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FEATURES OF THE IMPLEMENTATION OF CADMIUM-BASED ELECTROPLATING COATINGS

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Abstract. *Introduction.* The rapid economic, scientific and technical development of the Republic of Kazakhstan in order to achieve the modern level of technological development requires a wide production of metal products and equipment, using technically and economically effective methods. For this purpose, one of the main ways of producing corrosion-resistant and efficient metal products and parts is cadmium plating. Cadmium plating is flexible, easily amenable to rolling, stamping, bending. Freshly prepared sheathing is better welded on acid-free fluxes than zinc. *Goals and objectives.* A study of the technology of cadmium tape, made of stainless steel, grade 2X18H10T. A comparative analysis of the types and composition of cadmium electrolytes has been carried out. The factors affecting the quality of the resulting packaging are investigated, the calculation of the observed main indicators of products after electrolysis has been carried out. *Results.* Before coating the surface of metal products, geometric calculations of the surface of the coated products have been carried out, and their results have been processed to correctly select the density and current strength for a given operating mode. It has been established that the quality of the coating undergoes changes depending on the composition of the electrolyte, its temperature and current density. The surfactant has contributed to the production of a durable packaging layer with the possibility of increasing potency during use, including the work with such surfactants as dextrin, gelatin, carpentry glue. *Conclusion*. It has been shown that the cadmium-coated tape has no gloss unless a surfactant is used. It has been found that when the current is overvoltaged, the tape is covered with fine-grained granules and darkens. When the tape has been cadmated, the cadmium layer has deposited on the surface of the tape increasing with a time increase.

Keywords: electroplating coatings, cadmium plating, cadmium coating, metal products, electrolyte, surfactants, electrolysis, current density

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1. Introduction

The Republic of Kazakhstan is one of the most developed countries of galvanic production. The development of galvanic industries is high, as various coatings are used in order to protect metal products from corrosion. Cadmium coatings are in demand most of all for corrosion protection of steel parts, because cadmium is stable to corrosion in the atmospheric and marine conditions. Cadmium coatings are stable (especially in alkaline environments) and have different colors, as well as high ductility of the protective layer. The products for galvanic plating are usually contaminated with lubricants as a result of mechanical processing, and covered with oxides after heat treatment, or as a result of an atmospheric exposure.

Cadmium plating is a material deposition process that coats products with a thin protective layer of cadmium metal. Coatings are applied in several ways, including immersing receptacles in vials of cadmium salt solution through which an electric current flows. Cadmium plating processes involve mechanical and vacuum methods for smaller items and the transfer of highly uniform coatings. Cadmium is a popular coating material because it provides the products with high corrosion resistance, low friction coefficients and high degree of electrical conductivity. The use of cadmium coating material has been brought under strict control due to the environmental problems [1, 2].

Cadmied coating is a durable and versatile metallic coating. Cadmium is a soft white metal that acts as a “sacrificial coating”, which corrodes in front of the substrate material when applied on steel, cast iron, ductile iron, copper and powder metal. To increase the corrosion protection of the cadmium coating, chromate conversion coatings that give a golden color can be applied over the plated metal. Other colors are also available, such as an olive color [3].

Different types of cadmium plating compositions and processes are known, but many of them are not adapted for commercial use due to their existing cost or complexity of processing or difficulty in maintaining product uniformity. Galvanic coating always begins with the surface preparation, which is an integral part of the entire process, i.e. cleaning the surface of the coated products from fat and oxides [4, 5]. Thorough surface cleaning is an indispensable condition for the further galvanic operations.

2. Experimental part

An inexpensive and easy way to clean things before electroplating is to wash them in alkaline baths, containing hydroxides, carbonates, phosphates, polyphosphates, metasilicates, surfactants and detergents. Most of the cadmium coating is carried out in alkaline cyanide baths, prepared by dissolving (cadmium oxide in the sodium cyanide solution. Sodium hydroxide and sodium carbonate are formed as a result of reactions in the composition, and are part of them [6]. Cadmium balls suspended in steel wire meshes serve as cladding anodes. Sodium hydroxide has a high washability, but is aggressive to copper, zinc and aluminum alloys. Due to the possibility of silica formation in the parts to be cleaned, it cannot be used as an additive for electrolytic anode degreasing [7]. The composition of alkaline solutions for chemical degreasing is presented in Table 1.

