Protection of metal products from corrosion by means of plasma-electrolytic processing of its surface

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Abstract
Results of application of plasma-electrolytic processing when cleaning and application of coating for protection of steel products from corrosion are explained in the paper. The conducted researches specified a possibility of change of corrosion non-resistant materials into a class of resistant ones. The obtained results of the comparative analysis of properties of zinc coverings show that the new type of covering has essential advantages in comparison with the coverings obtained by hot (from melt) and galvanic methods. Namely, it provides achievement of the specified application properties of covering at its smaller surface density that makes it possible to economize the scarce non-ferrous metals used for coverings.
Key words: PLASMA-ELECTROLYTIC PROCESSING, ELECTRODISCHARGE PLASMA, CORROSION RESISTANCE, ELECTRIC POTENTIAL, CORROSION RATE, PERMEABILITY, SURFACE DENSITY, NON-PRESSURE WELDING, PRESSURE WELDING

Introduction

Protection of metal from corrosion is one of the relevant problems of the modern industry. For protection from manifestations of corrosion corrosion-resistant grades of steel are created and various protective coatings are applied. Plasma-electrolytic processing is a perspective alternative to the existing methods of protection against corrosion [1]. Being ecologically safe, this technology can be used for cleaning of metal surface [2, 3], applying of protective coatings, and also in the combined processes of cleaning and applying of coverings [4-7]. It is considered resource-saving as it gives an opportunity to reduce significantly the capital costs of means and production areas by creation of compact aggregates for its implementation.

Research methods

Researches on efficiency evaluation of application of plasma-electrolytic processing for protection from corrosion are conducted under the leadership of Professor V. L. Steblyanko within development of innovative activities of higher education institution in Laboratory of layered composites and coverings of Nosov Magnitogorsk State Technical University [8].

Quality control of surface treatment was performed by the size of its electric potential [1]. It is directly connected with many fundamental physical and chemical characteristics reflecting an energy condition of substance and its structure. Use of electric potential as integrated evaluation and accounting of interrelation of this parameter with other physical values such as energy of activation of self-diffusion, electronegativity, isobaric and isothermal potential gives the chance to evaluate systemically the surface condition. By means of the measured potential, it is possible to control corrosion resistance. It is known that resistance of corrosion increases with growth of potential [9].

Evaluation of corrosion resistance of the samples made of low-carbon grade of steel cleared from scale by plasma-electrolytic method was performed according to results of their holding within six months in the medium with 100% humidity. Samples with high electric potential zones (310-380 mV comparing with nickel electrode) and with significantly smaller potential zones (130-180 mV comparing with nickel electrode) were put on trial. The size of electric potential in samples was from 40 to 80 mV before plasma-electrolytic processing. Observed significant change of surface potential as a result of plasma-electrolytic processing is due to high-quality removal of scale from the surface, as well as modification of surface layer.

For comparison of corrosion resistance of the samples subjected to different ways of processing, the research on determination of rate of corrosion is conducted by gravitational method (by weight decrease after stay in 10% solution of sulphuric acid within certain time). For test, the raw samples and samples subjected to plasma-electrolytic processing, machining and chemical etching [1] were used.

As it has been noted earlier, plasma-electrolytic processing can directly be used for applying of coverings [4-7]. For research of protective ability of the coverings obtained by plasma-electrolytic way, comparative tests of samples with zinc covering created using this technology by hot and galvanic methods have been carried out.

Quality of zinc covering was estimated in accordance with GOST 792-67 "Low-carbon high-quality wire. Specifications" [10]. A measure of its estimation is the indicator of resistance of covering to its etch removal in solution of copper vitriol; it is equal to number of immersions of sample into this solution before emergence of sites covered with copper, which is not removed by rubbing with cotton wool or rag.

The protective capability of coverings was estimated in accordance with GOST 9.308-85 "The unified system of corrosion and aging protection. Metal and non-metallic inorganic coverings. Methods of accelerated corrosion testing" [11] (a test method in case of impact of neutral salt fog). Duration of testing was 720 hours.

