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PHYSICAL ASPECTS OF THE CAPILLARY CONTROL THEORY (LIQUID PENETRANT TESTING)

PETER PROKHORENKO

Institute of Applied Physics of the National Academy of Sciences of Belarus, Minsk, Belarus

The liquid penetrant testing, and its capillary variety, and control of airtightness, are based on the filling by the liquid defectoscopic substances of capillaries and capillary-porous bodies. Physicomechanical interaction on the boundary liquid - solid body influences seriously the eventual result of control. For the first time we investigated phenomena, as interaction in the capillary of two chemically noninteracting liquids, mechanism of double-sided filling of blind capillaries, ultrasonic capillary effect, size effect of viscosity. Their role in an increase of the effectiveness Interaction of the development of defects and productivity of control is shown.

The knowledge of laws governing these phenomena does make it possible to create the theory of the motion of liquids in capillaries from macro to micro sizes, does make it possible to govern the operations of control, gives possibility for creating of new defectoscopic materials and new testing methods.

"Liquid – liquid" interaction in capillary

During the control the conical defect is filled with different liquid defectoscopic materials: first with a washing liquid, then with a penetrant, after that with a cleaning liquid and, at last, with a liquid phase of developer.

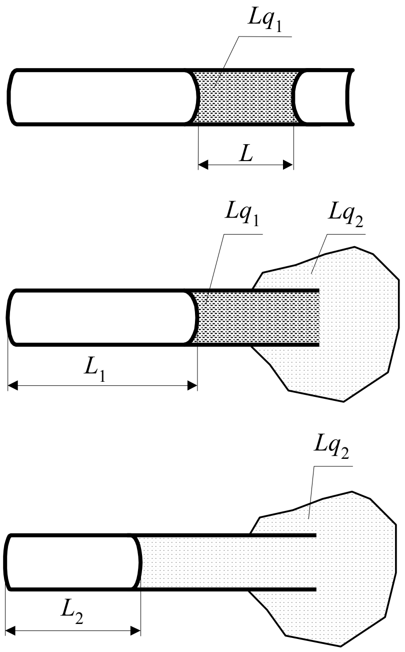
The mechanism of the liquids' interaction in the defect's channel is considered using the cylindrical blind capillary with liquids soluble in each other without chemical interactions. Let the cylindrical blind capillary is filled with the liquid Lq_1

to a depth L (Fig. 1). The capillary with liquid Lq_1 is now put into contact with the liquid Lq_2. The displacement of meniscus stops when the pressure of the entrapped gas p_1 corresponds to the compression pressure:

a)

b)

c)



blocking of Lq_1

complete drawing of Lq_1

Fig. 1. Interaction of two liquids in a capillary

According to our experimental data, when one liquid (Lq_1) partly fills the blind capillary channel and another liquid (Lq_2) comes into contact with the first one at the channel entrance (Fig. 1), the following interactions may occur: complete drawing of the liquid Lq_1 from the capillary channel (Fig. 1c), blocking of liquid Lq_1 in capillary, partial drawing.

We establish the condition of liquid's removal form the capillary channel during liquids' interaction:

$$\sigma_2 \cos\theta_2 < \sigma_1 \cos\theta_1 \quad (1)$$

This corresponds to the condition $p_2 > p_1$ (2).

$$p_2 > p_1 \quad (2)$$

When the inequality $p_2 < p_1$ is valid, the gas volume in the capillary will increase according to the Boyle's law, and the liquid will be forced out of the capillary. For the opposite case ($p_2 > p_1$) the result of the liquids interaction is further displacement of the meniscus into the capillary.

The knowledge of this criterion allows to predict results of defectoscopic liquids interaction used while cleaning, penetrant applying, removal of its excesses and development.

Two-side filling of a conical blind capillaries

During filling of blind conical capillary with a liquid the air gets into capillary and accumulates at capillary top. Air is slowly dissolved in most of liquids, therefore so-called diffusive impregnation is long.

As a result of our experiments with conical blind capillaries, we established the following phenomenon: the liquid fills the channel not only from the open side, but also from the close side, i.e. from the capillary top (Fig. 2).