Table 1 - Solution for electrochemical degreasing

Component, g/l	Type of solution		
	No.1	No.2	No.3
Sodiumhydroxide	200	-	35
Liquidglass	500	35	-
Sodiumphosphate	280	15	14
Anhydrouscarbonicacid	-	-	62
Humidifier	30	2	6

The solution No.1 is applied to steel and cast iron products. All components are dissolved in 0.6 L of water, and water is added to 1 L of volume. In practical use, the resulting concentrated solution should be diluted in the ratio of 1:10 to 1:30. Solution No.2 dissolves all components in 0.6 L of water and add additional water in a volume of 1 L. Solution No.3 is used for copper parts and its alloys. All components are dissolved in a small amount of water, and water is added in a volume of 1 L [8, 9].

In the course of experimental work, a tape made of non-oxidizing steel has been used according to the dimensions of the electrolyzer (tape of the brand 12X18H10T). The very first step in making work is to clean it with rat paper, the granules of which come in different sizes (coarse or fine). At first, the work has been carried out on processing products with coarse-grained rat paper. To completely eliminate large scratches on the surface of the product, the parts have been thoroughly washed with distilled water and degreased with sodium hydroxide. Later cleaned with a weak solution of sulfuric or hydrochloric acid. After processing, the tape has been dried in a desiccator and wrapped in white clean paper.

The degreasing process has been carried out in the presence of sodium hydroxide, with a current of 0.36 A/dm^2 for a period of 10 min. Electrochemical purification has carried out with sulfuric acid (H_2SO_4) with a current of 0.36 A/dm^2 in the presence of 20 min. In electrochemical cadmiling, the tapes made of non - oxidizing steel grade 12X18H10T have been used as cathodes (the total area of the tape is 8 cm^2). Graphite has been taken as an insoluble anode. Cadmium electrolyte containing cadmium salt, ammonium salt and various additives, such as NF dispersant, Carpenter's glue, undecylphosphinic acid diethanolamine salt, is known. The disadvantage of this electrolyte is that at the stage of formation of electrode plates of alkaline batteries, active materials exfoliate due to a dense smooth glossy precipitate.

3. Results and discussion

To prepare simple acid electrolytes, all components are dissolved separately in warm water, and galvanic baths are filled with water up to half. Later, the salt solutions are gradually added to it, after first carefully pouring sulfuric acid into it.

It is necessary to calculate the entire surface of the product to be coated, the formulas and values of the geometric calculation are presented in Table 2.

Table 2 - Geometric calculation formulas and values of the product surface

No	Formula			Values
1	Rectangle surface area	F = ab	F - area, sm^2 a - tape length, sm; b - tape width, sm.	8 cm^2
2	Rectangle face	S = 20P(a+b)/ab	S - surface area of the product, sm^2; P - product weight, g; a - tape length, mm; b - tape width, mm	23.968 cm^2
3	Weight of the metal to be coated	G = 10Saγ	G - weight of deposited metal, g; S - the surface to be coated, dm^2; a - thickness of the deposited metal shell, mm; γ - specific weight of the deposited metal, g/sm^3	6.183 g
4	Weight of the metal deposited at the cathode	P = CItη/100	P - weight of the metal deposited at the cathode, g; I - transmitted current strength, A; t -electrolysis time,hours; η- output by current	0.64 g
5	Volume of deposited metal	V = P/γ	P - weight of the metal deposited at the cathode, g; γ - specific weight of the deposited metal, g/sm^3	0.074 cm^3
6	Coating thickness	h = V/S	S - surface area of the product, sm^2	31 mk
7	Current density	ί = I/S	ί - current density, A/dm^2 I - transmitted current strength, A	0.36 A

The use of the proposed electrolyte allows you to give the surface of the product specific physical and chemical properties: to obtain good adhesion of the precipitate and its loose (porous) structure in a short exposure time. This makes it possible to obtain galvanic coarse-grained casings with a developed surface for use in the technology of manufacturing cadmium electrodes in nickel-cadmium lamellate alkaline batteries [10, 11].

The surface area of the product and any parts has been calculated in order to correctly select the current density and the required current strength during the installation of the operating mode before the metal bags. The area of the parts is first calculated separately and then summed up. The coating of the product or parts performs the task of obtaining a protective layer of metal of a certain thickness provided for by the technical specifications. It is also necessary to determine the time, required to obtain a precipitate of the same specific thickness, or the thickness of the precipitate, obtained at a certain time of electrolysis. To determine the effect of surfactants on cadmium coating, the applications that are not involved in the cathodic process, but have good electrical conductivity are added, to increase the electrical conductivity of electrolytes.

