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Research paper

Improving the Quality of Protective Silicate Coatings of Metal Surfaces

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Abstract

Reducing the chalking degree of protective and decorative silicate coatings of metal surfaces is achieved by increasing the free surface energy of the fillers by grinding them. The effect of surfactants on increasing the adhesive mechanical strength was confirmed.The increase in the dispersion of fillers (iron (III) oxide and chalk from 8–10 µm to 1–3 µm leads to a significant increase (~ by 2 orders of magnitude) of chalking index of protective-decorative silicate coatings for metal surfaces. It is shown that the introduction of a high content of latex and liquid glass into the formulation reduces the chalking index only ~ 2 times. The effect of anionic surfactants of polyethylene glycol sulfoethoxylates on the increase in wetting and adhesion effects, which is the result of the increased mechanical strength of fireproof and environmentally friendly coatings, was confirmed.

Keywords: *silicates, dispersion, chalking, surface-active substances, free surface energy.*

1. Introduction

Known methods of protecting metal structures and machine parts from corrosion, such as electroplating, metal spraying, galvanizing and anode protection, are associated with considerable material and energy costs, and toxicity and fire hazard of organic film-forming paint and varnish coatings does not allow this direction to consider as promising from the environmental point of view [1]. Therefore, given the environmental factor, it is more appropriate to use film formers on an inorganic basis, which, in addition to high environmental friendliness, have a lower market value. Such materials include lime, lime-cement and silicate coatings. The latter are of the greatest interest, since the main component of their liquid sodium or potassium glass is capable of quickly forming a protective solid film when applied to surface [2]. However, these silicate coatings are mainly used for coating on ceramic surfaces: concrete, brick, plaster, asbestos cement, etc. [3-7]. No information was found on high-quality silicate coatings of metal surfaces in the literature. Therefore, the authors have developed a formulation of a protective and decorative coating on metal surfaces [1]. It is shown that the increase in the mechanical strength of the silicate coating is achieved by introducing into the formulation of ~ 12 wt. % sulfoethoxylates, and ~ 15 wt. % of styrene-latex butadiene, and an increase in moisture resistance is achieved by introducing ~ 7 wt. % of polymethylsiloxane [1].
The quality characteristics of protective and decorative coatings in general and silicate in particular, are determined not only by mechanical strength and moisture resistance, but also by such indicators as spreadable life, opacity, viscosity, frost resistance, durability, fire resistance and absence of chalking. Of this list of indicators, chalking is a more important quality characteristic, since coatings with increased chalking are branded, that is, prone to abrasion and therefore not durable.

In order to clarify the effect of the ingredients of the coating formulation on the index of chalking, the corresponding experiments described below were carried out.

2. Source Materials and Research Methods

2.1 Raw materials

Dispersed commercial chalk produced by CJSC "BelselzkhozInvest".

1. Iron Oxide Fe_2O_3 (Temporary Technical Conditions RU-1059-56).
2. Liquid potassium glass produced by OJSC Russian Magnesium. Silicate module is 3.99; density is 1.24 g / cm ^{2}.
3. Latex SKS -65 GP (GOST 10564-63).
4. Sulfoethoxylates were synthesized by sulfoesterification of polyethylene glycols by the method of E.N. Voulach [8].
5. Polymethylsiloxanes (Russian Technical Conditions 6-02-326-65).

2.2 Research methods

The dispersed industrial chalk filler and pigment iron (III) oxide Fe_2O_3 were ground in a ball mill and classified (sorted) with regard to particle size according to GOST No. 12.536-79 (Laboratory methods for determining the grain size (grain) and microaggregate composition) by taking samples from a specific depth of the aqueous suspension after a certain time interval [9].
The particle size of each fraction was determined with the use of a laser particle size analyzer LS13320 (BECKMAH COULTER) by means of laser diffractometry in combination with recording the differential intensity of polarized light.
The coating was prepared by mechanical mixing of the initial ingredients in a mortar. After applying the prepared coating on a metal plate (substrate) (St.5 grade steel, GOST 380-71) and expir-

ing of a residence time of a day, the tests have been carried out for mechanical strength and chalking rate.

