CHEMMOTOLOGY AND CHEMICAL TECHNOLOGY

UDC 621.924, 669.715, 6676

Sergey Levchenko[1]
Volodymyr Ledovskykh[2]

SPARK MACHINING FOR STEEL SURFACES TO IMPROVE PAINT COATINGS QUALITY

[1,2]National Aviation University
1, Kosmonavta Komarova ave., Kyiv, 03680, Ukraine
E-mails: [1]levsv72@uk.net; [2]lvm2014nau@gmail.com

Abstract. *Spark machining of steel surfaces enhances the subsequent paint coatings adhesion and protective properties. These factors improvement was confirmed at the salt-spray chamber testing and by both adhesion to the surface and depth of corrosion penetration below the paint coating layer measurements.*

Keywords: adhesion; corrosion protection of metals; electrical discharge preparation of metal surfaces; metal corrosion; paint coatings.

1. Introduction

Metal surfaces are treated with various methods such as mechanical, electrophysical and electrochemical ones. Electrophysical and electrochemical methods include: electroerosive, electrochemical, anode-mechanical, electrohydraulic, electron-ray, plasma-based, ultrasound, etc. [1,2]

In treating materials with electroerosion the energy of electrochemical discharges is used which develop between a tool and work-piece under applied potential difference. In terms of discharge generation a distinction is made between electrical discharge, electric impulse, and electric-contact machining.

In addition, the methods specified have a number of drawbacks related to high cost of equipment, considerable amount power consumption, limitedness of metalware's geometrical forms, etc.

2. Analysis of researches

Earlier we offered the electrical discharge and mechanical method to treat steel surfaces using electrical grinding machines and specifically designed lubricating-cooling fluids (LCFs) with synergistic action of the components. Application of the latter allowed to reduce power consumption by 30-35 % and uplevel the surface cleanliness by 3 points. This can be achieved by SAA adsorption that leads to energy reduction of metal surface layers and facilitation of their mutual displacement and elimination of micro cracks in the course of being machined (Rehbinder effect). Along with the SAAs the process LCFs also contain component compositions of inhibiting agents of synergistic action, which ensure protection for steel surface against corrosion when being prepared [3-7].

At the same time the tests accelerated in the SSC-1 salt-spray chamber showed moderate corrosion inhibiting effectiveness of electrical discharge machining when protecting metals after being treated. To prolong the period after being treated we offer electrical discharge machining of steel surfaces with a galvanised wire wheel, which allows formation of Zn protective cells on the metal surface [8]. One might assume that the process specified will also facilitate improvement of the properties of paint coatings that are surfaced on the metals that have been prepared this way.

Purpose – to determine the influence of steel electrical discharge and mechanical machining on paint coating adhesion and protective properties, and also access efficiency from combining both methods for corrosion protection of metals (protective and coating ones).

3. Protective paint coatings

Paint coatings belong to the most commonly used and effective methods to protect metals against corrosion [9-12]. Paint is a homogeneous suspension of pigments and their compositions including fillers in filming agents, which, after being dried, converts to a non-transparent coating. Film-forming solutions make an important part of paint systems and determine their physical and chemical properties. They include: alkyd resins, i.e. the polyethers which are obtained through the interreaction of polyalcohols (ethylene glycol, glycerine, etc.) with polybasic acids (phthalic acid, isophthalic acid etc.); amino acids (amino-formaldehyde and melamine-formaldehyde ones); vinyl resins, i.e. the products of polymerization of compounds with vinyl groups (copolymers of vinyl acetate and vinyl chloride, etc.); nitro-cellulose, which is used to make durable and quick-drying paints; epoxide resins, i.e. high-molecular weight polyatomic alcohols with epoxide groups at the ends, and which prior to their use are cured with aliphatic polyamines, polyamides or other amino compounds.

Application of paint coatings requires surface cleaning and preparation to ensure the quality needed. Improper preparation of surface and presence of various contaminants (sand, grease, oil, etc.) results in development of defects in paint coatings. The corrosion products, i.e. rust and scale, remnants of old coatings, etc. can have a negative impact on them. Loose oxide films on the steel surfaces can be pervious to moisture and contain conducting electrolyte solution which participate in initiation and development of electrochemical corrosion of metals. Cleaning of metal surfaces ensures a close contact of the paint coating with metal, its perfect adhesion, durability, and paint coatings.

Paint films are not proof against water and oxygen, consequently they are practically unable to prevent steel corrosion by way of moderation of cathode oxygen reduction:

$$O_2 + 2H_2O + 4e^- = 4\ OH^-$$

Anode reaction of metal corrosion damage:

$$Fe = Fe^{2+} + 2e^-$$

can be moderated by negative offset of electronic potentials using cathodic protection. Usually it is made of special pigments that are made component of paints. Compared to iron, more active metals are used, i.e. zinc dust [12].

