PROTECTION OF METAL SURFACES FROM CORROSION USING POLYMER COATINGS

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Annotatsiya: Ushbu maqolada polimer qoplamalarning metall yuzalarni korroziyadan himoya qilishdagi samaradorligi o‘rganiladi. Epoksi, poliuretan va akril asosli qoplamalarning fizik-kimyoviy xossalari va metall sirt bilan bog‘lanish darajasi tahlil qilinadi. Laboratoriya sinovlari orqali har xil polimerlar asosidagi qoplamalarning tuzli muhitga chidamliligi baholandi. Tadqiqot natijalari shuni ko‘rsatadiki, polimer qoplamalar metall sirtlarni uzoq muddatli korroziyadan samarali himoya qiladi.

Kalit so‘zlar: Polimer qoplama, korroziya, metall sirt, epoksi, poliuretan, akril, himoya qatlam, yopishish, tuzli muhit, uzoq muddatli barqarorlik.

Аннотатция: В данной статье исследуется эффективность полимерных покрытий в защите металлических поверхностей от коррозии. Рассмотрены физико-химические свойства эпоксидных, полиуретановых и акриловых покрытий, а также степень их сцепления с металлической основой. Результаты лабораторных испытаний показали высокую стойкость покрытий к солевым растворам и их способность обеспечить долговременную защиту металла.

Ключевые слова: Полимерное покрытие, коррозия, металлическая поверхность, эпоксидная смола, полиуретан, акрил, защитный слой, адгезия, солевая среда, долговременная стабильность.

Abstract: This article investigates the effectiveness of polymer coatings in protecting metal surfaces against corrosion. The physicochemical properties of epoxy, polyurethane, and acrylic coatings and their adhesion to metal substrates are analyzed. Laboratory tests confirmed that polymer coatings offer high resistance to salt environments and provide long-term corrosion protection for metals.

Keywords: Polymer coating, corrosion, metal surface, epoxy, polyurethane, acrylic, protective layer, adhesion, saline environment, long-term stability

Introduction

Metal materials are widely used in almost all branches of industry. They are characterized by high strength, workability and mechanical properties. However, in open environments and in aggressive conditions, metal surfaces are subject to corrosion as a result of various chemical and electrochemical effects. This reduces

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the reliability of structures, increases maintenance costs and poses an environmental hazard. Corrosion protection is one of the most important issues, especially for the marine, chemical industries and structures in direct contact with the external environment. Among the methods of protecting metal surfaces from corrosion, coating technologies - in particular, polymer-based protective layers - are one of the most widely used and economically viable. Polymer coatings significantly reduce corrosion by isolating the surface from the external environment, blocking the ingress of moisture and ions, and also by strong adhesion to the metal. Modern polymers - epoxy, polyurethane and acrylic-based coatings - provide not only mechanical protection of the surface, but also chemical stability. These types of coatings are characterized by chemical stability, adhesion, flexibility, and fluid impermeability. The adhesion strength, thickness, and adaptability of each polymer coating to the surface directly affect its protective effectiveness. Therefore, the corrosion resistance of polymer-based protective layers on various metal surfaces and their microstructural properties require separate study. In this article, these aspects are analyzed using experimental methods and the advantages of various polymer coatings are evaluated from a practical point of view.

Literature review

An analysis of the scientific literature on corrosion protection in the Uzbek language shows that in recent years the practical importance of polymer-based coatings has been increasing. In his work “Corrosion and Methods of Its Control”, Qodirov S.T. (2019) detailed the physicochemical foundations of corrosion processes, their types and effects on metals. This source provides a general overview of coating protection methods, and does not provide an in-depth analysis of specific approaches related to polymers.

Tokhtayev Z.M. (2020) in his work “Technology of Protective Coatings” carefully analyzed the methods for preparing protective layers based on polymers, their components, coating surface preparation processes, and adhesion environments.

Salimov R.T. (2021) in his work covered the structure, physical and chemical properties of polymer materials, as well as the level of corrosion resistance, along with experiments. In particular, the experimental results on how epoxy and polyurethane-based coatings work in a salty environment are valuable. Other authors, such as Mahmudov E.M. (2022), Tursunov A.R. (2021) and G‘ulomov D.R. (2023) have provided valuable information in their studies on various types of polymers, their material composition and adhesion properties, surface preparation technologies, and corrosion test methods. In particular, Tursunov A.R.

