New Potentials of Penetrant Testing

N. P. MIGOUN, A. B. GNUSIN, Institute of Applied Physics, Minsk, Belarus
M. STADTHAUS, G.-R. JAENISCH, Federal Institute for Materials Research and Testing, Berlin, Germany

Abstract. Liquid penetrant testing (PT) methods represent a multi-process procedure and require substantial time costs, which decrease the testing efficiency. Therefore the both problems, the optimization of all technological stages of PT and the search for additional possibilities to increase the efficiency of PT, are of principal importance. Some results of investigations, which enable increasing the efficiency of PT are presented: development of up-to-date means for quantitative evaluation of product families' sensitivity; thermal actions to intensify PT; optimization of PT technological stages and others.

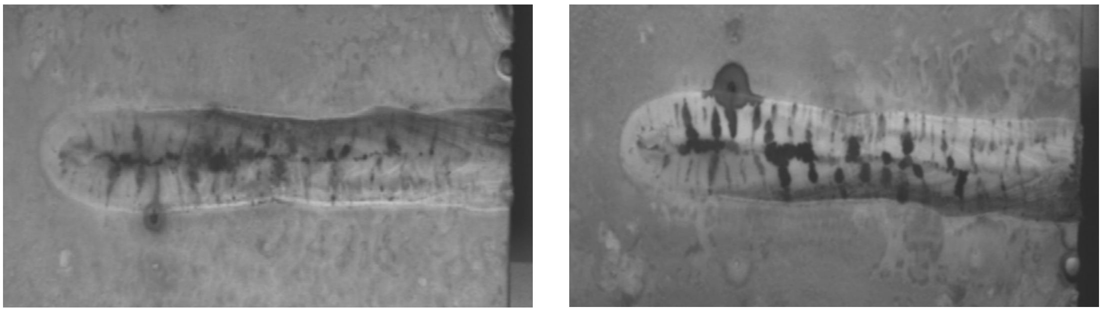
The widely used liquid penetrant testing is a reliable, high-sensitive non-destructive method to detect surface discontinuities. The method is based on a whole complex of physical processes. Therefore, both to optimize the technological process of PT and to develop new, high-sensitive product families (penetrant, remover and developer) one needs to establish quantitative description of physical correlation between these processes. General principles of PT theory were described about 20 years ago in [1]. Later the experimental and theoretical results we summarized in the book [2].

One effective instrument for quality evaluation of product families is application *of machine vision system* developed by us. As the device for recording images of test surface, the television system is used allowing 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. The developed software allows performing a 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 are offered.

We carried out special experiments to define *optimal regimes for all technological stages* of the penetrant testing process, providing the high detectability of defects in tested parts. Optimum values of the main characteristics of various technological stages for some widely used product families were defined. Incorrect observance of optimum technological regimes in penetrant testing can lead to the significant decrease in sensitivity. The influence of various parameters of the main technological stages of the penetrant testing upon detectability of defects was investigated. Two certified test panels corresponding type 1 of international standard ISO EN 3452-3 [4] were used.

Quality of pre-cleaning of a test surface has the major (sometimes determinative) importance in practice of penetrant testing. However when operating with test panels, for example, during certification of product families when flaws cavities do not get contaminated with difficultly washed off pollutions, and the test surface is smooth, qualitative process of cleaning is carried out for very short time. Comparison of images of defect's indications on the same test panel, gained under various conditions of pre-cleaning a test surface with other things being equal, shows the following. Brightness and contrast of indications at dwelling time of test panel in cleaning liquid during only 5 minutes with the subsequent 0,5 minutes ultrasonic cleaning practically do not yield to corresponding characteristics of indications after 24-hour dwelling of test panel in cleaning liquid with the subsequent 5-minute ultrasonic cleaning. Water-washable fluorescent penetrant of 3-rd sensitivity level was used.

It is shown that for *test panel* at durations of the stages of penetrant and developer application larger than 1 min its further increase poorly influences detectability of defects. However for *real articles* where depth of defects can considerably exceed 50 microns, the increase of the durations of penetrant application and development stage up to 10 mines led to essential increase of their detectability and testing sensitivity (fig. 1).



a b

Fig. 1. Growth of a defect indication in welded seam at increase of penetrant "Pion" dwell time: a - 1 min, b - 10 min.