Our study shows that Zn protective cells can be coated on the steel surface simultaneously with its preparation using the electrical discharge method [8]. This made necessity to determine the influence of the technology proposed on the paint coatings' properties and which is considered in this paper.

4. Experimental

To prepare the steel surfaces with electrical discharge and mechanical methods we used a TCM1-150 electrically driven polishing machine with a rotating wire wheel. We used the X1849 steel wire wheels with zinc coated spears (a zinc coating is 200 microns thick) to provide simultaneous application of Zn protective cells on the steel surface when it is being machined. The process liquid was fed into treatment zone including the surface active and inhibiting components [7]. Between the steel sample and wire wheel tool we applied the difference of potentials (steel — cathode, polishing machine — anode).

To compare the various methods of steel surface preparation that influence the quality of paint coatings we have undertaken the studies as follows. We prepared the steel samples conditioned in a sandblast cleaner, electrical discharge methods using a conventional and Zn-coated wire wheel, and then we applied paint which had been preliminary prepared by way of blending the Ticurilla Termacout TM-40 epoxide component adding a hardener. We applied 4 layers resulting in the overall thickness of 200 microns as required by GOST 9.032-74. The process was controlled by a paint thickness gauge (K-5 constant). We used an adhesiometer to measure their adhesion to the steel surface and determine the force which is required to tear the coating off the protected surface at the direction which is perpendicular to the coating area using the glued metal disk and dynamometer (according to DSTU 4219-2003).

To conduct accelerated tests on the steel corrosion resistance and paint coatings' protective properties we used KST-1 salt-spray chamber. We chose a testing method under increased values of relative humidity and temperature induced by sulphur dioxide and periodic moisture condensation (according to GOST 9.308-85). In order to assess the depth of corrosion penetration below the coating we manually damage it on some of the samples. Duration of exposure in the chamber amounted to 168 hours.

5. Results and discussion

The study showed that paint coatings' adhesion depends very heavily on the method of steel surface preparation. We provided the comparison measurements of this value for the machining of steel surface by the sandblast and electrical discharge method using the conventional and Zn-coated rotating wire wheels before and after the accelerated tests of the samples in the salt-spray chamber that lasted for 168 and 720 hours. The results are shown on Fig 1.

Fig. 1 shows that for steel samples treated with different methods the initial values for paint coating adhesion are at the short range and make up 12.2 MPa (the sandblasting method), and 11.95 and 12.0 MPa (the electrical discharge method with the conventional and Zn-coated wire wheel, respectively). The advantage of electrical discharge and mechanical machining can be seen during the tests of the surfaces in the salt-spray chamber,

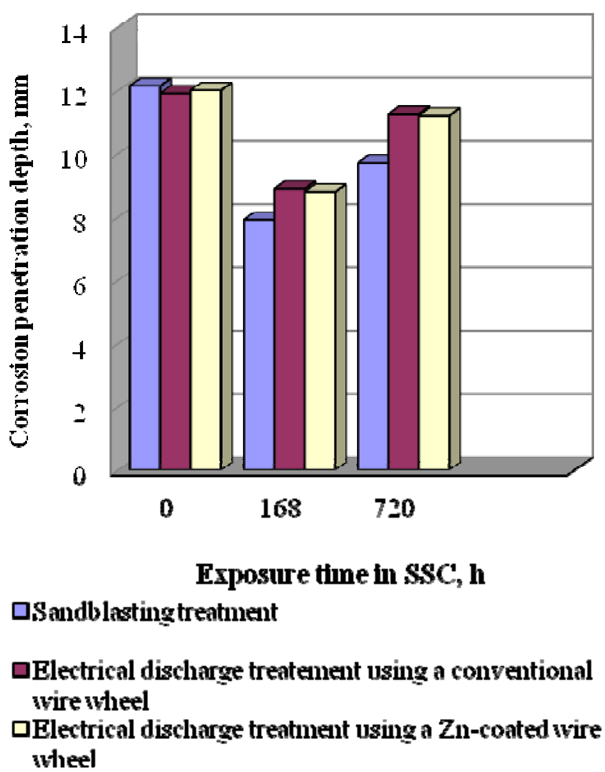

Fig. 1. Adhesion of Ticurilla Termacout TM-40 paint coating (thickness of 200 microns) to the St.20 steel surface depending on the method of metal surface preparation and exposure duration in the salt-spray chamber.

moreover this advantage tends to rise with the exposure time increase. Thus, after exposure of the samples in the SSC during 168 hours the adhesion increases from 7.9 to 8.9 MPa (in case of the sandblasting method) and from 7.9 to 8.8 MPa (in case of the electrical discharge method with the conventional and Zn-coated wire wheel, respectively). We also obtained the similar relations when measuring the paint coating adhesion to steel, treated with various methods when exposed the samples in the SSC during 720 hours (9.7 MPa and 11.25 MPa, and 11.23 MPa, respectively).