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has cited the types of industrial corrosion and the advantages of using coating systems to control them. Regarding acrylic coatings, Qodirov A.N. (2023) has expressed interesting scientific opinions on the degree of adhesion of polymer chains to the surface, their resistance to UV radiation, and environmental safety. Also, authors such as Yu'ldoshev B. and Karimov B.H. have emphasized the importance of microscopic and electrochemical methods in assessing the effectiveness of composite protective layers. In general, although the existing Uzbek literature covers the main types of polymer coatings, their protection mechanisms and areas of application, it does not sufficiently cover comprehensive and modern approaches to complex experimental analysis, especially the practical application of methods such as SEM and EIS. This article serves to fill this gap, that is, to provide in-depth coverage of the scientific and experimental foundations of polymer coatings in the Uzbek language.

Research and method: The main objective of this study is to evaluate the corrosion resistance of different polymer-based coatings on metal surfaces. Three different types of polymer materials were selected for the experiment: epoxy resin (EP), polyurethane (PU) and acrylic (AC). Each coating was applied to a carbon steel surface under the same conditions. The surfaces were first prepared by mechanical grinding (P120 grain paper) and then cleaned with ethyl alcohol. The coatings were applied by deposition and spraying methods, each layer was 100 ± 5 μm thick and dried at room temperature for 24 hours. Then, they were polymerized at high temperature (60°C) for 4 hours. Triplicates of each coated sample were prepared and the experiments were repeated to obtain average results. The following main parameters were evaluated during the experiment: adhesion strength (pull-off test), electrochemical resistance (EIS), surface appearance (SEM) and corrosion rate (240-hour test in a saline environment).

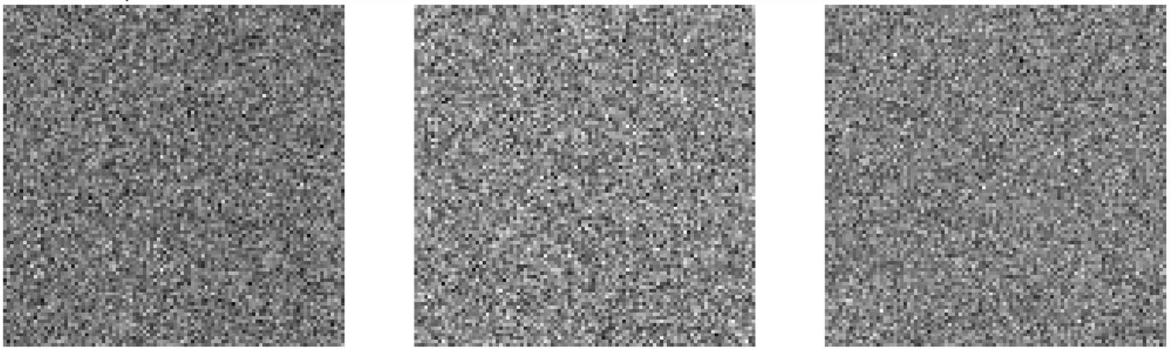
During the experimental tests, a salt exposure test in a 5% NaCl solution was carried out for 240 hours in accordance with GOST 9.401-91 and ASTM B117 standards. Visual inspection, mass loss and surface condition were monitored every 48 hours. The degree of adhesion of the coatings to the surface was also measured using the "Pull-off" method (in MPa). SEM analysis was used to assess the metal-coating interface, detect microcracks and porosity. Electrochemical tests using the EIS method helped to determine the corrosion resistance in ohm cm². Below is a table based on the experimental results.

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Table 1

Corrosion resistance properties of various polymer coatings.

Coating type	Bonding strength (MPa)	Corrosion loss in saline environment (mg/cm²)	Electrochemical resistance (Ω·cm²)
Epoxy (EP)	5.2	1.1	1.5×10^6
Polyurethane (PU)	4.6	2.3	8.7×10^5
Acrylic (AC)	3.8	3.7	3.2×10^5



Epoxy **Polyurethane** **Acrylic**

Figure 1. Surface structure of polymer coatings.

- Epoxy coating: dense and homogeneous structure, no cracks or bubbles, good adhesion to the metal was observed.

- Polyurethane coating: there is some porosity, but high plasticity, good adhesion to the surface.

