

Penetrant Testing: The Software Tool for Comparison of Sensitivity and Estimation of Contrasts, Color and Brightness Characteristics of Penetrant Systems

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Abstract. Some approaches to the solution of the important task for conducting of the penetrant testing, namely, comparison of sensitivity and estimation of contrast, color and luminance characteristics for penetrant systems are considered. Algorithms for estimation of penetrant system sensitivity analyzing luminance characteristics of images of test-objects by means of software for decrease of human factor influence and improvement of estimation accuracy are provided.

Introduction

As is well known the reliability of the penetrant testing depends on quality of surface finish and surface cleanness, correctness while selecting and on quality of penetrant system components and now to the certain extent on operator reliability because in the most cases observing of results for the penetrant testing is made visually.

The quality of a penetrant system shall be understood not as only physical and chemical properties of the basic components of a penetrant system which are penetrant and developer (penetrant viscosity, chemical and temperature stability of both components, developer sensitivity), but also as luminance and color characteristics of indications which this pair is capable to give in case the conditions of monitoring are met including adhering to standards for white light exposure or intensity of UV light depending on what method is applied contrast or luminescent ones respectively. Luminance, color and contrast of indications influence reliability and adequacy while observing and registering of results for the penetrant testing [1, 2].

At MSIA "Spectrum" has been developed SPECTR PMS software application allowing estimating of contrast, luminance and color characteristics for contrast and luminescent penetrant systems and consumable materials of magnetic particle testing. The software application is a part of a hardware-software system for analyzing of indications for penetrant and magnetic particle testing and for estimating of sensitivity penetrant systems and magnetic particle means.

SPECTR PMS allows obtaining color characteristics of penetrant systems in color coordinates RGB and comparing them, calculating (in percentage) and comparing contrast of indications for penetrant systems and magnetic particle means.

In the frames of the report we shall consider an estimation and comparison of sensitivity for penetrant systems; while analyzing of sensitivity for magnetic particle means the same procedures and algorithms in view of the test-objects for definition of sensitivity for magnetic particle testing are used.

While using a test-object according to JIS Z 2343 the SPECTR PMS software application allows quantitative comparing of sensitivity for two various penetrant systems within the one level.

In the long term the SPECTR PMS software application will be added with an option to analyze indications on the monitor of penetrant testing system like PSM-5. As a result it is supposed to generate the description of prospective infringements of process in the automatic line of the penetrant testing.

1. Test bodies for liquid penetrant testing

As is well known the purpose of the test-object according to JIS Z 2343 is control of penetrant system indication and comparison of two systems, one of which can be accepted as a reference one ("exemplary").

There are 4 types of manufactured panels with depth of cracks 50, 30, 20 and 10 microns for penetrants of low, average, high and very high sensitivity respectively. The covering of panels is made with thickness equal to required depth of cracks, error 10 %. Opening of cracks is equal to 1/20 depths in average (it is measured by the metallographic microscope). The passport for the test-object is so-called reference photo containing unique figure ("pattern") of indications relevant to the panel received by means of the penetrant system accepted as reference at full observance recommended temperature and moisture, surface cleanness and other parameters.

In case of using a set of nickel-chromic panels for the testing of penetrant sensitivity (penetrant system) one panel is used as working and another one is kept as a reference one. In case of, for example, significant losses of indications on the working panel the penetrant system is checked by means of the reference panel and if there are losses of indications on the reference panel as well we can make a conclusion if the penetrant system can be used or not.

While using for comparison one plate (*A*) is processed by penetrant system to be examined (by penetrant to be examined) and plate *B* is processed by some known or reference penetrant according to the manufacturer instructions.

The estimation of indication ability and comparison are conducted by the comparison method using a reference photo.

While testing of penetrant sensitivity the working plate is processed by penetrant system according to the manufacturer instruction. The obtained picture of indications is compared with a passport photo.

Thus, the task of definition of an absolute sensitivity level for a penetrant system and comparison of sensitivity levels for penetrant systems is limited to definition and comparison with a reference photo for the number of the indications obtained during real experiment and to estimation of quality for indications, namely, how bright, contrast and indistinct they are.

Other known and widely applied test-object is the test-panel *PSM-5* intended for an estimation of sensitivity of a method at a whole while mass line penetrant testing having an option for revealing of equipment faults for penetrant testing system, namely, faults influencing sensitivity of the method.

Characteristic figure on the working side of the panel shows depending on sensitivity a maximum five star-shaped indications.

The centers of cracks are shown as star-shaped or sun-shaped indications while increasing. The largest concentric grid of cracks has diameter of 6,4 mm, then 4,0 mm; 2,4 mm; 1,6 mm; and, at last, the least concentric grid of cracks has diameter less than 1 mm.

The largest center of cracks becomes visible using a penetrant of low sensitivity, the least center is shown only using high-sensitivity materials. The least defect is shown in most cases more likely as one or two lines, than sun-shaped indication or "star". There are no two identical test-panels. Figure of cracks is unique for each panel, the same as in case of JIS Z 2343.