In order to obtain comparative values for effectiveness of electrical discharge and mechanical surface preparation we studied the corrosion penetration depth in relation to the samples with the manual damages of paint coating 5 mm in diameter after being exposed in the CSS for 168 hours. Fig. 2 shows the averaged values of corrosion penetration depth below the paint coating.

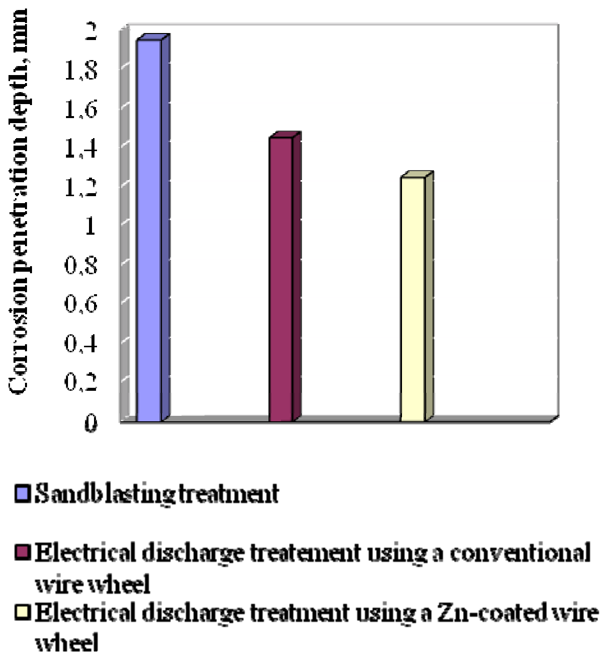

Fig. 2. Corrosion penetration depth below the Ticurilla Termacout TM-40 paint coating depending on the method of St.20 steel surface preparation prior to its application.

In accordance with GOST 9.401.91 the samples where the corrosion penetration depths below the paint coating is lower than 2 mm are considered to pass the corrosion resistance tests. The samples treated with the sandblasting had 1.95 mm corrosion penetration depth, the samples treated with electrical discharge using a conventional wire wheel had 1.45 mm corrosion penetration depth and the in ones treated with Zn-coated wire wheel it equalled to 1.25 mm. The results obtained show considerable increase in protection against corrosion efficiency in case of paint and Zn protective coating combination.

6. Conclusions

The electrical discharge and mechanical method of steel surface preparation allows to improve protective properties of paint coatings which is confirmed by the study of anticorrosion properties of epoxide surfaces in the salt-spray chamber, measurement of adhesion and corrosion penetration depth.

Using the Zn-coated wire wheel and subsequent application of the paint coating we obtained particularly high values due to the reciprocal gain effect between Zn-cathodic electrochemical protection and paint coating.

References

[1] *Popilov D.Ya.* Electrophysical and electrochemical handling materials : Reference book – 2nd ed. / D. Ya Popilov – M .: Mechanical Engineering, 1982. – 400 p. (In Russian).

[2] Handbook of electrochemical and electrophysical methods of processing / G.L. Amitan, I.A. Baysupov, U.M. Baron and others. // Ed. Volosatova V.A. – L .: Mechanical Engineering, 1988. – 719 p. (In Russian).

[3] *Levchenko S.V.* Electrochemical aspects of surfactants on the surface of the steel pipe with electric spark processing / S.V. Levchenko, S.G. Polyakov, V.M. Ledovskykh // Proceedings of the National Technical University "HPI". 2005. N6. 96-99 pp. (In Ukrainian).

[4] *Ledovskykh V.M.* Thermodynamic aspects of the development of inhibitory methods of protecting steel from corrosion in water-salt medium / V.M. Ledovskykh, S.V. Levchenko // Proceedings of the the National Aviation University. 2008. – N 4. 126-131 pp. (In Ukrainian).

[5] *Levchenko S.V.* The corrosion resistance of steel in its electric-spark processing / S.V. Levchenko V.M. Ledovskykh, S.G. Polyakov // Materials III International scientific conference "Problems of himmotology." – K .: NAU. 2010. 149-152 pp. (in Russian).

[6] *Ledovskykh V.M.* Extremums synergistic mixture of corrosion inhibitors metal in aqueous-salt solutions / V.M. Ledovskykh, S.V. Levchenko, S.M. Tulayinov // Physico-chemical mechanics of materials. 2013. N 6. – 107-111 pp. (in Ukrainian).