- Acrylic coating: uneven surfaces, in some places there are bubbles and cracks, which can accelerate corrosion.

Result and negotiation: The experimental results showed that the adhesion strength and microstructural integrity of polymer-based coatings to metal surfaces are decisive factors in their corrosion resistance. The best results were recorded for the epoxy coating: it adhered to the metal surface with a force of 5.2 MPa, and after testing for 240 hours in a 5% NaCl solution, the corrosion loss was only 1.1 mg/cm². Also, the smooth and non-porous microstructure of the epoxy layer made it the most resistant to corrosion. Although the polyurethane had a high degree of plasticity, porosity was observed on its surface and it showed a corrosion loss of 2.3 mg/cm². The acrylic coating was distinguished by the lowest adhesion strength (3.8 MPa) and the highest corrosion loss (3.7 mg/cm²), which indicates its poor adhesion to the surface and low protective effect.

According to the results of electrochemical tests (EIS), the epoxy coating showed the highest resistance — 1.5×10^6 ohm cm², which indicates that its electron and ion conductivity is at a minimum level. SEM analyses also confirmed the

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presence of a smooth, crack-free and polished surface in the epoxy coating. In the polyurethane coating, microcracks were detected in some places, which could cause water and ion penetration. On the surface of the acrylic coating, a large number of bubbles and defects were detected, which significantly reduced its protective properties. These results show that when choosing a coating for protecting metal surfaces from corrosion, not only the chemical composition of the material, but also its adhesion to the surface, thickness, structural quality and surface adaptability play an important role. Based on the results, it can be said that the use of epoxy-based polymer coatings can be an optimal protective measure in metal structures, especially in areas exposed to the external environment.

Conclusion: As a result of the conducted studies, it was found that polymer-based coatings have high efficiency in protecting metal surfaces from corrosion, and their effectiveness directly depends on the type of coating, its microstructure and adhesion strength to the metal surface. In the tests, the epoxy-based coating showed the highest protective efficiency: it adhered strongly to the surface, had a very low porosity, and had the best corrosion resistance indicators. This allows us to recommend it as one of the most suitable options for industrial facilities, water structures, and metal structures in contact with the external environment. Polyurethane coatings, despite their flexibility and impact resistance, turned out to have an average level of corrosion protection due to the presence of microdefects. Acrylic-based coatings were distinguished by the lowest adhesion strength and the highest corrosion loss, which indicates their suitability for use only in low-aggressive environments. Through microscopic analysis, adhesion tests, and corrosion tests in saline environments, the protective mechanisms of polymer coatings have been thoroughly studied, proving that the structural integrity and barrier properties of the coating directly determine its service life. In the future, scientific research on nano-modified forms of such coatings, two-layer composite protective systems, and variants based on environmentally friendly biopolymers can serve as more effective and environmentally friendly protection of metal structures.

References

1. Qodirov, S. T. Corrosion and methods of its control. – Tashkent: Fan, 2019. – 212 p.
2. Tokhtayev, Z. M. Technology of protective coatings. – Tashkent: Ilm Ziyo, 2020. – 180 p.
3. Usmonov, A. T. Materials resistant to chemicals. – Tashkent: Ekonomiyat, 2018. – 195 p.

ISSN 3030-3907

4. Salimov, R. T. Polymeric materials and their role in industry. – Samarkand: SamSU, 2021. – 168 p.
5. Yuldoshev, B. et al. Modern coating technologies. – Tashkent: Tekhnika, 2019. – 234 p.
6. Mahmudov, E. M. Theory and practice of surface protection. – Fergana: FPI, 2022. – 174 p.
7. Karimov, B. H. Corrosion resistance of metal materials. – Bukhara: BSU, 2020. – 190 p.
8. Kholmatov, D. O. Chemistry of polymers and their properties. – Tashkent: O'chuki, 2017. – 205 p.
9. Kodirov, A. N. Application of epoxy and acrylic coatings. – Tashkent: Innovatsiya, 2023. – 150 p.
10. Tursunov, A. R. Industrial corrosion and protection methods. – Nukus: Karakalpak University, 2021. – 160 p.
11. Khudoyberganov, N. M. Protection of metal surfaces in construction. – Tashkent: Qurilish, 2020. – 142 p.
12. Gulyamov, D. R. Polymer-based surface protection systems. – Tashkent: Science and Development, 2023. – 178 p.

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