Effectiveness of the using powder coating for protection of metal construction

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Abstract. Current state of the Ukrainian economy causes to resolve a range of questions related to the improvement of production and increase in the ecological safety of products, including paint-and-varnishes materials, in combination with ensuring high operational properties of coatings based on them.

This questions can be solved by scaling up production using eco-friendly powder coating. The increase in popularity of powder coatings can be explained by their environmental adequacy and attractiveness from the perspective of the environmental protection as well as high effectiveness related to the possibility of obtaining high quality protective and decorative coatings with the high corrosion and chemical resistance as well as controllable physical and mechanical and dielectric characteristics during the one-layer application.

The analysis of research results shows that the effectiveness of use of metakaolin and talc as fillers in the powder coating increases in proportion to their content in the system. The optimal area of the powder coating with metakaolin and talc is limited to the additive in the range of 20 to 30 % and polyester resin in the range of 55 to 65 %. Using the mentioned range of fillers in the powder coating contributes to the decrease in the peeling width and metal corrosion width and places the coating into atmospheric corrosivity categories C3 and C4 according to ISO 12944-2:2017 having a high (H) lifespan from 15 to 25 years in accordance with DSTU ISO 12944-1

In this case, one of the most common methods of influence on properties of paint-and-varnishes coatings is to create polymer composites by combining polyester raw materials with inorganic fillers.

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Keywords: powder coating, talc, metakaolin, polymer, corrosion resistance, peeling width, metal corrosion width.

INTRODUCTION

Corrosion construction activities using the organic paint coatings became the most common in practice thanks to the relatively low cost of materials and their availability [1]. Main requirements for the coating are good adhesion, impermeability to the aggressive media, durability, technological effectiveness of the repeated coating, cost-effectiveness subject to the useful life. Despite their variety and comparatively low cost, ordinary organic paint coatings have one substantial defect, namely, short useful life, which requires construction materials to be often recoated; this, in its turn, causes large expenses due to the short overhaul life. However, the 60s of the previous century have brought a new type of paint coatings, that is, powder ones [2, 3].

With the strengthening of environmental requirements and the need to adapt Ukrainian legislation on quality and safety of construction materials to EU requirements, the priority direction of development is to minimize the negative impact of harmful substances in their composition on consumer health and the environment. This issue is especially acute for goods of the paint and varnish industry using volatile organic compounds [4, 5]. In recent years, the world has paid considerable attention to the environmental aspects of production and use of paint and varnish materials, which has led to a steady increase in production and use of powder coating.

It should be noted that in Ukraine the powder coating are also becoming more common due to their environmental friendliness by virtue of the absence of harmful solvents, ease of use and storage, as well as obtaining a durable coating [6].

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The technology of use of decorative and protective coatings based on powder coating has many advantages compared to paints based on liquid systems: powder coatings are supplied to the construction plants already finished and do not require to be prepared, intermixed, stirred and the viscosity also does not need to be regulated [7]. Powder coatings can be easily disposed and recycled; thus the economic efficiency of production increases. Coatings manufacturing energy costs decrease because of lack of solvents (no additional air purification and handling equipment required, decrease in energy costs). The full automation of production becomes possible, which allows decreasing the number of employees and production areas as well as increasing production capacities.

All industrial powder coatings are polydisperse systems, which are usually characterized by the following range of particle sizes varying from 5 to 60 μm for thermosetting paints and from 5 to 350 μm for thermoplastic coating [8]. In the 90s of the last century the production of thermoplastic coating prevailed in the industry. However, at the beginning of the 21st century the production of thermosetting powder coatings increased drastically and makes up more than 80% of the total production of powder coating materials today in various countries around the world, which is evidence of their effectiveness [9].

The thermosetting powder coating contains of five key components: polymer resin, hardener, pigments, functional additives and fillers [10]. In general, the polymer resin and hardener play a key role in ensuring necessary mechanical characteristics and lifespan of the powder coating. But exactly the right choice of the filler allows regulating such functional coating properties as hardness, glance, flexural and impact strength, elastic modulus, permeability and corrosion [11]. Since fillers for the powder coating are imported from abroad, the research [8] found that using Ukrainian-made silicate fillers in the powder paint allows obtaining a coating with controllable physical and mechanical characteristics as well as increasing its corrosion resistance. The most unique feature of such fillers is that they have hydroxyl groups playing a defining role during the interaction of fillers with thermosetting oligomers.

