Research of adhesion of a covering on cylindrical surfaces

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Abstract. The approaches have been assessment of adhesion of a thin layer covering the surface of a cylindrical cover have been developed. An example of determination of adhesion from internal pressure and also an example of a research of adhesion have been considered at a cover bend. The method is a reliable tool for adhesive definition.

1. Introduction
Among the film and membrane elements, combining ease with high durability, the thin-walled structural coverings are especially distinguished. They find broad application in all industries of production and activity [1–5]. For ensuring functional work of designs with a protective coating it is necessary to estimate authentically properties of adhesive of a covering, and their change in use. In articles [6–8] approaches and methods of a research of adhesion of a film to a flat substrate are described. There is a need of development of the tool of assessment of the adhesive properties of a covering created on nonplanar substrates. The approaches of assessment of adhesion of the thin layer covering created on a surface of a cylindrical cover are developed. The impact of deformation of a cover on adhesion of a covering is investigated.

2. Experimentally-theoretical method
The first approach of assessment of adhesion. The device for test (figure 1) consists of the cylindrical capacity 1, a source of pressure 2, the highway with manometer 3 and the gate for giving of environment 4, measuring complex 5, the highway for etching 6.

Is on the side surface of the capacity.  The 1 has a hole 7. On a surface of cylindrical capacities 1 a covering on the set technology is formed.

![Figure 1. Installation diagram.](image)
At an experimental stage give from the 2nd the environment to capacity 1. At a certain pressure, separation of the coating occurs with the formation of a local dome with the parameters of the elliptical base of the dome \(a, b\) and deflection \(H\) (figure 1). On the basis of a measuring complex the measurement of geometrical parameters of a dome from \(p\) pressure is performed. At a theoretical stage we determine local value of tension of coupling of \(\eta_{otr}\), normal to a cylindrical surface, by a contour of single length areas of a separation:

\[
\eta_{otr} = T_1 \frac{ab \sqrt{R_c^2 A - a^2 b^2 \sin^2 \theta}}{RR_c Ah_0 (1 - \varepsilon_1 - \varepsilon_2)}, \quad A = b^2 \cos^2 \theta + a^2 \sin^2 \theta, \quad (1)
\]

\[
R = \frac{2R_c \Delta z - \Delta z^2 + (H + \Delta z)^2 \sin^2 \theta}{2(H + \Delta z) \sin^2 \theta}, \quad \Delta z = \frac{a^2 b^2 \sin^2 \theta}{\sqrt{A^2 R_c^2 - Aa^2 b^2 \sin^2 \theta}},
\]

where \(T_1\) – tangential efforts, normal to a contour, in a film in the field of a separation; \(h_0\) – is covering thickness before deformation; \(\varepsilon_1, \varepsilon_2\) – is deformation of a covering in the normal and tangent directions near a contour.

The cylindrical cover with \(R_c = 174\) mm with covering thickness \(h_0 = 0.17\) mm is investigated. Diameter of an opening in cover \(d = 5.5\) mm. From an experiment at \(p = 0.19\) MPas are received: \(H = 0.29\) mm, \(a = 7\) mm, \(b = 6.5\) mm.

For definition of the intense deformed condition of a covering final SOLID186 elements (educational ANSYS option) were used. According to "adjustment fire" for experimental parameters of a dome at Poisson's coefficient of \(\nu = 0.4\) and \(H = 0.296\) mm the module of elasticity of a covering \(E_{covering} = 25000\) MPas. Distribution of intensity of tension of \(\sigma_i\) on a contour of a covering is presented in (figure 2).

Further according to (1) tensions of coupling of \(\eta_{otr}\) depending on \(\Theta\) corner (counting of \(\Theta\) goes from forming a cylinder) were calculated: at \(\Theta = 15^\circ\), \(\eta_{otr} = 1.49\); at \(\Theta = 90^\circ\): \(\eta_{otr} = 5.52\). The maximum sizes \(\eta_{otr}\) were observed in the field of tops of half shafts of \(b\).

The second approach of assessment of adhesion. For assessment of the intense deformed state (IDS) of a cylindrical cover with a covering it is possible to use also the elements with model of contact Rough (educational ANSYS option) at which a relative sliding in contact of a covering with a substrate is excluded.

The scheme of splitting into final elements for a cylindrical cover \(L\) long \(L = 50\) cm, with the outer diameter of \(D_N = 15.4\) cm, with an internal diameter of \(D_V = 15.0\) cm, with covering \(h\) thickness \(h = 0.1\) cm is given in figure 3.

The through opening is provided in the central part of a side surface of a cylindrical cover. In the presence of \(p\) pressure in a cylinder the "cylindrical cover-a covering" system is deformed. And in the
field of an opening the covering at increase of pressure of $p$ gradually comes off a cylindrical cover, forming a dome.

![Figure 3. Scheme of splitting into final elements.](image)

Picture of deformation of a covering in the field of an opening on a cylindrical cover for a case when the module of elasticity of material of a cylinder of $E = 200000$ MPas, Poisson's coefficient of $\nu = 0.3$, and Poisson's coefficient of a covering of $\nu = 0.4$, is given in figure 4.

![Figure 4. Deformation of a covering in the field of an opening on a cover.](image)

By analogy with the adjustment fires the method described by an example, varying the module of elasticity of a covering for geometrical parameters of the formed dome and Poisson's coefficient of $\nu = 0.4$, it is possible to reach experimental value of the maximum deflection of a covering.

3. Conclusion
The experimentally-theoretical method of assessment of adhesion of the covering created directly on a cylindrical cover has been developed. Two approaches are have been considered. The offered method is the reliable tool both for the assessment of mechanical properties of adhesive, and for the study of influence of physical fields and environments on change of these properties.
References

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