Resistance of the powder coatings obtained in the electrostatic field of the corona discharge to the static action of liquids

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Abstract. The results of an experimental study of the static action of liquids on polymer-powder coatings obtained in the electrostatic field of the corona discharge are presented. Epoxy, epoxy-polyester, polyester, polyurethane and silicone powder materials have been studied. It has been shown experimentally that epoxy-polyester coating EP111095G is resistant, while epoxy EX611434SG, polyester PD810119G, polyester PD510226G and polyurethane PD010186G coatings are relatively resistant.

1. Introduction

Electrostatic powder coating was first introduced to the finishing industry in early 1960s [1]. In recent years, the polymer powder coatings are widely used in various industries. Major application area is obtaining protective, functional and decorative coatings in the finishing industry. The electrostatic coating of powders for the finishing industry is an important and increasing commercial business [2].

Several ways of producing powder coatings are existing. The most often used at present is a method of applying powder coatings in the electrostatic field [3]. A large number of spraying devices both by tribostatic [4-5] and electrostatic methods have been developed [6]. The great advantages and most commonly used at present is the spraying of powder coatings with spray guns with external powder charging [2]. Often this method is called “the production of coatings in corona discharge plasma” [7].

Powder paints are multicomponent disperse systems consisting of solid particles – film-forming basis and air-separating medium [8]. The main advantage of powder coatings is the absence of solvents. Therefore, the physical, mechanical and dielectric properties of powder coatings are significantly higher than for paint and varnish materials, in particular, their protective properties [9].

There are two types of polymer powder coatings: thermosets and thermoplastics. For obtaining protective coatings in recent years in most cases, are used thermosetting polymer powders. These coatings are formed by fusion of the powder particles and further chemical transformations.

By type of film former, the most common thermosetting compositions are epoxy, polyester, epoxy-polyester, polyurethane and polyacrylate [10, 11].

In [12, 13] was proposed to use powder coatings for the protection and recovery of medical ultrasound sensors.

Ultrasound is the most popular method of non-destructive testing and diagnostics in various fields including medicine. In [14, 15] are shown results of research and development of new methods and equipment for non-destructive testing multiphase and biological objects.
Ultrasonic sensors are used for measurements and diagnostics in various liquids, aggressive gases and multiphase media (e.g., drilling mud, etc.). Thereby, it is important to use protective coatings that are resistant to contaminants and prevent the destruction of the sensor.

In the process of diagnosis liquid and solid objects, the close contact of the ultrasonic transducer with the test object is necessary. This requires to use different protective coatings and prisms. They prevent the damage of sensor and protect it from aggressive environments. Particularly in the medicine, copolymers of vinyl chloride and ethyl acrylate are applied. However, the protective coatings are abraded and are damaged, resulting in a failure of the transducer. To solve this problem, the applying of polymer powder coating in the electrostatic field are proposed [12, 13, 16, 17].

The main task of this work is to study powder coatings for resistance to aggressive liquids.

2. Materials and methods

For most tasks of ultrasound diagnostics and probing the frequency range 0.5-15 MHz is used. Ultrasonic vibrations in this frequency range provide sufficient resolution in the low-level vibration damping. In previous paper [17] was shown that the thickness of the matching layer the piezoceramic at these frequencies is 10-300 μm.

The studies [12] of polyether PD510226G (Inwer, Italy) and epoxy-polyether EP110022G (Inwer, Italy) powder coatings properties was showed the suitability of using this types of coatings to the surface of the ultrasonic transducers. Such parameters as impact strength, flexibility, adhesion, gloss, hardness and wear resistance was studied.

In this paper we studied powder coatings (Inwer, Italy): epoxy EX611434SG (blue, 5019), epoxy-polyester EP111095G (white, 9016), polyester PD810119G (grey light, 7035), polyester PD510226G (green, 6029), polyurethane PD010186G (colourless varnish), silicone PD208120MRT (black matte). Colours are indicated in brackets according to the RAL colour catalogue. All powder coatings meet safety requirements due to the absence of organic solvents and heavy metals.

The substrate samples for studies are chosen according to ISO 1514:2016. The steel plates with dimensions of 10×5×0.2 sm are used in this study.

The surface preparing process was discussed in [13] and it is carried out according to ISO 1513:2010. It should be noted that surface must be clean and dry.

Spraying the coating is carried out using a spray gun START-50 (Radar, Russia) with voltage minus 30 kV on the corona discharge electrode. The measurement of the potential electrostatic field during application polymer powder coatings on metallic substrates using different speeds of micro-particles and the distance to the substrate was carried out [18]. Spraying is carried out in the chamber of coating powder materials at the samples.

Experimental studies in [17] were shown optimum operating parameters of the system of homogeneous coating polymer powder coatings. Based on these data the following parameters are chosen: time of spraying – 6 sec., distance from gun to substrate – 15 sm., air pressure – 200 kPa. The homogeneity of the obtained coatings was shown in [19, 20].

Baking was carried out in a drying chamber. In this work, we used a drying chamber ES 4610 (Ekohim, St. Petersburg, Russia).

For polymer coatings based on epoxy and silicone resins, the rejection time is 15 minutes at 200 °C, based on polyester and polyurethane – 15 minutes at 180 °C.