Salts of acid ions of the same name can be added to acidic electrolytes, and NaOH, KOH can be added to alkaline electrolytes. Weakly acid, neutral, and weakly base electrolytes include salts of alkaline or alkaline earth metals so that electroconducting applications do not alter the acidity of the electrolyte.

Since many electrolytes work in the known ph interval, the buffered applications are introduced for monitoring. Most often, boric acid, sodium acetate, acetic acid, etc. are used [12, 13]. By adding surfactants to the electrolyte during the cadmiling process, a high-quality, smooth product can be obtained. In the industrial conditions, the surfactants such as sintanol DS-10, gelatin, glue, DCU fixative, starch, op-10, dispersant NF-5, thiocarbamide are added to the electrolyte solutions. During this experiment, gelatin, dextrin and carpentry glue have been used.

The sedimentation rate of cadmium, depending on the cathode density and the dependence of the applied current at different current yields, is shown in table 3.

Table 3 - Cadmium sedimentation rate (mkm/hours) depending on the current output

Current density, Dk, A/dm^2	Current output, %					
	75	80	85	90	95	100
0.5	9.1	9.7	10.3	10.9	11.5	12.1
1.0	18.2	19.4	20.6	21.8	23.1	24.2
2.0	36.4	38.8	41.2	43.6	46.2	48.4
3.0	54.6	58.3	61.8	65.4	69.3	72.6
4.0	72.8	77.6	82.5	87.2	92.4	98,8
5.0	91.0	97.0	103	109	115	121
6.0	109.2	116.6	124.0	130.8	138.6	145.2
7.0	127.4	136.0	144.6	152.6	161.7	169.4
8.0	145.6	155.2	165.0	174.4	184.8	197.6
10.0	182.0	194.0	206.0	218.0	231.0	242.0

In all electrolytes, cadmium is present in a divalent form, and its electrochemical equivalent is 2.2 g/A hours. The sedimentation rate of cadmium varies depending on the current density of the cathode being used and the current output [14]. Further, the change in the structure of cadmium precipitates upon changing the current density is tracked.

Change in the current density in the electrolyte solution with 3 drops of dextrin solution:

1A/dm^2: a gray film is formed on the surface of the tape. A coarse-grained film is formed on the metal base, which is well integrated.

1.5 A/dm^2: a whitish-gray film is formed on the surface of the tape. The surface of the tape is coated almost evenly.

2 A/dm^2: a gray film is formed on the surface of the tape. The formed film is poorly fused to the surface of the tape, and the plate surface is flaky. Depending on the composition, temperature, mixing intensity of the electrolyte, the current density can be used in the interval of 0.5-5 A/dm^2. With an average approximate cadmium concentration of 20 g/l, the current density is 1.5 - 2 A/dm^2, with the cadmium concentration of 40 g/l, the current density is 3-4 A/dm^2. In the usual simple mode, the anode current density, which ensures a stable electrolyte composition, should not exceed 2 A/dm^2. Often the temperature is kept in the range of 20-35°C, but it can be increased, if necessary. The current output varies between 85-98%, which often corresponds to 90-95%. The output of cadmium in the electrolyte in terms of current increases if the concentration, temperature, and mixing intensity are increased. With an increase in temperature, a concentrated electrolyte is used, because the solubility of the initial components increases. Besides, the electrical conductivity of the electrolyte increases and the passivation of the anode decreases. All these factors require the use of high current densities. But, due to an increase in temperature, the processes of dissociation and diffusion increase, leading to a decrease in the cathodic potential of the sludge. The effect of temperature, combined with an increase in the current density, leads to the formation of fine crystal packs. At the temperature of 30ºC, a gray film with a metallic sheen is formed on the surface of the tape. This film is not well combined with the metal base, and covers only part of the tape. The temperature of 45ºC resulted in a gray color with a metallic sheen on the surface of the tape. The shell is not evenly coated. Well combined with a metal base. A dense, fine crystalline precipitate can be obtained with the high temperature at the current density and continuous mixing. Mixing is carried out with continuous or periodic filtration, as undissolved particles settle at the cathode with a convection flow, which leads to the formation of a poor-quality coating.

To control the quality of the coating, the first assessment is made, using daylight or artificial light, based on the appearance. Lighting should not be lower than 300 lk. According to the results of the appearance assessment, it can be attributed to one of the valid, defective, unsuitable groups. A part is considered defective if it is necessary to remove poor-quality packaging and carry out repeated planting, and if it is included in the above list of parts, which require complete processing without removing the packaging. Defective parts include the foci of corrosion, mechanical and other defects.