Influence of various characteristics of penetrant excesses removal process before applying developer upon detectability of defects is also studied. In our experiments careful wash by water of test panels during 6 seconds with their simultaneous wiping by wetted lint-free fabric led to the full absence of a false background. However penetrant was partially washed out from defect's cavities that reduced brightness and area of the indications. For example, decreasing the duration of washing and wiping by 2 times of the same test panel under the same other test conditions led to increase of light flux from indications of the same area of a test surface by 5,1 times, and an average light flux from the background - on 62 %.

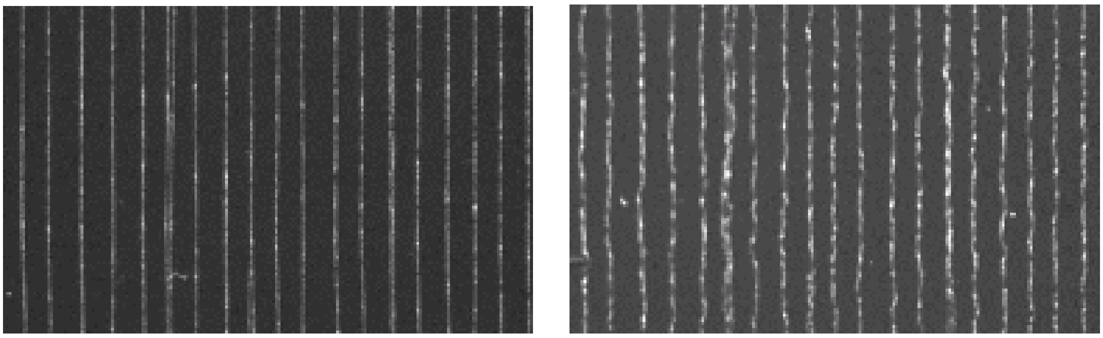
On the other hand, as a result of this on some parts of test panel the background luminescence became so bright, that deterioration of indication contrast has led to detectability of only about 25 % of lengths of analyzed indications. At the same time with more careful penetrant excesses removal, about 80 % of lengths of indications of all defects were clearly visualized. Such ambiguity of visualization conditions of indications means that for maintenance of reliable repeatability of sensitivity estimation results the same conditions for carrying out the procedure of penetrant excesses removal is necessary.

While evaluating product familie's sensitivity and penetrant testing results the procedure of applying a developer on a test surface has crucial importance. Two basic factors, depending on method of applying a developer, influence the shape, width and brightness of defects indications. They are thickness of a developer layer and dynamic action of developer particles, depending from velocity and incidence angle of particles.

It is recommended to use experimental optimum values of thickness of a developer layer for each developer. Selection of corresponding duration of development stage and a distance between spraying nozzle and test surface provide optimal thickness of a developer layer. In the most widely used method of applying of suspension developer – an aerosol spraying – the dynamic action of an aerosol cloud upon character of formation an area impregnated by penetrant is appear in a form of small-scale set of winding indications lines.

For example, in case of developer applying at distance from spray nozzle to a test surface l = 60 cm sharp and contrast defects indications were formed (fig. 2, a). Decreasing the distance l up to 30 cm leads to a blurring and tortuousness of indications and therefore to decreasing of their contrast (fig. 2, b). With increasing of distance between the tortuousness of indications disappears. The similar effect takes place when the aerosol jet is directed to a test surface under an angle, which is substantially differs from 90^0.

The results of our experiments indicate, that, for example, when using some suspension developers it is possible to provide the necessary thickness of a developer layer by uniform spraying of suspension from aerosol can of a part zone with length 250 mm during 3 second at a distance 400 – 450 mm from a test surface.



a b

Fig. 2. Dynamic effect at the close distance between spray nozzle and test surface.

Maintenance of results repeatability in sensitivity evaluation of products families requires the same conditions of applying the developer on the test surface, corresponding to optimal thickness of developer layer and absence of developer particles shift during developer application.