Therefore, the purpose of this paper is to determine a role of silicate fillers in the form of metakaolin and talc on the formation properties of coating based on powder coatings

THE PURPOSE OF THIS WORK

The purpose of this paper is to determine the influence of metakaolin and talc on the corrosion resistance of coatings based on powder coatings and to optimize their compositions.

MATERIALS AND METHODS OF RESEARCH

The powder coatings consisted of the following components: film-forming component, filler, pigments, functional additives.

The carboxylated polyester resin Crylcoat 2618-3 by Alnex has been used as a film-forming component. It is also necessary to use a structure-forming hardener together with the carboxylated polyester resin. In this paper we have used the hardener in the form of Primid XL-552 by EMS-Griltech.

Titanium dioxide K-2190 by Kronos has been used as a white pigment. The agent Resiflow PV88 of 1 % of the powder coating mass by Estron chemical has been used as a rheological additive. Benzoin of 0.6 % of the powder coating mass by Estron chemical has been used as a degassing agent.

Research methods. The role of silicate fillers in the form of metakaolin and talc in the corrosion resistance of the coating based on powder coating has been studied in the following sequence:

1. The powder coating of various compositions has been applied on steel plates Ст3 (150x60 mm in size), whereby it has been used in the form of metakaolin in the filler. The powder coating has been applied by electrostatic method according to ISO 1514:2016 using the spray gun Start 50.

2. The powder coating has hardened on sample plates in the polymerization oven at 200 ºC within 10 min.

3. The corrosion resistance of decorative and protective powder coatings using silicate fillers has been studied in the salt spray chamber with the condensation of 5 % of the sodium chloride (NaCl) water solution on the surface of samples within 720 hours at 35 ºC according to ASTM B-117. The average peeling and development of metal corrosion after testing have been determined according to the method DSTU ISO 4628-8:2012.

RESEARCH RESULTS

The composition of the powder coating has been prepared by mixing together dosed raw materials in wheel-type mixers and homogenizing the mixture (at 80...120 ºC) in thermostatic screw mixers (extruders), pressing the pasty mixture out the extruder, cooling it and breaking to pieces with special mills.

The content of the polyester resin (50 – 70 %), filler in the form of metakaolin or talc (0 – 40 %) as well as pigment in the form of titanium dioxide (10 – 20 %) have been selected as variation factors in the compositions of the powder coating above 100 % of the composition mass. Results of corrosion resistance tests for decorative and protective powder coatings are shown in the Fig. 1, Fig. 2.

Research results show that adding silicate fillers in the form of metakaolin and talc to the composition of the powder coating allows increasing corrosion resistance in general by decreasing the peeling width and metal corrosion width in comparison to the control composition. The effectiveness of use of metakaolin and talc depends on their content and polyester resin and pigment costs.

Adding metakaolin of 40 % to the composition of the powder coating contributes to the decrease in the peeling width from 18.25 mm (control composition) to 3.63 mm and in the metal corrosion width from 13.75 mm (control composition) to 4.2 mm when having polyester of 50 % and titan of 20 %. After the increase in the polyester resin in systems to 65 % when having metakaolin of 40 % the decrease in the peeling width to 2.75 mm and in the metal corrosion width to 2.6 mm is observed compared to the control composition. After the decrease in the pigment in the form of titanium dioxide to 10 % (Fig. 1) when having metakaolin of 40 % the peeling width and the metal corrosion width are 3.4 mm and 3.8 mm, respectively, while the peeling width and metal corrosion width in the control composition are 18.25 mm and 13.75 mm, respectively.

It should be noted that adding metakaolin of 20 % (Fig. 1) when having titanium dioxide of 10 % and resin from 45 to 65 % contributes to the smallest peeling width of 2.13 mm and to the low metal corrosion width of 1.38 mm, while the control system (without metakaolin) has the peeling width of 18.25 mm and the metal corrosion width of 13.75 mm. The corrosion resistance of coatings increases as a result of participation of metakaolin functional groups in the formation of strong interfacial relationships between the surface of the filler and molecules of the polymer matrix, which specifies the formation of the dense structure of the coating and increases operational properties of the material, respectively.