[7] *Ledovskykh V.M.* Method of surface treatment of steel / V.M. Ledovskykh, S.G. Polyakov, S.V. Levchenko, M.B. Stepanov // Patent of Ukraine №67694 of 13.032013. – Bull. №5. (in Ukrainian).

[8] *Ledovskykh V.M.* Method of sacrificial protection of steel from corrosion / V.M. Ledovskykh, S.V. Levchenko, V.I. Skoropad // Patent of Ukraine №94182 from 10.11.2014.- Bull. №21. (In Ukrainian).

[9] Sanzharovsky A.T .. Physical and mechanical properties of polymeric and paint coatings / A.T. Sanzharovsky – M .: Chemistry. 1978. – 183 p. (In Russian).

[10] Shampete G. Chemicals varnishes, paints and pigments. / G. Shampete, G. Rabate; In 2 tom. // Trans.. with fr. ed. A.A. Belovitskogo. – M .: Goskhimizdat, 1960. – 584 p. (In Russian).

[11] Drinberg A. Ya Technology of film forming agents: natural and synthetic resins, varnishes, lacquers and paints. / A. Ya Drinberg. – 2nd ed. – L.: Goskhimizdat, 1955. – 652 p. (In Russian).

[12] Corrosion. Handbook / Ed. Schreyer L.P. – Trans. from English. – M .: Metallurgy, 1981. – 632 p. (In Russian).

Received 01 September 2015.

С. В. Левченко[1], В.М. Ледовських[2]. Застосування електроіскрової обробки сталевих поверхонь для підвищення якості лакофарбових покриттів

Національний авіаційний університет, просп. Космонавта Комарова, 1, Київ, Україна, 03680

E-mails: [1]levsv72@uk.net; [2] lvm2014nau@gmail.com

У роботі використовувався електроіскровий метод підготовки сталі електричними шліфувальними машинами із застосуванням технологічних рідин, які містять синергічні суміші ПАР і інгібіторів. Також проводилась обробка оцинкованими щітками, під час якої цинк переходив на поверхню металу і створював осередки протекторів. Показано, що поєднання протекторного захисту з інгібіторами і лакофарбовими покриттями характеризується нададетивністю. За рахунок цього досягається підвищений ефект інгібування корозії сталі, підвищення адгезії і захистних властивостей лакофарбових покриттів.

Ключові слова: адгезія; електроіскрова обробка; інгібітори; лакофарбові покриття; нададетивність; поверхнево-активні речовини (ПАР); протекторний захист.

С. В. Левченко[1], В.М. Ледовских[2]. Применение електро-искровой обработки стальных поверхностей для улучшения качества лакокрасочных покрытий
[1,2]Национальный авиационный университет, просп. Космонавта Комарова, 1, Киев, Украина, 03680
E-mails: [1]levsv72@uk.net; [2] lvm2014nau@gmail.com

В работе использовался электроискровой метод подготовки стали электрическими шлифовальными машинами с применением технологических жидкостей, которые содержат синергические смеси ПАВ и ингибиторов. Также проводилась обработка оцинкованными щетками, во время которой цинк переходил на поверхность металла и создавал области протекторов. Показано, что совмещение протекторной защиты с ингибиторами и лакокрасочными покрытиями характеризуется нададетивностью. Благодаря этому достигается повышенный эффект ингибирования коррозии стали, повышение адгезии и защитных свойств лакокрасочных покрытий.

Ключевые слова: адгезия; ингибиторы; лакокрасочные покрытия; нададетивность; протекторная защита; поверхностно-активные вещества (ПАВ); электроискровая обработка.

Levchenko Sergey (1987). Candidate of Engineering. Lecturer.
National Aviation University, Kyiv, Ukraine.
Education: Chernihiv State Pedagogical Institute, Chernigiv, Ukraine (1994).
Research area: development of technological liquids for the steel parts electric and mechanical processing aiming to protect it against corrosion in neutral water-salt mediums..
Publications: 16.
E-mail: levsv72@uk.net

Ledovskykh Volodymyr (1939). Doctor of Chemical science. Professor.
National Aviation University, Kyiv, Ukraine.
Medals of the USSR (1974, 1980, 1984), "Veteran of Labor" (1988), an honorary sign "For the best student scientific work of the USSR" (1963), "Inventor of the USSR" (1982), "Excellence in Education of Ukraine" (1999) .
Education: Kyiv Polytechnical Institute, Kyiv, Ukraine (1962).
Research area: development of highly efficient various purposes surfactants directional synthesis foundations; its use for metals protecting from corrosion, for metals machining and electrodeposition, modification of petroleum and lubricants.
Publications: 150.
E-mail: lvm2014nau@gmail.com