Tests on the mechanical strength of the coating were carried out by repeated bending of the substrate (with a cured coating) at a right angle up to the destruction (peeling) of the coating. For this purpose, cuts to a depth of ~ 5 mm were made from the side edges of the substrate (plate). Next, the plate was clamped in a vice along a straight line between the cuts on it, and the free upper half of the plate was clamped in a clamp with which the bends were made.

The essence of the method for determining chalking of coverage according to GOST 19.976-71 [10] consisted in sequential imposition on the same place of the chalking coating being under load of 20 kg of photographic paper on which particles of the pigment printed on it were visible to the naked eye. The imposition continued until the visible pigment particles remained on the photo paper.

3. Results and Discussion

On the basis of experiments conducted by the authors earlier [1], it was found that to increase the adhesion strength of silicate coatings for metal surfaces, it is necessary to introduce sulfoetoxylates into the composition of the coating, in addition to potassium glass and fillers.

It was assumed that increasing the strength of the coating can also lead to a decrease in its chalking. For this purpose, experiments were carried out; their data are shown in Table 1.

Table 1: Effect of sulfoethoxylates on the quality of metal silicate coatings

No.	The composition of the formulation, wt. %						Test results	
	Potassium glass	Latex	Dispersed commercial chalk	Iron (III) oxide	Sulfoethoxylates, 10% solution	Water	Mechanical strength, the number of bends up to destruction of the coating	Chalking, number of prints on photo paper
1	15.4	10	34.7	15.4	-	24.5	4	8 hard
2	15.4	10	34.7	15.4	8.1	16.4	11	6-7, average
3	30.0	10	30.0	12.0	-	18.0	4	5-6, average
4	30.0	10	30.0	12.0	5.0	13.0	11	5-6, average
5	20.0	15	10.0	20.0	7.0	28.0	18	5-6, average
6	15.4	-	34.7	15.4	8.1	26.4	9	10, very hard

Indeed, the introduction of sulfoethoxylates to the formulation significantly increases the strength of the silicate coating, what can be clearly seen from a comparison of experiments 1 and 2: the introduction of a 8.1% solution of sulfoetoxylates with a concentration (0.81% based on 100% SAA (Surface active agent) increased the mechanical strength in 3.5 times. And if an additional amount of active filler of iron (III) oxide and latex is additionally introduced into such a formulation (by reducing the content of chalk and potassium glass), then the mechanical strength additionally increases from 11 to 18 bends (tests 4 and 5). This confirms the previously obtained experimental data [1].

Comparing the results of experiments 1-6, we can conclude that the introduction to the formulation of a coating with 10 wt. % latex and the increase in the content of liquid glass from 15.4 to 20-30 wt. % somewhat reduces the chalking of the hardened coating from 10 to 5-8 prints on photo paper.

To test this preliminary result, additional experiments were conducted with different content of liquid glass and latex. Experimental data are shown in table 2.

Table 2: The effect of liquid potassium glass and latex on the chalking index of the cured silicate coating on metal

No.	The composition of the formulation of the silicate coating, wt. %						Chalking, number of prints on photo paper	Mechanical strength, the number of bends to the destruction of the coating
	Liquid glass	Dispersed commercial chalk	Iron (III) oxide	Latex	sulfoethoxylates	Water		
1	10	42	20	10	8	10	9 hard	15-20
2	20	42	20	10	8	-	8 hard	15-20
3	30	37	15	10	8	-	6-8, average	15-20
4	50	27	5	10	8	-	3-4 weak	14-19
5	10	47	25	-	8	10	10 hard	13-16
6	20	47	25	-	8	-	7 hard	13-16
7	50	32	10	-	8	-	4-5, average	13-16