It would be appropriate to mention here that even at observance of all technology requirements to carrying out the stages of penetrant excesses removal and developer applying, some dispersion in evaluation results of light flux and area of indications can take place. Therefore at least triple repeating of penetrant testing procedure of the same test panel with the purpose of receiving the average values of the indications area and brightness is necessary for a reliable evaluation of product families sensitivity. In each measurement the same areas of the test panel should be compared. Besides both an ultraviolet irradiance (in case of the fluorescent penetrant testing) and illumination intensity of object should be the same and strongly defined in power and arrangement with respect to a test surface.

In wintertime at low air temperature duration of drying of a suspension developer layer applied on a test surface, often exceeds tens of minutes. It strongly reduces the productivity of the test that can be the critical factor when an effort is substantial. The investigations with the purpose *of increase of penetrant testing productivity at low air temperatures* were carried out in the Institute of Applied Physics (IAPh) of National Academy of Sciences of Belarus. Several types of modern widely used product families, which provide high productivity and sensitivity of penetrant testing at low ambient temperatures, were defined. The technological regime with use of warm airflow of a test surface was developed. It both substantially reduces the duration of development stage and also provides essentially brighter and more contrast defects indications.

Investigations with the purpose of an establishment of qualitative and quantitative relationships between the duration of several types suspension developer layer drying process and detectability of defects were carried out. Experiments were carried out with a use of metal test panels according to international standard EN ISO 3452-3 [4]. Five widely used in practice suspension developers were used. As a penetrant in all the experiments we used ‘Magnaflux ZL-19B’.

The requirement for the identity of all technological characteristics of testing was strictly observed: durations of penetrant impregnation and excesses removal conditions, an ambient temperature, a distance from spray can nozzle and test surface, requirements of illumination intensity and ultraviolet irradiation, etc. The main characteristics of defects indications were determined: brightness, area and light flux of given zone of an indication.

It is obvious, that the increase of each of the measured characteristic of an indication with other things being equal corresponds to improvement of defect’s visibility. It was established that using the various types of developers the more quickly developer layer dries, the more brightly and, accordingly, more contrast the indications are; however the light flux and the area of indication decrease. Besides distinct dependence has been established: with increase of duration of developer layer drying the blurring of an indications is also increased, that, in turn, deteriorate the defect’s visibility. Defect’s indications in test panels, obtained with use of suspension developers with high (a) and low (b) developer layer drying speed are presented on fig. 3.

Thus, competing action of some factors upon defect’s detectability takes place. As a result of carrying out several series of comparative experiments the developer corresponding maximum efficiency is determined.

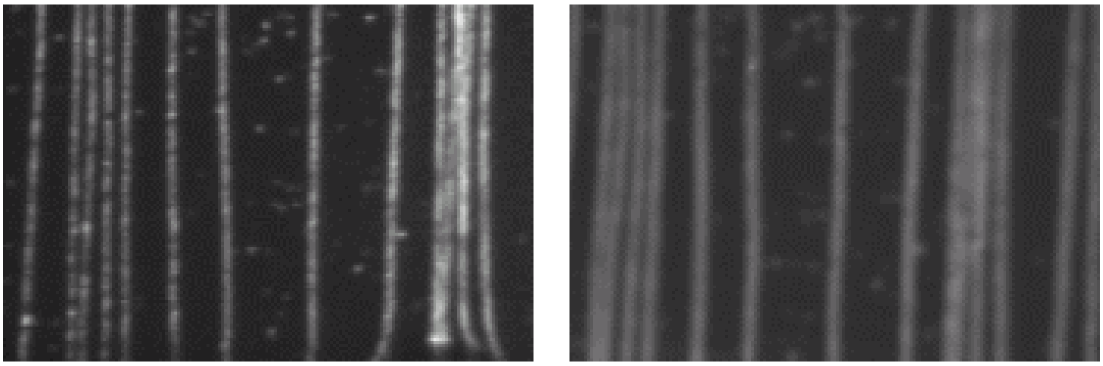


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Fig. 3. Defect’s indications in test panel: developers with high (a) and low (b) developer layer drying speed.

An influence of ambient temperature upon developing characteristics. Two series of the experimental researches have been carried out with the purpose to define the influence of a low ambient temperature upon duration of developer layer drying and, accordingly, upon the shape and contrast of indications, and also the influence of warm airflow of test object upon developer layer drying, shape and contrast of indications.