The corrosion resistance of a metal will depend on the ability to withstand chemical or electrochemical disturbances, caused by the environmental influences due to its transport. A more correct opinion on the corrosion resistance of parts can be obtained by testing under natural operating conditions. But it is not suitable for use in the industrial conditions due to the long duration of conducting such a sample. This is because in the production conditions, the 3 fast-performing test types are used. To speed up the test, it is necessary to mix the solvent, as well as hold the sample in the solution one by one. The principle of repeated removal of the sample into the solution is performed automatically in some installations.

The simplest and most affordable method for determining the corrosion resistance of metals in electrolytes is testing in an open container, which allows one to use most of the corrosion indicators. The samples are hung on a glass hook or nylon thread and tested by full, partial or alternating immersion in a stationary or mixed corrosive solution, through which air, oxygen, nitrogen or other gas passes. During testing, the samples of each metal to be tested are placed in a separate container. The model is sometimes mounted using a glass or plastic stand.

The thickness of the resulting galvanic coating is determined by the drip method, for which the solutions are gradually dripped onto the metal-coated product and dissolved by holding it for a certain period of time. The operation is performed by wiping the dripped areas with filter paper until an entire area of the base metal is visible. The drop method differs from the removal method by the fact that in the drop method the thickness of the coating in a certain area of the part can be determined. The disadvantage of this method is that for thick-layer coatings, such a test is carried out at the long intervals. The drip method is not suitable for measuring the thickness of the coating on the surface of complex shapes and small parts. This is because the solution flows without being caught during the drip period. Although this method is simple in terms of technical execution, it only gives errors when determining the thickness of a thin coating. For a coating with a layer thickness of 2 mm, the accuracy of this method is variable in the area of ±30%.

On the tape covered with a layer of cadmium, a solution of potassium iodide has been dripped every 30 s according to the results of the drip method, the thickness of the coating has been 31 microns.

In accordance with the state standard 9.303-84, cadmium-coated products are allowed to be used for protective purposes during the experiment.

4. Conclusion

A study has been conducted on the technology of cadmiling of stainless steel tapes of the 12X18H10T brand. A detailed description of the cadmiling process and metal products covered with cadmium coating has been presented, its technological features have been noted. A comparative analysis of the types and composition of cadmium electrolytes has been carried out. The factors affecting the quality of the resulting coating have been studied, and the calculation of the main observed indicators of the products after electrolysis has been carried out (surface area, metal weight, current density, volume of deposited metal, coating thickness, weight of deposited metal at the cathode, current density). It has been found that the quality of the coating undergoes changes depending on the composition of the electrolyte, its temperature and current density. The surfactant (dextrin, gelatin, carpentry glue) is able to increase the potential during the use, and has helped to obtain a strong coating layer. If the surfactant is not used, the cadmium-coated tape has no shine. It has been found that when the current is supplied in excess, the tape becomes coated with fine granules and darkens. In the process of cadmiling the tape, as the time value increases, the layer of cadmium deposited on the surface of the tape increases.

