The study of powder coatings based on Al and Ni, obtained by supersonic plasma spraying

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Abstract. In present research are presented the results of the study and evaluation of the strength characteristics of Al and Ni-Al coatings applied by supersonic plasma spraying on plastic and aluminum substrates. The spraying of coatings with various compositions was carried out on the supersonic plasma unit. It is shown that the coating is sufficiently strong, it also has satisfactory corrosion resistance and has sufficient shielding effectiveness against electromagnetic radiation. The screening efficiency was measured by the ZVA 24 VectorNetworkAnalyzer.

1. Introduction
When applying protective and technological coatings, the researchers set a task to create conditions and obtain a coating with high performance properties.

The manufacture of lightweight, anti-electromagnetic interference, structures based on metal and plastic materials coated with supersonic plasma spraying, coating, and the evaluation of their characteristics and material stability as a replacement for aluminum alloys in the manufacture of electronics housing parts is considered in this paper.

Polyamide plates of PA-6, 3 mm thick, 63 mm diameter, polyamide washers PA-6 (16 × 7), aluminum plates 3 mm thick, diameter 63 mm were used as test samples.

The aim of the work was a development of technologies for applying plasma-deposited screening coatings of Al, Ni-Al-based powders [1, 4]. The requirements for the resulting coatings are the appearance, surface roughness, coating thickness, coating thickness uniformity, adhesive strength, level of shielding.

2. Methods and results of measurements
In constructing and manufacturing EMI screens out of various materials the main advantage is technological effectiveness of products manufacturing. The high performance of the equipment and the relatively low cost of the raw materials and the production process determine using plasma spraying technology to be a very promising approach in order to create designs of screens and absorbers of electromagnetic radiation.

The spraying of coatings with various compositions was carried out on the MAK-100 supersonic plasma unit. The modes of plasma torch operation, the composition of the coating are presented in table 1. The screening efficiency was measured by the ZVA 24 VectorNetworkAnalyzer. The operating frequencies of the device are from 10 MHz to 24 GHz.
Table 1. The coating composition, modes of plasma torch operation.

| N | Substrate thickness, mm (washer PA-6 16x7) | Thickness inc. coating, Al mm | Thickness inc. coating, Ni-Al mm |
|---|---|---|---|
| 1 | 3.41 | | 3.55 |
| 2 | 3.03 | 3.66 | 3.66 |
| 3 | 3.1 | 3.3 | |

| Operation modes of the plasma torch |
|---|---|---|
| Current (A) | Voltage (V) | Gas consumption (l/min) |
| 130 | 350 | 330 |

3. Studies of corrosion resistance and the effectiveness of protection against electromagnetic interference

The objects of study are aluminum plates: 3 mm thick, 63 mm in diameter coated with a powder-deposited Al-coating method of various thicknesses (60–180 microns). The preparation of the metal surface before applying powder coatings by the method of plasma spraying consisted in removing fatty contaminants with a detergent and bead-blasting.

The protective properties of the coatings were determined by the standardized method ASTM B117 "Standard test method in a salt fog chamber". The coatings were placed in a chamber where a 5% neutral aqueous solution of NaCl was continuously sprayed at a temperature of 350 °C in the form of salt fog. Tests continued until significant differences in protective properties appeared. During the tests, periodically conducted a visual assessment of the appearance of the coatings, which characterizes the protective properties, according to GOST 9.407-84 “A unified system of protection against corrosion and aging. Method of assessing the appearance”. The appearance of the plates before and after the test is presented on figures 1, 2.

Figure 1. Al plate before testing.  
Figure 2. Al plate after testing.

Measurements of the effectiveness of shielding of EMR coatings showed that the level of shielding is reduced after testing for corrosion resistance (80 → 55 ~ 70dB). A thin Al coating (60 µm) showed more effective protection after surface oxidation (shielding level ~ 70 dB). Thick Al coating (180 µm) has higher rates at the initial stage of testing (up to ~ 80 dB, after ~ 55 dB). The aluminum plate is dense and has a transparent oxidizing layer (~ 1 µm), although aluminum coating is porous and has no noticeable borders. Unlike the aluminum plate (Al ~ 84%), the aluminum coating contains more Al2O3 (Al ~ 55%).

For the following experiment, washers (16x7) mm out of PA-6 polyamide, with plasma-deposited Al and Ni-Al coatings, were selected as test samples. The appearance of the coatings obtained on samples of polyamide PA-6 is shown on figures 3–5. The average surface roughness (Ra ~ 50µm). Adhesion strength: Al coating (1.7 ~ 3.2 MPa), Ni-Al coating (3.7 ~ 5.1MPa).
is determined by two parameters, where one determines the degree of reflection of the incident EM wave from the shield surface, the other characterizes the attenuation rate of the EM wave in the thickness of the shield material. The measurements were carried out in the frequency range 0.1 MHz – 2.7 GHz. The applied coatings have good reflective properties, but the absorbing properties of the substrate material are small. On figure 6 presents the results of measuring the effectiveness of shielding coatings, and figure 7 data on screening coefficients $K_s$. The highest level of reflection $S_{11,max}$ is observed in sample 2 with a coating (Al + Ni-Al) at $K_{s,max} \approx 4.1$. Sample 3 with coating Al – $K_{s,max} \approx 3.1$. Sample Ni-Al coated specimen – $K_{s,max} \approx 1.8$.

Figure 3. Coating Al on PA-6.  
Figure 4. Coating Ni-Al on PA-6.

Figure 5. Washers out of polyamide PA-6 (16×7) with coating.

Studies have shown that the level of screening effectiveness is influenced by the thickness of plasma-deposited coatings. Coating (60 ~ 150 µm) provides a fairly good level of shielding efficiency in excess of 80 dB. In a coating of > 200 µm, a decrease in the level of screening efficiency is observed. A thicker coating layer may have a higher porosity and a higher resistivity (higher oxidation level). On figure 8 shows samples of sprayed coatings (Al + Ni-Al). Table 2 presents the generalized requirements and the results of measurements.

Table 2. Generalized requirements and measurement results.

| Name                        | Requirements to the coating | Measurement results                                      |
|-----------------------------|-----------------------------|----------------------------------------------------------|
| Thickness and roughness     | < +/- 50 µ                  | +/- 50 µ. Thickness and roughness satisfactory           |
| Adhesion strength           | > 2.5 MPa                   | 3~5 MPa. High adhesion has been confirmed               |
| Test for E / M interference | > 80dB                      | 80~85 dB. High protection against electromagnetic interference has been confirmed. |
| Corrosion resistance        | 7 cycles, saving e / m durability | Reduction from 80 dB to 55 ~ 70 dB Corrosion resistance satisfactory |
4. Conclusion

The conducted studies suggest that powder materials and coatings based on them allow us to solve the

Coating thickness (60 ~ 150 μm)
Porosity = 2~5%
Resistivity $R = 2.2 \times 10^{-3} \Omega/\text{sq}$
Resistance ($\rho$) = $1.54 \times 10^{-7} \Omega$

Coating thickness (>$200$ μm)
Porosity = 8~13%
Resistivity $R = 0.9 \times 10^{-3} \Omega/\text{sq}$
Resistance($\rho$) = $2.34 \times 10^{-7} \Omega$

Figure 6. The results of measuring the effectiveness of shielding coatings.

Figure 7. Shielding coefficient $K_s$.

Figure 8. Combined Coating Structure (Al+Ni-Al).
stated problem. Thus, the manufacture of lightweight metal-plastic hybrid materials protecting against electromagnetic interference using supersonic spraying technology makes it possible to recommend them as a replacement for an aluminum alloy.

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