The increase in the content of liquid potassium glass from 10 to 50 wt. % allowed chalking of the coverage to reduce from 9 to 3-4 prints. However, this phenomenon took place against the background of the availability of 10 mass. % latex in the formulation (experiments 1-4). In the absence of latex (experiments 5-7), a decrease in chalking was still observed, but to a much lesser extent, from 10 to 4-5 prints. It should also be noted that the mechanical strength of coatings containing both latex and sulfoethoxylates is very high (15–20 bends until the coatings were destroyed, tests 1–4). While formulations containing only sulfoethoxylates with the presence of latex, the mechanical strength of the coating somewhat decreased (13–16 bends until the coating was destroyed, experiments 5–7).

The main conclusion from the data in Table 2 is that despite a significant reduction in chalking due to the introduction of latex into the formulation and an increase in the content of liquid glass to 50 wt. %, reducing of chalking degree was completely failed. But this figure in terms of high quality coating should be almost close to zero, that is, there should be no chalking.

Based on the above theoretical prerequisites, experiments were conducted to study the effect of dispersion (degree of chalking) of fillers and pigments on the chalking rate of the cured metal silicate coating. Experimental data are shown in table 3.

Table 3: The influence of the filler and pigment grinding degree on the index of chalking of the cured silicate coating on metal *)

No.	The average particle size of the fillers and pigments, microns		Test results	
	Dispersed commercial chalk	Pigment iron oxide (III)	Chalking, number of prints on photo paper	Mechanical strength, the number of bends to the destruction of the coating
1	8-10	12-15	7-8, hard	18-20
2	5-6	5-6	4-5, average	20-21
3	2-3	2-4	2-3 weak	22-24
4	1-2	2-3	0-1, missing	23-25

*) The composition of the coating formulation, mass.%: (1) - Liquid potassium glass - 30; (2) - Dispersed commercial chalk - 25; (3) - Iron (III) oxide - 22; (4) - Latex - 15; (5) - Sulphoethoxylates - 8.

As it follows from the theoretical justification, the increase in the dispersion of the chalk filler of the technical dispersion and pigment of iron (III) oxide allowed reducing to significantly the chalking of the coating. So, by reducing the particle size of the filler and pigment to 1-3 microns, it was possible to achieve a complete absence of chalking.

Also noteworthy is the fact that an increase in dispersity has a positive effect on the mechanical strength of the coating to the substrate. A decrease in the average size of solid particles from 8–10 µm to 1–3 µm made it possible to increase the mechanical strength index by about 1.2 times (experiments 1.4).

From the provisions of the theoretical foundations of physico-chemical mechanics, it follows that the liquid silicate coating is a dispersed structure in which solid particles of fillers and pigments (dispersed phase) are separated by liquid glass (dispersion medium). During the solidification of liquid glass and the phase transition, the liquid-solid system transforms into a dispersed solid-solid structure. At the same time, solid particles of fillers and pigments reinforce the entire volume of the disperse system. Durability against destruction (wearing-chalking) of such systems depends on the physico-chemical conditions of their occurrence and development, as well as the physical and chemical nature of the dispersion medium and the dispersed phase. However, ceteris paribus, the strength values vary from 10^4 N / m ^{2} for coarsely dispersed structures with coagulation contacts to about 10^7 –10^8 N / m ^{2} for highly dispersed structures with phase contacts [11–13]. Consequently, the theoretical foundations of the physicochemical mechanics that the high strength of a material is achieved primarily due to the high dispersion of the dispersed phase, since dispersion leads to an increase in free surface energy, have been justified [14-15]. The composition of this silicate coating of metal is patented by Belgorod State University [16].

4. Conclusion

The effect of sulfoethoxylates and latex on the increase in mechanical strength of protective-decorative silicate coatings for metal was confirmed.

Reducing the chalking level of these coatings can be achieved by increasing the free surface energy of fillers and pigments by their grinding.

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