According to the results of testing, it has been established that developed compositions of the powder coating with the silicate filler in the form of metakaolin with its content from 20 to 30 % can be placed into the high atmospheric corrosivity category C4 'Industrial and coastal areas with the moderate salt content' according to ISO 12944-2:2017 having a high (H) lifespan from 15 to 25 years in accordance with DSTU ISO 12944-1, which confirms their high effectiveness.

When using the filler in the form of talc in the polyester powder coating (Fig. 2) it has been established that adding it in the quantity of 10 % contributes to the decrease in the peeling width from 18.25 mm (control composition) to 14.2 mm, whereby the decrease in the metal corrosion width from 13.75 mm to 9.8 mm is also observed. The increase in the talc content to 20…30 % in powder systems allows decreasing the peeling width to 10.37 mm and the metal corrosion width to 8.4 mm. After the increase of the talc content to 40 % the partial increase in the peeling width to 14.5 mm and in the metal corrosion width to 10.7 mm is observed; however, these values have decreased by 28 % and 35 %, respectively, compared to the control composition.

Thus, developed compositions of the polyester powder coating with the silicate filler in the form of talc of 20 % can be placed into the moderate atmospheric corrosivity category C3 'Urban and industrial atmosphere, moderate pollution with sulfur dioxide; coastal areas with the low salt content' according to ISO 12944-2:2017 having a high (H) lifespan from 15 to 25 years in accordance with DSTU ISO 12944-1, which also confirm their effectiveness.

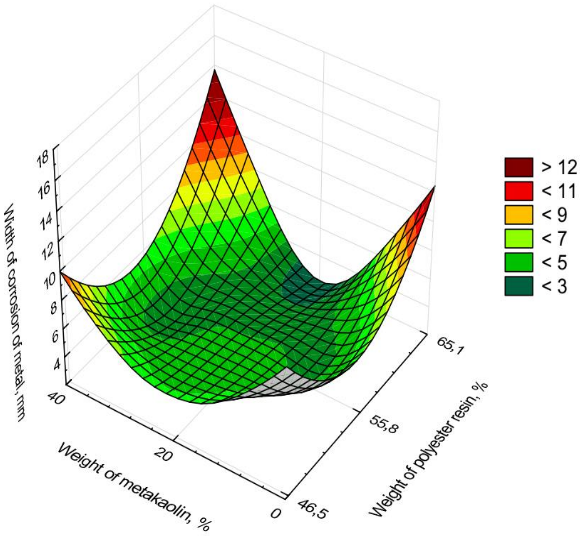

Fig. 1. Isoparametric diagram of change in the metal corrosion width using metakaolin in powder coating

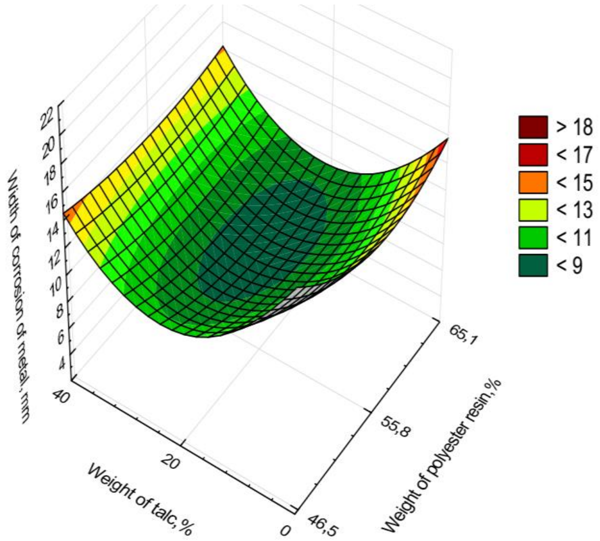

Fig. 2. Isoparametric diagram of change in the metal corrosion width using talc in powder coating

CONCLUSIONS

Thus, a study was conducted on the fire and bioprotection of paper and products made of it with an impregnating composition that can effectively protect against fire and biological degradation without compromising the aesthetic and performance characteristics of these materials, taking into account modern environmental requirements. According to the research results, we have obtained eco-friendly paint-and-varnishes coatings of high corrosion resistance based on powder coating containing silicates as a filler in the form of metakaolin and talc. Using the mentioned range of fillers in the powder coating contributes to the decrease in the peeling width to 2.13 mm and metal corrosion width to 1.38 mm after testing in the salt spray chamber with the condensation of 5 % of the sodium chloride water solution and places obtained coatings into atmospheric corrosivity categories C3 and C4 according to ISO 12944-2:2017, which creates conditions for using these compositions in the context of the excessive corrosivity.