There are several internationally recognised standards for assessing chemical resistance. All standards are grouped in section 87.040 Paints and varnishes of the International Organization for Standardization (ISO). Immersion method is described in the standard ISO 2812-1:2017, method using an absorbent medium in the ISO 2812-3:2017, spotting method in the ISO 2812-4:2017. In the Russian Federation, the standard GOST 9.403-80 “The uniform system of protection against corrosion and aging. Paint and varnish coatings. Test methods for resistance to static effects of liquids” is applied.

In this work, tests of coatings were carried out in accordance with GOST 9.403-80. The method B was used (with a high degree corresponds to ISO 2812-3:2017). In this method, 10 drops of liquid are
applied to a horizontally placed testing plate at a distance of 20 mm from the edge of the plate. The distance between the droplet centres should not be less than 20 mm. The tests were carried out for 1 hour under atmospheric conditions at air temperature (20 ± 2) °C and relative humidity (65 ± 5) %.

The following liquids were used for the tests: acetic acid according to GOST 61-75 (CH$_3$COOH), 8% solution; sulphuric acid according to GOST 4204-77 (H$_2$SO$_4$), 25% solution; acid hydrochloric in accordance with GOST 3118-77 (HCl), 25% solution; nitric acid according to GOST 4461-77 (HNO$_3$), 25% solution; sodium hydroxide according to GOST 4328-77 (NaOH), 3%, 5% and 10% solutions; sodium chloride according to GOST 4233-77 (NaCl), 5% solution; mineral oil according to GOST 20799-88 and petrol.

3. Experimental results and discussion

After the tests, the decorative and protective properties are determined by comparison with the control sample using a magnifying glass (change in gloss, shade, appearance of bubbles, peeling, wrinkling, corrosion, etc.). The physical and mechanical properties of the coating are also determined (adhesion, bending elasticity, impact strength). The coating is considered stable if after the tests all characteristics correspond to the initial values.

Table 1 shows the test results. The symbol "+" marks the resistance of the coating, the symbol "−", if there are changes in any characteristics of the coatings.

Table 1. Test results for coatings for resistance to liquids.

| Powder coating | CH$_3$COOH | H$_2$SO$_4$ | HCl | HNO$_3$ | NaOH | NaCl | Mineral oil | Petrol |
|----------------|------------|------------|-----|---------|------|------|-------------|--------|
| EX611434SG     | −          | +          | +   | −       | +    | +    | +           | +      |
| EP111095G      | +          | +          | +   | +       | +    | +    | +           | +      |
| PD810119G      | +          | −          | +   | −       | +    | +    | +           | +      |
| PD510226G      | +          | +          | +   | −       | +    | +    | +           | +      |
| PD010186G      | +          | +          | +   | −       | +    | +    | +           | +      |
| PD208120MRT    | +          | +          | −   | −       | −    | +    | +           | +      |

3.1. Acetic acid.
Influence of the 8% acetic acid solution did not cause any changes in all samples, except the epoxy coating EX611434SG. On this sample, there was an insignificant colour change, i.e. sombreness. Also, the gloss of the coating was changed. No changes in the physical and mechanical properties were observed in any sample. Also, no changes were observed on the metal substrate surface. Tests with less concentrated solutions were not performed.

3.2. Sulphuric acid.
Influence of the 25% sulphuric acid solution did not cause any changes in all samples, except the polyester coating PD810119G. On this sample, there was a small spot and the shine of the coating was changed. No changes in the physical and mechanical properties were observed in any sample. Also, no changes were observed on the metal substrate surface.

3.3. Hydrochloric acid.
Influence of a 25% hydrochloric acid solution did not cause any changes in all samples except the silicone coating PD208120MRT. There was a complete destruction of the coating. During the test, a chemical reaction occurred with the formation of gas bubbles. On the plate surface were formed traces of corrosion and rust. The remaining samples showed no changes in the in the physical and mechanical properties. Tests with less concentrated solutions were not performed.
3.4. Nitric acid.
Influence of the 25% nitric acid solution resulted in colour change of the EX611434SG epoxy coating. On the epoxy polyester coating EP111095G, no changes were detected. The sample of polyester coating PD810119G changed colour (yellowed). Gloss change occurred on the samples of polyester PD510226G and polyurethane PD010186G coatings. Changes in the physical and mechanical properties of the above samples were not observed, except for the sample PD810119G. This sample deteriorated all the physical and mechanical properties (adhesion, impact strength, flexural elasticity). No changes were observed on the metal substrate surface in any of the above samples.

The sample of silicone coating PD208120MRT was destroyed, rust formed on the metal surface.

3.5. Sodium hydroxide.
Influence of 3%, 5% and 10% sodium hydroxide solutions did not cause any changes in all samples except the silicone coating PD208120MRT. Also, in all samples, except PD208120MRT, no changes in the physical and mechanical properties and changes on the metal substrate surface were observed.

Influence of the 3% sodium hydroxide solution resulted in a slight peeling, 5% solution to a significant peeling, 10% solution to complete peeling of the PD208120MRT coating. Tests with more concentrated solutions were not performed.

3.6. Sodium chloride, mineral oil and petrol
Influence of the 5% sodium chloride solution, mineral oil and petrol did not lead to any changes in any sample.

4. Conclusions
The results of an experimental study of the static action of liquids on polymer-powder coatings obtained in the electrostatic field of the corona discharge are presented in this article. Epoxy, epoxy-polyester, polyester, polyurethane and silicone powder materials have been studied. It has been shown experimentally that epoxy-polyester coating EP111095G is resistant, while epoxy EX611434SG, polyester PD810119G, polyester PD510226G and polyurethane PD010186G coatings are relatively resistant.

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