Results of research and their discussion

The experiment on determination of corrosion resistance in the medium with 100% humidity has shown that areas with high values of electric potential were not subject to corrosion for the entire period of holding in the damp medium and have kept an original form, and within the first two weeks in zones with a low potential corrosion was formed did not gain further development.

The obtained results reflect objectively the interrelation of electric potential with quality of processing of surface and its corrosion resistance.

Comparative evaluation of corrosion resistance (Table 1 [1]) of the samples subjected to plasma-electrolytic processing, machining and chemical etching in 10% solution of sulphuric acid has allowed drawing of conclusion on impossibility of achievement of corrosion resistance comparable by level to corrosion resistance of samples after plasma-electrolytic processing with application of traditional methods of processing of metal surface.

Table 1. Results of determination of corrosion properties in case of various ways of processing of metal surface [1]

Type of processing	Rate of corrosion, $g/m^2 \cdot h$	Permeability, mm/year
Plasma-electrolytic processing	0,0197	0,022
Chemical etching	0,0470	0,053
Mechanical treatment	0,1530	0,172
Without treatment	0,8280	0,930

Application of electrodischarge plasma for processing of samples made of low-carbon grade of steel led to considerable reduction in the rate of corrosion and allowed changing them from the “law-resistant” group (7 points on scale of corrosion resistance in accordance with GOST 5272-68 "Corrosion of metals. Terms" [12]) to the “resistant” group (4 points), which also contains some grades of stainless and alloyed steel. In comparative evaluation of corrosion properties, the fact that the best results are achieved in case of implementation of ecologically safe technology is important.

Results of testing for quality of zinc covering are provided in Table 2[1]. Due to electrodischarge plasma, the covering of higher quality was obtained comparing with application of traditional methods. The obtained results allow drawing a conclusion that required high quality of zinc covering can be provided with covering of new type with significantly smaller surface density. It should be considered as the effective way of economy of scarce non-ferrous metal.

Table 2. Results of tests for quality of zinc covering [1]

Type of covering	Surface density, g/m^2	Number of immersions
Plasma-electrolytic	117	12

Hot	235	6
Electroplated	112	3

The improved quality of samples with plasma-electrolytic covering is explained by formation processes. As a result of influence of electrodischarge plasma on the processed surface, non-pressure welding of particles of zinc in places of micro-arcs connection takes place, and also pressure welding as a consequence of cavitation phenomenon, at which particles of covering are transferred in these zones. As a result, in covering the welded areas are formed. They are of discontinuous nature due to discretization of influence of electrodischarge plasma, and also owing to internal tension emerging in the course of formation of coverings. First of all, process of destruction of covering under the influence of solution of copper vitriol takes place between borders of these areas. Certainly, even higher resistance of covering can be achieved by increase in uniformity of welded areas.

Results of determination are presented in Table 3. Samples have passed the test (there is no corrosion of the basic metal). But at the same time, the area and rate of corrosion at electroplated coating was much higher, than at hot and plasma-electrolytic ones. Extent of affection by zinc corrosion (white corrosion) for plasma-electrolytic covering is much lower, than for a hot covering, but time rates of their corrosion differ not so significantly. It is due to the fact that depth of penetration of corrosion in case of plasma-electrolytic covering is higher, than for samples with hot covering. Plastic deformation of metal with covering can serve as a reserve of improvement of corrosion properties of plasma-electrolytic covering.

Table 3. Results of corrosion tests of samples with zinc covering [made by authors]

Type of covering	Extent of affection by white corrosion, %	Loss of weight per unit of area Δm, g/m^2	Corrosion rate K, $g/m^2 \cdot h$
Hot	11,6	25,8	0,036
Electroplated	32,4	72,5	0,101
Plasma-electrolytic	6,7	21,7	0,030

Conclusion

Results of the conducted researches show that plasma-electrolytic processing increases significantly corrosion resistance of steel and allows reduction of costs for steel products with protective coatings by means of economy of the non-ferrous metals used for coverings.

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