REFERENCES

1. **De Lange, P. A.** (2004). History of Powder Coating P. De Lange. Paint & Coatings Industry Magazine Available, Vol.2, pp.16 – 24.
2. **Richart, D.S.** (1990). Powder Coating – Past, Present and Future: A Review of the State of the Art, Powder Coating, Vol.1, pp. 16 – 24.
3. **Linak, E., Kishi, A., Yang, V.** (2008) Thermosetting Powder Coatings, SRI consulting, 20.
4. **Loar, D.** (1993). Proc.20th Int. Waterborne, High Solids & Powder Coatings Symp., New Orleans, Feb., 536.
5. **Al-Sherrawi M.** (2018). Corrosion as a source of destruction in construction International Journal of Civil Engineering and Technology, 306-314.
6. **Gots V., Lastivka O., Tomin O., Kovalchuk O.** (2019) Influence of film-forming components on the corrosion resistance of powder coating Tech Publications Ltd, Switzerland 143-152.
7. **Spyrou V. E.** (2004). Powder Coatings - Chemistry and Technology. European Coatings Tech Files 3rd, 384.
8. **Puig M., Gimeno J.** (2018). Anticorrosive Properties Enhancement in Powder Coating Duplex Systems by Means of ZMP Anticorrosive Pigment Assessment by Electrochemical Techniques 1993-1999.
9. **Golterova T, Obukhova** (2018). Problem problems of economics of design and construction Scientific herald of construction 284-288.
10. **Gots V. I., Lastivka O. V., Tomin O. O., Tymoshenko S. A**. (2020) Fillers for modification of polyester powder coating. Materials Science and Engineering. – Innovative Technology in Architecture and Design 6.
11. **Tager A. A., Askadsky A. A.** (2007). Physical chemistry of polymers Scientific world, 573.

Ефективність використання порошкових покриттів для захисту металевих констукцій

Олесь Ластівка

Анотація. Сучасний стан розвитку економіки України обумовлює вирішення низки актуальних питань, пов’язаних з удосконаленням виробництва та підвищенням рівня екологічної безпеки продукції, зокрема лакофарбових матеріалів, у поєднанні із забезпеченням високих експлуатаційних властивостей покриттів на їх основі. Вирішити це питання можна за рахунок розширення виробництва з використанням екологічно чистого порошкового фарбування. Зростання популярності порошкових фарб можна пояснити їх екологічною відповідністю та привабливістю з точки зору захисту навколишнього середовища, а також високою ефективністю, пов’язаною з можливістю отримання високоякісних захисно-декоративних покриттів з високою корозійною та хімічною стійкістю, а також контрольовані фізико-механічні та діелектричні характеристики при одношаровому нанесенні. Аналіз результатів досліджень показує, що ефективність використання метакаоліну і тальку як наповнювачів у порошковому покритті зростає пропорційно їх вмісту в системі. Оптимальна площа порошкового покриття метакаоліном і тальком обмежена добавкою в діапазоні від 20 до 30 % і поліефірною смолою в діапазоні від 55 до 65 %. Використання зазначеного ряду наповнювачів у порошковому покритті сприяє зменшенню ширини відшаровування та ширини корозії металу та відносить покриття до категорій атмосферної корозійності С3 та С4 згідно з ISO 12944-2:2017 з високим (H) терміном служби від 15 до 25 років згідно з ДСТУ ISO 12944-1. При цьому одним із найпоширеніших методів впливу на властивості лакофарбових покриттів є створення полімерних композитів шляхом поєднання поліефірної сировини з неорганічними наповнювачами.

Ключові слова: порошкове покриття, тальк, метакаолін, полімер, стійкість до корозії, ширина відшаровування, ширина корозії металу.