK-3 cures after 25-30 minutes (the beginning of curing), then after pre-treatment with ultrasound, the specified composition cures within 5-7 minutes.

The obtained research results show a high potential for modifying polymer materials in an ultrasonic field to improve their functionally important properties in relation to the operating conditions of the equipment.

The results of the study show that through physical modification it is possible to significantly change the physical, mechanical and operational properties of composite polymer materials operating under abrasive friction conditions in relation to the operating conditions of forming equipment. It should be noted that the effect of physical modification with organomineral fillers on the properties of epoxy compositions varies depending on the type and quantitative ratio of fillers. At the same time, epoxy compositions treated in an ultrasonic field have more stable and high-performance properties, regardless of the type of components.

4 Conclusion

Based on the study findings, the following conclusions can be made:

The study demonstrated that modifying the composition using an ultrasonic field can significantly alter the wear resistance and other operational and physical-mechanical properties of epoxy compositions.

The optimal exposure time to enhance wear resistance is between 900-1800 seconds, while for improving adhesive strength, exposure to ultrasound for 1500-2000 seconds is effective. The optimal processing parameters for ultrasonic treatment have been identified, showing that desired outcomes are achieved with 1800-2000 seconds of exposure to a field with a power of $N=5\ kW/m^2$ and a frequency f=1 MHz.

These research findings highlight the broad potential for utilizing fillers of various natures in different combinations to precisely adjust the properties of epoxy compositions.

References

1. S. S. Negmatov, et al., Universum: technical sciences **11-5(104)** 54-59 (2022).
2. M.B. Mukhitdinov, Universum: technical sciences **12(117)** (2023).

3. S.S. Negmatov et al., Composition materials **72**, (2012).
4. S. S. Negmatov, et al., AIP Conf. Proc. **3045,** 060026 (2024).
5. M. B. Mukhitdinov, Universum: technical sciences, **2-1(118)**, 32-34 (2024).
6. A. Arifjanov, D. Atakulov, I. Akhmedov, A. Hoshimov, IOP Conference Series: Earth and Environmental Science, **1112,** 012137 (2022)
7. S. Tadjiboyev, X. Qurbonov, I. Akhmedov, et al., AIP Conference Proceedings **2432,** 030114 (2022); https://doi.org/10.1063/5.0089643
8. A. Arifjanov, et al., E3S Web of Conferences, **365** 03017 (2023)
9. A. Borotov, et al., IOP Conf. Series: Earth and Environmental Science **1284** 012013 (2023)
10. A. Borotov, et al., E3S Web of Conferences **390** 04038 (2023)
11. F. M. Mamatov, et al., IOP Conference Series: Earth and Environmental Science **1231(1)** 012008 (2023)
12. A. Arifjanov, et al., E3S Web of Conferences **390,** 04035 (2023)
13. A. Khamidov, et al., E3S Web of Conf., **390** 06040 (2023)
14. U. Umarov, et al., E3S Web of Conf., **401** 03019 (2023).
15. A. Obidjonov, et al., E3S Web of Conferences **401,** 01084 (2023)