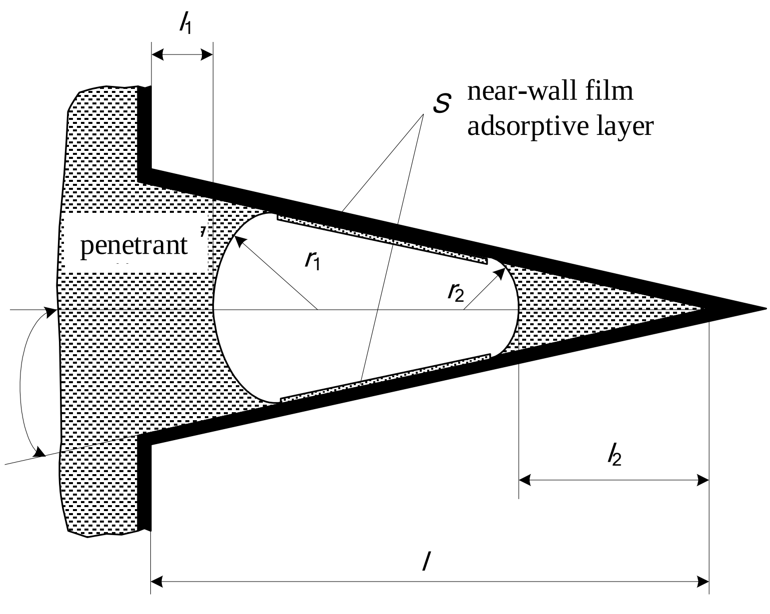


Fig. 2. Two-side filling of a conical blind capillary with a liquid: r_1 и r_2 – meniscus radius, S – near-wall film adsorptive layer of a liquid; l_1 – the depth of liquid column at capillary opening; l_2 – the depth of liquid column at capillary top (liquid, entrapped in capillary top mainly due to near-wall flow of film adsorptive layer S).

Dimension-dependent viscosity effect

The dimension-dependent viscosity effect can be observed for penetrants widely distributed in practice, which can be demonstrated experimentally.

The results of these capillary-radius-dependent measurements are illustrated in Fig. 3. The correlation $\mu(R)/\mu^{\mathrm{N}}$ shows that the increase of the effective viscosity μ, which is connected to a decrease of the radius R, is stronger in the case of P_2 and the weakest in the case of P_1. The examined penetrants consist of some components with various basic ones such as butyl alcohol (P_1), water (P_2) and ethyl alcohol (P_3). Water is the most polar liquid. Consequently it has the largest and most stable poly-molecular associates. If we assume that the structure formation is responsible for the increase of the effective viscosity, the dimension-dependent viscosity effect will be the greatest in the case of a strongly polar liquid. Our assumption was confirmed by the experiment.

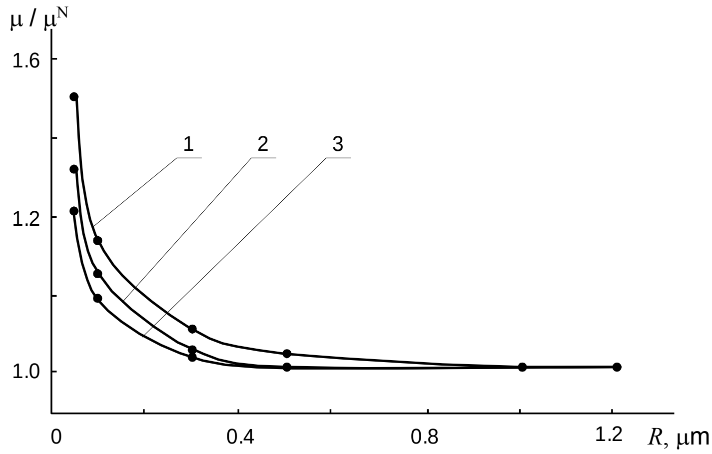


Fig. 3. Dependence of relative viscosity of penetrants $\mu(R)/\mu^{\mathrm{N}}$ on the capillary radius: 1 - P_2, 2 - P_3, 3 - P_1.

The knowledge of dimension-dependent viscosity effect allows to make analytical calculations of characteristics of liquids migration not only in macro– but also in micro capillaries.

Ultrasonic capillary effect

In penetrant testing for a long time an ultrasonic vibrations of low industrial frequencies 15-80 kHz are successfully applied to an intensification of various operations (cleaning, impregnation, development). The great influence of ultrasonic vibrations on various technological operations is based upon strong local hydrodynamic and temperature cavitation influences, and upon its influence practically on all physical properties of materials and results of their interaction.

Ultrasound has most influence in volumes of a liquid on the border with a firm surface, when conditions for occurrence of ultrasonic capillary effect are created. Ultrasonic capillary effect – the phenomenon of increase of depth and speed of liquid penetration in capillary channels under action of ultrasound (in comparison with depth and speed caused only by capillary forces). Inventing of ultrasonic capillary effect belongs to Belarus scientist academician E.G. Konovalov. Ultrasonic processing is especially effective for the products with complex shape used in electronic and instrument-making industry.

Advantage of ultrasonic processing is that such ecologically harmful, fire dangerous and explosive traditional substances as gasoline, acetone, spirits it is possible to replace with water and water solutions. The reason is that cavitation activity of water is much more than acetone, spirit and gasoline, consequently therefore much grater influence of water and water solutions is.

References

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