Formation of adhesive properties of surfaces of multicomponent materials

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Annotation. An experiment was conducted to determine the change in the adhesive strength of PF-115 enamel depending on the energy properties of the surfaces of various metals to assess the adhesive strength of paint-and-lacquer coatings. The adhesive strength was evaluated using the method of lattice cuts. Samples of brass CUZN39PBL, aluminium alloy 2024T35, C45, X10CrNiTi18-10 were taken as the test object.

1. Introduction
Along with electrochemical and chemical ways to protect metal products and structures from aggressive environmental impact, paint-and-lacquer coatings are widely used. This method is most popular due to its low cost and ease of recovery, it does not require expensive equipment, and also allows for achieving the required appearance and colour.

Paint-and-lacquer coatings are multicomponent mixtures. Such mixtures are applied to a product and then dried, thus forming an attractive film which protects the surface from corrosion. The quality of paint-and-lacquer coatings is determined by their mechanical, chemical and adhesive properties and the painting process itself. The adhesive strength of the coating is its most important operational characteristic [1-4]. Enamels, primers, putties and other paint-and-lacquer coatings are most frequently used for painting.

The adhesive strength depends on the conditions of paint coating application, its thickness, as well as on the area of the surface to be coated.

2. Materials and methods
To assess the adhesive strength of paint-and-lacquer coatings, an experiment was conducted to determine the change in the adhesive strength of PF-115 enamel depending on the energy properties of the surfaces of various metals. The adhesive strength was evaluated using the method of lattice cuts. The essence of the method is to evaluate the degree of adhesion of a paint film to the substrate judging by the number of cells that fall away from the substrate when the film is cut. To determine the stability, experiments were carried out in the laboratory using additional equipment: Mitutoyo micator, measurement accuracy up to 0.001 mm, white spirit, green PF-115 enamel, paint sprayer (Fig.1).

PF-115 enamels are intended for painting metal, wood and other surfaces exposed to weather impact, and for painting indoors. The advantages of using PF-115 are: the enamel coating is weather-resistant, resistant to water, cleaning solutions, industrial oils, resistant to temperature changes from minus 50 to plus 60°C.
Samples of brass CUZN39PBL, aluminium alloy 2024T35, C45, X10CrNiTi18-10 were taken as the test object. The surface of some samples of each material was subjected to grinding, and the other part of the samples was diamond smoothed. This allowed us to obtain different levels of surface energy of the samples. Before enamel was applied, each sample was treated with a cloth moistened in white spirit, followed by wiping. According to the method selected, the thickness of the enamel applied should not exceed 60 μm. It was controlled by measuring the height of the samples using the micrometer, before and after application. In this experiment, enamel was applied to the treated surfaces using the method of pneumatic spraying with a paint sprayer. The paint is applied on the samples for several seconds. According to standards, enamel was dried at a temperature of (20±2)°C for 48 hours (Fig.2).

After the enamel dried up completely, a special tool was used to make 5 parallel cuts on the surface of the samples to the substrate separated by 1 mm from each other. The same number of similar cuts were made perpendicularly to the first ones. Adhesion was assessed by the state of the cuts in the coating expressed in points (according to a four-point system) in accordance with the table below:

3. Results and discussion
The results obtained during the experiment are added to Table 1, 2.

| The number of cells that fell off, % | 0 | Less than 35 | More than 35 | 70-100 |
|-----------------------------------|---|--------------|--------------|--------|
| Points                            | 1 | 2            | 3            | 4      |

Table 2. Experimental results.

| Sample | The number of cells that fell off | The number of cells that fell off, % | Point |
|--------|----------------------------------|--------------------------------------|-------|
| ground CUZN39PBL                     | 1                                  | 4                                   | 2     |
| Smoothed/CUZN39PBL | 0 | 0 | 0 |
|--------------------|---|---|---|
| Ground 2024T35     | 14| 56| 3 |
| Smoothed 2024T35   | 0 | 0 | 0 |
| Ground C45         | 6 | 24| 2 |
| Smoothed C45       | 1 | 4 | 2 |
| Ground X10CrNiTi18-10 | 20 | 80 | 4 |
| Smoothed X10CrNiTi18-10 | 12 | 48 | 3 |

The results of adhesive strength depending on the level of surface energy are presented in the graphs (Fig.3, Fig.4, Fig.5, Fig.6):

**Figure 3.** The results of adhesive strength depending on the level of surface energy (CUZN39PBL)

**Figure 4.** The results of adhesive strength depending on the level of surface energy (C45)

**Figure 5.** The results of adhesive strength depending on the level of surface energy (X10CrNiTi18-10)

**Figure 6.** The results of adhesive strength depending on the level of surface energy (2024T35)
The graphs show that the samples subjected to diamond smoothing had the highest energy value, unlike the samples with a ground surface. Thus, the higher the level of surface energy, the higher the adhesion strength.

4. Conclusions
According to the Young model, the larger the surface energy of the sample to be coated, the smaller the wetting angle of the surface. In other words, liquid enamel spreads better on a surface with a large value of surface energy. And the improved spreadability of enamel contributes to filling the surface irregularities, which in turn provides adhesive strength. Due to surface energy, surface tension appears. According to studies [5-13], the method of processing the surface of metals has an impact on the amount of surface energy. It may be recommended choosing surface treatment methods providing a higher level of surface energy to ensure adhesion strength of coatings.

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