1.6.3. PENETRANT TESTING: ABILITY EXTENSION AND SENSITIVITY EVALUATION

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Several ways of the increasing of penetrant testing (PT) efficiency and ability extension are described in the paper. The first one is the application of testing object heating at various stages of PT process. One more effective way to improve PT process can be realized by the optimization of various parameters of the process for prescribed product family with the use of image processing system. The third possibility to extend PT possibilities is a working out of special technology and means for revealing defects at the surfaces with comparatively high roughness. Practically important problem is also a development of suitable test panels for the evaluation of PT materials' sensitivity level.

New test panels with several cracks of various dimensions at the same surface (fig. 1) were developed recently at the Institute of Applied Physics and applied both for the evaluation of sensitivity level of penetrants and for researches described in the paper.

The increasing of PT efficiency by testing surface warming can be achieved both before penetrant application stage and during development stage. Maximal effect we get using the heating for both PT process stages.

The essence of PT sensitivity increasing by the warming of testing surface before a penetrant application consists in the following. The pressure of a gas (an air, as a rule) locked in defects cavities is one of the major factors limiting defects filling by penetrant. Preliminary heating of a test object before penetrant application to the temperature exceeding initial by T_2 = 20 – 40°C (depending on demanded method sensitivity and test object temperature stability) leads to the reduction of air quantity in available surface defects in the object. At the subsequent penetrant application and cooling to initial temperature it causes the reduction of closed air' pressure, allowing penetrant to fill defects to greater depth. Thus at the subsequent development process defects with smaller width will be revealed (fig. 2). Using the hydrodynamic model of defects development [1] we derive the formulas describing dependence of PT sensitivity on the temperature of preliminary heating.

Sensitivity increasing by the heating a test object during development process takes place due to the fact that a pressure of an air locked in defect's cavity is increasing that leads to larger and faster penetrant displacement from a defect and as a result the sensitivity and the productivity are increasing as well. The optimal results can be reached using combined heating of tested objects both at the stage of penetrant application and at the stage of defects development. For example, fig. 2 illustrates the result of fluorescent PT in the case of consequent heating of the test panel at stages of penetrant (to T_2) and developer application (to T_3) One can see that in this case the sensitivity is substantially increased.

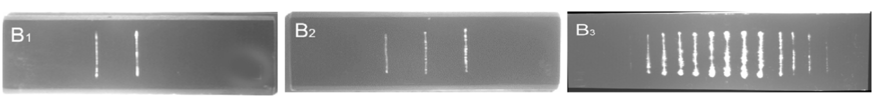
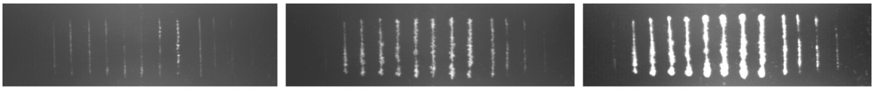


Fig. 1. Test panels (B_1, B_2 and B_3) with different cracks' openness:
B_1 – depth $l_{01} \approx l_{02}$ = 400 – 450 μm, openness h_1 = 1.5 μm, h_2 = 2,5 μm; B_2 – $l_{01} \approx$ 150 μm, $l_{02} \approx$ 300 μm, $l_{03} \approx$ 450 μm, h_1, h_2, $h_3 \approx$ 1.5 μm; B_3 – l_{01}, l_{02} – $l_{012} \approx$ 400 – 550 μm, h_1, h_1, … h_{12} = 1 – 11 μm



(a) (b) (c)

Fig. 2. Defects indications revealed by fluorescent PT using the heating at several technological stages:
(a) conventional testing procedure (without heating): T_1 = 21°C; (b) preliminary heating of test panel before penetrant application: T_2 = 49°C; (c) combined heating of the panel at stages of penetrant and developer application T_2 = 49°C, T_3 = 45°C

The heating during development process possesses one more useful ability: at low ambient temperatures it also decreases the duration of development stage by several times and, moreover, provides substantially brighter and contrast indications. We studied the influence of ambient temperature upon developing characteristics and the effect of warm airflow upon defects' detectability [2]. Obviously on the basis of the obtained results it is possible to solve a problem of penetrant testing productivity increase at low ambient temperatures.

More than 20 years ago the image processing system (IPS) with corresponding software was proposed for the first time in BAM [3] for quantitative evaluation of PT results. The IPS represents an effective instrument for quantitative analysis of defects' indications. As the device for recording images of test surface, the IPS allows detecting and automatically recording defect's indications of small size and poor contrast. The important advantage of such system is the opportunity of carrying out a fast and reliable quantitative assessment of product families' quality.

But the software used in [3] didn't provide adequate results of PT evaluation for some practically important cases. Later principally upgraded software based on another algorithms was developed in IAPh and successfully applied with the IPS by two teams from IAPh and BAM for quantitative evaluation of PT results [2, 4, 5]. During the last 10 years our software allows performing a reliable quantitative evaluation of defect's indications by its optical and geometrical characteristics. Simple coefficients for a complex evaluation of geometrical and optical characteristics of defect's indications revealed on the test surface were proposed and used in our investigations.

The possibility of quantitative evaluation of PT results enables to improve a testing process by the optimization of principal parameters of various stages of PT procedure. Obviously, applying the characteristics of main testing stages (penetrant application, penetrant excess removal and developer application), which don't correspond to their values for optimal regimes we can get significant decrease in sensitivity. We studied the influence of various parameters of the main stages of PT process upon detectability of defects [4]. Optimum values of the main characteristics of various technological stages for some widely used product families were defined.

Penetrant testing methods can be applied under the condition that the roughness of tested surface is lower than the certain critical value. Many industrial objects have comparatively rough surface therefore the application of penetrant testing of their surfaces in these cases is impossible or at least problematic. To overcome this difficulty preliminary preparation of the surface with the aim to decrease the roughness can be applied. But in the most cases the surface treatment leads to inadmissible decrease (or even complete closing) of defect' opening. The influence of several kinds of surface treatment upon defects shape and form was studied in [5]. Some results of researches, which enable the application of penetrant testing for rough surfaces were presented in this paper as well.

References:

1. **Prokhorenko P., Migoun N., Stadthaus M.** Theoretical Principles of Liquid Penetrant Testing. Berlin, DVS-Verlag, – 1999. – 252 p.
2. **Migoun N., Gnusin A., Stadthaus M., Jaenisch G.-R.** Proceedings of the 9th European Conf. on NDT, Berlin, Germany, – 2006. – CD. – 6 p.
3. **Stadthaus M., Thomas H.-M.** Materialprufung, – 1988. – V. 30. – N 2. – P. 109 – 113.
4. **Migoun N., Prokhorenko P., Gnusin A., Stadthaus M., Thomas H.-M.** Review of Progress in Quantitative NDE, American Institute of Physics. – New York, 2002. – V. 21B. – P. 1991 – 1996.
5. **Migoun N., Delenkovsky N.** Proceedings of 17th World Conf. on NDT, Shanghai, China, – 25–28 Oct., 2008. – CD. – 5 p.