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Experimental study of the polymer powder film thickness uniformity produced by the corona discharge

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Abstract. The results of an experimental study of the polymer powder film thickness uniformity are presented. Polymer powder films are produced by the electrostatic field of corona discharge. Epoxy and epoxy-polyester powder films with thickness in the range of 30-120 microns are studied. Experimentally confirmed possibility of using these coatings as protective matching layer of piezoceramic transducers at frequencies of 0.5-15 MHz.

1. Introduction
In recent years polymer powder coatings are widely used in various industries. Major application area is obtaining protective, functional and decorative coatings in the finishing industry [1].

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 [2]. Powder coating guns are widely used in industry for manual and automatic operations. Two types of gun are available: the triboelectric [3,4] and the corona gun [5]. Both techniques have some advantages and disadvantages.

In recent decades, electrostatic spraying techniques are used in such fields as pharmaceutical [6] and food [7]. Corona discharge plasma is widely used in different branches of industry and manufacturing, in particular for the surface modification [8].

Electrostatic powder coating was first introduced to the finishing industry in 1962. Since then are developed many types of guns: conventional corona guns, low-voltage (EGD) guns, electrokinetic gun, cyclo gun, edge effect guns [9]. All these guns can be classified into two types: with external and inner powder charging. The most perspective and have the greatest advantages is conventional corona guns.

Conventional corona guns are versatile and cater for a wide variety of workpieces of different shapes and sizes. An air flow, which must be carefully regulated, conveys powder via a diffuser and through a region rich in ions from a corona electrode. Ion attachment occurs to a proportion, but by no means all, of the particles so that the grounded workpiece is bombarded by charged particles, ions and even some uncharged particles. Negative corona charging is normally used [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 powder 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.

The main source of ultrasonic vibrations are electromechanical transducers based on piezoelectric materials. Despite the appearance of new piezoelectric composite materials and various polymer piezoelectric films the most common materials remain barium titanate (BaTiO$_3$) and lead zirconate titanate (PZT) ceramics. The main problem of these materials is the brittleness.

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 are preventing the damage transducer 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 [16].

2. Materials and methods of research
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 [16] was shown that the thickness of the matching layer the piezo ceramic at these frequencies is 10-300 um.

The studies [12] of properties the samples of the coatings of polyether paint PD510226 («BECKER»), epoxy-polyether paint EP110022G («BECKER») showed the suitability of using this type of coating to the surface of the ultrasonic transducers. Such parameters as impact strength, flexibility, adhesion, gloss, hardness and wear resistance were evaluated.

In this paper we investigated the epoxy-polyether powder coating EP111095G («BECKER»). This powder coating also corresponds 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 quartz glass panels with dimensions of 10x5x0.2 sm are used in this studies. The surface of the glass is polished. It should be noted that quartz glass is a dielectric. Therefore, powder coating by electrostatic spraying is difficult. To solve this problem, on the glass surface previously suffered by the magnetron sputtering an aluminum oxide layer about 200 nm thick. The surface preparing process are discussed in [13]. It should be noted that surface must be clean and dry.

Spraying the coating is carried out using a spray gun START-50 with voltage 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 [17].

Spraying is carried out in the chamber of coating polymer powder materials at the samples. The chamber designed to prevent scattering and collection powder coating particles are not deposited on the painted product.

Experimental studies in [16] was 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.

Baking was carried out in a SNOL 350 drying chamber at 200 °C for 10 min.

3. Experimental results and discussion
The experiments to measure uniformity of the polymer powder film thickness produced by DektakXT Stylus Profiler. Was chosen following settings: Scan type – Standard Scan, Range – 65.5 um, Profile – Hills and Valleys, Stylus Type – Radius 12.5 um, Stylus Force – 1 mg, Duration – 100 sec, Length – 30 mm. Experimental result are shown at Figure 1.
Figure 1. The distribution of the coating thickness on the substrate: spraying time \( t = 6 \) sec, air pressure \( P = 200 \) kPa

Measurement carried out from left to right along the central axis of substrate. The length of the scanned surface was 3 cm. Spraying center is located at around 1.5 cm, 0 the left from the center the mark from the high-temperature adhesive tape width of 5 mm was applied. It is necessary to reference the ground from the surface.

Figure 1 shows that the surface within the 1.5 cm is homogeneous with small dips in the range of 5 microns. It can be noted that the left from the mark coating thickness at 25-30 microns larger than the right. Apparently this is explained by the fact that the charged powder particles did not deposited to the dielectric layer adhesive tape and carries away with the air flow to the left from the center of the substrate and the deposited there. In the next time will be necessary to carry out measurements with a careful selection of the location of reference mark.

Earlier, in [18] were produced coating thickness measurements of polyether powder PD810119G («BECKER») sprayed in various modes. The measurement of thickness the obtained coatings was carried out symmetrically relative to the centre of the substrate to the left and to the right in increments of 5 mm using an ultrasonic thickness gauge PosiTector 200 B/Adv. It was shown that the coating is heterogeneous with a maximum thickness at the centre, followed by a decrease and an increase closer to the substrate edge.

Comparison with the published data [19,20] simulation of spraying process was produced. Conducted calculations [20] showed that during application the aerosol to a flat surface oriented normal to the axis spraying in an electrostatic field, the solid phase is applied nonuniformly and its density increases towards the free edge. At free edge the solid phase reaches the highest value. This is defined bigger intensity of the electrostatic field in this area. The experimental results confirm these calculations.

Optimal modes to obtain uniform coating was chosen. Result of this process are shown in Figure 1. The powder coating in chosen mode was sprayed at the spherical piezoceramic PZT26 [21].

4. Conclusions
Results of experimental studies the distribution coating thickness are presented. The modes to obtain polymer powder coating of ultrasonic transducers with different geometric forms is proposed. Experimentally confirmed possibility of using these coatings as protective matching layer of piezoceramic transducers at frequencies of 0.5-15 MHz.
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