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Estimation of resistance to destruction of multi-element coatings

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Estimation of resistance to destruction of multi-element coatings

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Abstract. It is proposed to experimentally determine the work of destruction of a coating by their surface tension. The surface tension of the coating is determined from the dimensional dependence of its microhardness. Comparison of the destruction of multi-element coatings with nitride coatings shows that the use of multi-element coatings is very promising for machine building.

1. Introduction

Already in the middle of the last century it became clear that it was necessary to go beyond the path of creating expensive special alloys for the needs of many industries, but to develop coating technologies for already known steels and alloys that had the necessary technological properties. This is due to the fact that 90% of the details of mechanisms and machines fail due to surface wear.

There is a large flow of publications on this subject, of which we mention only the works [1–6], where a more extensive bibliography is given.

In recent years, the concept of highly entropic or multielement alloys and coatings based on them has been developed [7–11].

Stability of structure and composition, as well as high performance characteristics of high-entropic systems, create a very attractive possibility of forming coatings on their basis in order to improve the surface characteristics or to use them as protective films preventing harmful impurities from entering the near-surface layers.

2. Formulation of the problem

Surface wear of machine parts refers to surface phenomena and is the subject of numerous studies. These studies led to the emergence of a new direction in materials science - surface engineering [12].

Most of the existing methods for assessing the destruction and wear of materials, including coatings, are based either on a large number of statistical experimental data [13] or on complex mathematical calculations [14].

Therefore, a simple quantitative assessment of the energy of the destruction of coatings will be very useful for testing the technology of their application.

3. Theory

The work required to destroy the coating is:

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$$W = \sigma \cdot S, \tag{1}$$

where σ is the surface tension of the coating, and S is the coating area.

The method of experimental determination of the surface tension of coatings was proposed by us in [15]. The dependence of the microhardness of the deposited coating on its thickness is described by the formula:

$$\mu = \mu_0 \cdot \left(1 - \frac{d}{h}\right), \tag{2}$$

Where μ is the microhardness of the deposited coating; μ_0 is a "thick" sample; H is the thickness of the deposited coating.

The parameter d is related to the surface tension σ by the formula:

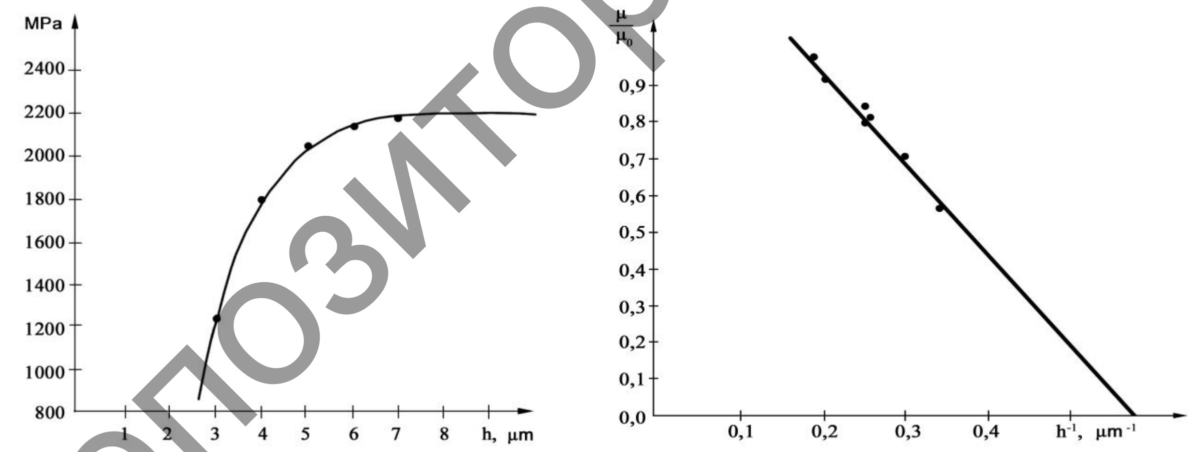
$$d = \frac{2\sigma\upsilon}{RT}. \tag{3}$$

Here σ is the surface tension of a massive sample; υ – the volume of one mole; R is the gas constant; T is the temperature.

In the coordinates μ – 1/h (1/h – the inverse thickness of the deposited coating), a straight line is obtained, the slope of the slope which determines d, and the surface tension of the deposited coating (σ) is calculated from (3).

As an example, let us consider the determination of the surface tension of titanium reinforcing coatings nitride on steel.

The results are shown in figures 1. In the coordinates $\mu / \mu_0 \sim 1 / h$, the experimental curve is rectified in accordance with (2), giving a value of h = 1.3 μm. For titanium nitride υ = 11.44 cm^3 / mol and from the ratio (3) for surface tension, we obtained: σ = 0.474 J / m^2.



a b

Figure 1. Dependence of microhardness on thickness (a) and inverse thickness (b) titanium nitride coating on steel X12.

4. Experimental results

For the deposition of coatings, composite cathodes and cathodes made of X12 steel were used simultaneously. With the help of these cathodes, coatings were applied on the NNV-6.6Il unit on a steel substrate of steel X12 in argon gas for 40 minutes at an arc current Iu = 80 A, a reference voltage U = 200 V, and a gas pressure in the chamber P = 5 × 10^{-5} Pat.

The surface tension of the coatings was determined according to the procedure described above. The work of destruction of the coating with an area of 1 m^2 was calculated from formula (1). The results are shown

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in table 1.

Table 1. Work of destruction of multielement coatings obtained in argon.

Coating	W, J	Coating	W, J
12X18H10T+Zr	0,95	12X18H10T+Zn-Al	1,08
12X18H10T+Zn-Cu-Al	1,07	12X18H10T+Al	1,12
12X18H10T+Fe-Al	1,27	12X18H10T+Cu	1,42

5. Discussion of the results

Let's compare the results with nitride coatings, which are widely used in various fields of engineering. The results are shown in table 2.

Table 2. Work of destruction of nitride coatings.

Nitride	W, J	Nitride	W, J
TiN	0.474	NbN	0.670
ZrN	0.518	TaN	0.735
HfN	0.610		

Comparison of table 1 and table 2 shows that it is much more difficult to destroy a multielement coating than a coating of metal nitrides.

High-entropy alloys and coatings, as a rule, have a single-phase structure [13]. In this case, work on the destruction of coatings can be estimated without using the experimental value of surface tension, according to the formula [16]:

$$\sigma = 0{,}7 \cdot (X_1 T_{m1} + X_2 T_{m2} + \cdots + X_n T_{mn}), \quad (4)$$

where T_m is the melting point of the i-th component of the coating. Xi is the percentage of the i-th component.

6. Conclusion

The results presented in the work show that the work of the coating destruction can be estimated experimentally by its surface tension. Knowing the composition of the coating and the melting point of its components, the work of destruction can also be estimated from formula (4). Summarizing, we can say that high-entropy coatings should have high performance characteristics.

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