It was established that during revealing a surface crack by the given product family, with decrease of ambient temperature the brightness and contrast of defect’s indications are essentially decreasing. This is caused, obviously, by increasing of duration of developer layer drying. However indications become wider and blur. For example, the images of the same areas of the test panel tested with the same penetrant materials and under the same conditions, but at the temperature -5^0 C (a) and with use of warm airflow (b) are presented on fig. 4.

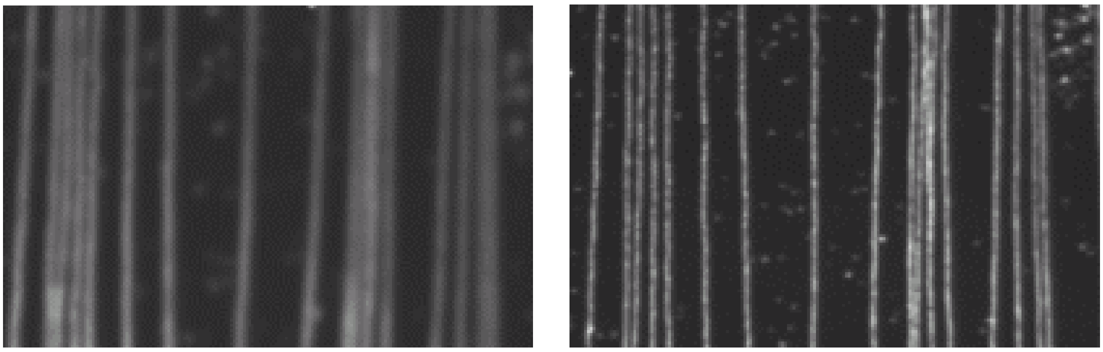

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Fig. 4. Development of the cracks without heating (a) and using warm airflow (b).

From fig. 4 it is clear that without warm airflow the indications are less bright and more blur. Besides duration of the complete drying of a layer of specified developer at temperature -5^0 C is 460 seconds, whereas using warm airflow it decreases till 40 seconds. It is necessary to notice, that with decrease of duration of developer layer drying the values of light flux and area of indication are decreasing. However, it does not lead to losses in brightness and contrast, i.e. to the worst detectability of indication.

Thus, the use of warm airflow of test surface not only decreases the duration of development stage by several times, but also provides substantially brighter and contrast indications. Notice that such regime facilitates penetrant to be more extracted from defects by the developer, providing increase of sensitivity [5]. It is obvious, that on the basis of the obtained results it is possible to solve a problem of penetrant testing productivity increase low ambient temperatures.

Test panels for the evaluation of product families sensitivity were recently developed at the IAPh corresponding to the requirements of last version of international standard EN ISO 3452-2 [3].

The algorithms for reduction a background luminescence in digital image processing of the images of defect's indications on surfaces with high roughness, and also the methods of decreasing a roughness are successfully developed in IAPh. It enables new possibilities of application a fluorescent penetrant testing in NDT of the objects with high surface roughness (for example, welded joints).

Now only a dye penetrant method is used to test the most of welded joints, because fluorescent penetrants, being much more sensitive, form a high luminescent background caused by a high surface roughness. The method and corresponding equipment for applying fluorescent penetrant to test welded joints were recently as well developed at the IAPh. It is based on special method of electrochemical processing of a welded joint after it's cutting-down and corresponding original equipment, and also a new method of digital computer processing of indication's images.

References

[1] P.Prokhorenko and N.Migoun, Introduction to Penetrant Testing Theory, Science & Technology, Minsk, 1988, 207 p.

[2] P.Prokhorenko, N.Migoun, M.Stadthaus, Theoretical Principles of Liquid Penetrant Testing. – Berlin, DVS-Verlag, 1999, 252 p.

[3] EN ISO 3452-2. Non-destructive testing - Penetrant testing - Part 2: Testing of penetrant materials (ISO 3452-2: 2000).

[4] EN ISO 3452-3. Non-destructive testing - Penetrant testing - Part 3: Reference test blocks (ISO 3452-3: 1998).

[5] N.Migoun, A.Gnusin. The dependence of penetrant testing sensitivity upon temperature regime of the development stage. Russian Journal of NDT, 2001, № 6, p.93-97.