Thin-layer films and coatings

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Abstract. The coatings are widely used in all industries. There is a need to establish an
effective tool for evaluating the mechanical properties of coatings and adhesive. The process
for determining the mechanical characteristics of coatings and adhesive. Modern developments
in the field of coatings trends.

1. About coverings
There is no sphere of human activity in which technical and economic problems aren't tried to solve on
the basis of films and coatings. In the future, this trend will increase even more. The rapid
development of nanotechnology and nanomaterials promotes effective problem solving. Variety of
coatings and adhesive components are created. Necessary qualities of coatings are provided by
development of thin-layer complex composite structures and adhesives which are formed directly on
the surface of the structure.
To create effective tools for diagnosing the state of coatings and adhesive, and to evaluate the
mechanical properties of produced or acquired coatings and adhesive there is need of deep knowledge
of the known methods and models of determine the mechanical properties of coatings and adhesive
properties of coating to substrate [1].

2. Determination of mechanical properties of coatings
For studies of coatings with complex structure, including samples with defects or holes physical
methods are not always applicable. Particularly, the method of “indentation” [2] – is not effective in
the study of surfaces which have complex surface structure.
The molecular approach of the study of the mechanical properties of thin structures is in the
embryonic state. The study of the mechanical characteristics of coatings by standard uniaxial testing
gives a large variation of test results. It is impossible to study mechanical properties of coatings having
a complex structure, defects and injuries by the standard uniaxial method.
By this theme there are domestic inventions (AS № 1742671, 1458766, 601599A, 1441243A1,
76597A) and foreign inventions – United States Patent 5764068A and Japanese Patent JP 8313422A.
It should also be noted the Russian Federation patents: № 1756786, 2184361, 2296976.
An effective approach of determining the mechanical properties of shell coating is experimental-
theoretical method [3, 4]. This method allows determining the mechanical properties of coating and
can be used for the study of nano-coating [5].
Experimental-theoretical method for testing the mechanical properties of plane [3, 6, 7] and
spherical surfaces [8] is based on a synthesis of experimental data and theoretical relations derived
from the nonlinear theory of thin shells, the theory of elasticity and plasticity. Scheme of the
installation is shown in figure 1. Using the experimental data it is possible to build curve "deflection $H$ – pressure $p$". Using the obtained results of measurements produce a theoretical data processing, this make possible to define, in particular, the elastic modulus or conditional elastic modulus, build curves of deformation and make a conclusion of the degree of deterioration of the material.

The method is also developed for the study of mechanical properties of biological membranes. This test methods and devices which use in the experimental-theoretical methods have the RF patents for inventions: № 2184361, 2296976, 2310184, 2387973, 2403556.

In particular, the influence of solar radiation on mechanical properties of polymer films of thickness 0.1, 0.12 and 0.18 mm with black and white substrates was studied. There are the curves "deflection – pressure $p$" (figure 2) and "stress intensity $\sigma_i$ – deformation intensity $\varepsilon_i$" (figure 3) for films of thickness 0.12 mm. It also was found that with film thickness increasing the effect of influencing of solar radiation increase too.

By the separate studies of the substrate and the coated substrate (titanium oxide) the mechanical characteristics of the nano-coatings are defined in the system "coating-substrate" – figure 4 [1, 4, 9].

3. Determination of coating adhesion
The method for determining the adhesion of film to substrate using the parameters of the "bubble" [10] is known, it also has a number of disadvantages. Scheme of installation for determining the adhesion by the patent [11, 12] is shown in figure 5. A tensile load is applied to the covering through the hole, it is possible to watch the pressure change and formed shape of the dome, measure the change in diameter of base of the dome in the process of peeling of coating. Then the experimental data is used
in the ratio of the non-linear theory of shells. The method allows studying the adhesive properties of hard coatings and getting consistent results.

Method of determining the adhesion by the patent [12] improves accuracy of determining of the parameters of adhesion taking into account the mechanical properties and material thickness of coating, as well as height and elliptical form of base of the dome (figure 6). Polymeric coating adhesion to the metal substrate is defined.

![Figure 5. Plant layout.](image)

![Figure 6. Parameters bubble.](image)

4. About current trends

The most interesting data about surfaces and the trends in field of functional coatings for protection against corrosion of metal surfaces are noted. With the development of new technologies for the treatment of surfaces of construction elements it becomes possible to change the properties of materials and create new functional materials which have various applications [13–15], and others. Encapsulation of functional substances reacting on polymeric or inorganic supports, allows the creation of a new generation of intelligent coatings.

4.1. Self-treat covers

Protection from corrosion can be realized by "treatment" of defects in polymer coating by the addition polymerizable agents, or delay of corrosion due to the presence of corrosion inhibitors. Including the capsules with functional substances in coating is considered by Dry and Sottos [16]. Capsules are destroyed during the development of cracks in coating material and outputting the substances for polymerization of destroyed volume of polymer coating. Important moment for corrosion protection is an antifouling effect of coating. New biocides group are developed, in particular encapsulated antifouling substances are produced [18].

4.2. Super-hydrophobic coatings

Hydrophobicity is achieved by the encapsulation of functional substances [19] or by changing composition of outer surface of coating layers. Super-hydrophobic composite coating of a styrene copolymer, methyl methacrylate and silica nanoparticles was reviewed by Huang et al. [20].

4.3. Modification of coatings

Modification of coatings with carbon nanotubes and nanofibers make possible to produce nanostructured surfaces with increasing the mechanical properties [21]. Epoxy paints containing siloxane, allow to obtain coatings with the desired properties [22]. Siloxane allows creating self-cleaning and not covered by ice coatings. Conductive polymers – polyaniline, polypyrrole and thiophene – can be used to change the conductivity of anti-corrosion barrier coatings [13, 23].

5. Conclusions

The effective methods of evaluating the mechanical properties of coatings and adhesive which allows studying the perspective newly established modern functional coatings are developed.
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