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КАДМИЙ НЕГІЗІНДЕГІ ГАЛЬВАНИКАЛЫҚ ҚАПТАМАЛАРДЫ ЕНГІЗУ ЕРЕКШЕЛІКТЕРІ

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Түйіндеме. *Кіріспе.* Қазіргі заманғы технологиялық даму деңгейіне қол жеткізу үшін Қазақстан Республикасының экономикалық, ғылыми-техникалық қарқынды дамуы техника-экономикалық жағынан тиімді әдістерді қолданып, металл бұйымдары мен құрылғыларын кеңінен өндіруді қажет етеді. Сол мақсатта коррозияға төзімді, әрі тиімді металл бұйымдары мен бөлшектерін өндірудің негізгі жолдарының бірі - кадмийлеу болып табылады. Кадмий қаптамасы икемді, жаншып қаптауға, штампылауға, бүгілуге жеңіл ұшырап, жаңадан түзілген қаптамалары мырышқа қарағанда қышқылсыз флюстарда жақсы дәнекерленеді. *Мақсат пен міндеттері.* 2Х18Н10Т маркалы болаттан жасалған тотықпайтын таспаны кадмийлеудің технологиясына зерттеу жүргізілді. Кадмий электролиттерінің түрлері мен құрамына салыстырмалы талдау жүргізілді. Алынатын қаптаманың сапасына әсер ететін факторлар зерттеліп, бұйымдардың электролизден кейінгі байқалатын негізгі көрсеткіштеріне есептеу жүргізілді. Қаптаманың сапасы электролиттің құрамына, оның температурасына және ток тығыздығына байланысты өзгеріске ұшырайтыны анықталды. *Нәтижелер.* Бұйымдардың беттік ауданын металмен қаптар алдында жұмыс режимін орнату барысында ток тығыздығын және қажетті ток күшін дұрыс таңдап алу үшін қапталатын бұйымның беттік ауданы есептеліп, кейін жиынтықталды.Қаптаманың сапасы электролиттің құрамына, оның температурасына және ток тығыздығына байланысты өзгеріске ұшырайтыны анықталды. Беттік активті зат пайдалану барысында потенциал арту мүмкіндігіне ие болып, берік қаптама қабатын алуға септігін тигізді. Соның ішінде декстрин, желатин, столяр желімі сияқты беттік-активті заттармен жұмыс жасалды. *Тұжырымдар.* Беттік-активті зат қолданылмаған жағдайда кадмиймен қапталған таспаның жылтырлығының болмайтыны көрінді. Ток шамадан тыс берілген кезде таспа майда түйіршіктермен қапталып, қарайып кететіндігі анықталды. Таспаны кадмийлеу барысында уақыттың мәні артқан сайын таспа бетіне шөгілген кадмий қабаты арта түскені байқалды. МемСТ 9.303-84 сәйкес тәжірибе барысында кадмиймен қапталған бұйым қорғаныштық мақсатта қолданылуға рұқсат етіледі. Қаптаманың қалыңдығы қапталған бұйымға ерітінділерді біртіндеп тамшылатып, белгілі бір уақыт аралығында оны ұстау арқылы ерітуге негізделген. Тамшылату әдісінің нәтижесінде алынған қаптаманың қалыңдығы 31 мкм екені анықталды.

Түйінді сөздер: гальваникалық қаптамалар, кадмийлеу, кадмийленген қаптама, металл бұйымдар, электролит, БАЗ, электролиз, ток тығыздығы

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ОСОБЕННОСТИ НАНЕСЕНИЯ ГАЛЬВАНИЧЕСКИХ ПОКРЫТИЙ НА ОСНОВЕ КАДМИЯ

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Резюме. *Введение.* Для достижения современного технологического уровня, стремительного экономического и научно-технического развития Республики Казахстан требуется широкое производство металлических изделий и оборудования с применением эффективных с технико-экономической точки зрения методов. Для этого одним из основных способов получения коррозионностойких и эффективных металлических изделий и деталей является кадмирование. Кадмированное покрытие гибкое, легко поддается смятию, штамповке, изгибу, лучше паяется в некислотных флюсах, чем покрытия на основе цинка.*Цели и задачи.* Проведены исследования по технологии кадмирования детали из нержавеющей стали 2Х18Н10Т. Проведен сравнительный анализ типов и состава кадмиевых электролитов. Изучены факторы, влияющие на качество получаемого покрытия, рассчитаны основные показатели, наблюдаемые после электролиза. *Результаты.*Перед нанесением покрытия поверхности металлоизделий были проведены геометрические расчеты поверхности покрываемых изделийи обработаны их результаты, для правильного подбора плотностии силы тока при заданном режиме работы.Установлено, что качество покрытия меняется в зависимости от состава электролита, температуры и плотности тока. Во время использования ПАВ потенциал увеличился что способствовало получению прочного слоя покрытия. В качестве поверхностно-активных веществ были использованы декстрин, желатин, столярный клей. *Заключение.*Было обнаружено, что пластинка с кадмиевым покрытием не имеет блеска в отсутствие поверхностно-активного вещества, при чрезмерном употреблении тока металлическая пластинка покрывается мелкими вкраплениями и чернеет. При нанесении гальванического покрытия на основе кадмия отмечено, что слой кадмия, осажденный на поверхности пластинки увеличился по истечение времени. В соответствии с ГоСТ 9.303-84 допускается использование полученного в ходе эксперимента кадмированного изделия в защитных целях. Толщина покрытия основана на растворении покрытого изделия путем капельного метода с помощью растворов и выдержки в течение определенного периода времени. Было определено, что толщина покрытия, полученного в результате капельного метода, составляет 31 мкм.

Ключевые слова: гальванические покрытия, кадмирование, кадмированное покрытие, металлоизделия, электролит, ПАВ, электролиз, плотность тока

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