The field with star-shaped defects serves for definition of process sensitivity, and the field of a roughness gives the information about physical properties of used components of the penetrant system (viscosity, ability to be washed out for a penetrant and so on) and about separate modes of the entire process (observance of drying time and so on).

The alarm that *process* is inadequate (not necessarily only substances) means that the system detects only 3 defects (at weak indication of the third), at full absence of 4-th and 5-th ones.

Thus, for interpretation of indications for test-object PSM-5 it is necessary to allocate an area with star-shaped indications, to calculate the number of visible ones and to analyze traces on a roughness area, as a rule, they are not contrast pink or luminescent spots due to not washed off penetrant or the grey spots observable in visible light due to not dried developer or due to the water remained on the test-object.

PSM-5 shows that all elements of system, namely, clearing, penetrant, emulsifying agent, washing, drying and developer are working correctly. The analysis result will draw controller attention to the significant changes in operating parameters of the system. Analyzing characteristic traces on test-panel PSM-5 it is possible to receive the information about the following infringements in the penetrant testing system:

1. Infringement of penetrant composition (according to the extent of pollution);
2. Infringement of emulsifying agent composition (according to the extent of pollution);
3. Infringement hydrophilic emulsifying agent composition because it is not enough or too much water;
4. Wrong concentration of developer;
5. Infringements of the mode and time of penetrant contact with a surface of testing objects;
6. Wrong waiting time for an emulsifying agent;
7. Wrong waiting time for a developer;
8. Wrong pressure and temperature of water while washing out, time of washing;
9. The temperature and waiting time in a dryer are under or over the required level.

The provisional estimation of sensitivity for penetrant testing system is made as follows: super high-sensitivity fluorescent penetrants should show all 5 indications if the system works correctly; high-sensitivity fluorescent and contrast penetrants should show 4 defects and sometimes (but it is not obligatory) the least 5-th ones; medium-sensitivity fluorescent and contrast penetrants should detect 3 of the largest defects and sometimes 4-th ones.

2. The primary goals for estimation of penetrant system quality

Using penetrant systems for conducting of the penetrant testing there are following primary goals for an estimation of quality of these systems.

1. Comparison with the standard while estimating class of sensitivity.
2. Comparison of two penetrant systems.

If the specified problems are solved by means of the test-objects according to the JIS Z 2343, the following attributes of test-object images are monitored.

1. Number of the strips detected on the test-objects. Fall (absence) of indications on a pattern of the system to be examined means misfit to the class of sensitiv-

ity due to the worst than it is required for the class properties of the penetrant or the inhomogeneity of the penetrant and/or the developer.

2. The maximum luminance of indications. Insufficient luminance of indications can cause the skipping defects, in particular while automatic analyzing of the penetrant testing results.
3. Diffuseness of indications. It also reduces reliability of the testing. Using the system giving indistinct indications can cause incorrect definition of defects due to merging of indications.
4. Noise at the background. It reduces reliability of the testing due to falling contrast of indications and as result it raises the probability of the skipping for defects.

3. Quantitative indicators of penetrant systems quality

While solving the task of quality estimation for penetrant systems by means of SPECTR PMS software application it is suggested using some algorithms of test-object image examination: creating of luminance profiles, segmentation according to luminance, morphometric analysis. Further the algorithm of a quantitative estimation of quality for penetrates including creating and analyzing of luminance profiles for test-object images will be considered.

Using the function to create luminance profiles it is supposed that they are creating along lines perpendicular to indications on the test-objects (the number of cross-sections is a parameter of algorithm). Thus it is possible to use following numerical characteristics of luminance profiles.

1. *The number of connected peaks* N above the straight line defined by the selected threshold (for example, a threshold according to the mean value of luminance for the profile) for the length $[0, T]$. The characteristic allows estimating the number of the strips detected on the test-objects and thus it defines one of the important factors of penetrant efficiency, namely, visibility.
2. *Contrast of profile.* We shall break the length $[0, T]$ into certain number of parts by points which are maximum points for connected peaks (see item 1). We shall receive division of the length $[0, T]$: $x_0 = 0 < x_1 < \dots < x_n = T$. Then, for each length of division $[x_i, x_{i+1}]$ we shall find a minimum. Let M_i is a maximum, and m_i is a minimum along the length $[x_i, x_{i+1}]$ (the maximum M_i is reached at the point x_{i+1}). Then contrast of profile is the following value

$$S = \frac{\sum_{i=0}^{n-2} (M_i - m_i)}{n - 1}$$

The quantity indicator characterizes contrast of penetrant indications. In case of contrast penetrants, the higher contrast range means presence of significant amount of a colouring agent in penetrating substance-carrier and the higher quality of the

developer extracting the penetrant from hollows. For luminescent penetrants the higher contrast is a consequence of increase in luminance of penetrating material.

3. *Boundary contrast along a profile.* Similar to the item 2 we shall break a length $[0, T]$ into certain number of parts by points, which are points of maximum for connected peaks (see item 1). We shall receive division of the length $[0, T]$: $x_0 = 0 < x_1 < \dots < x_n = T$. Then, for each length of division $[x_i, x_{i+1}]$ we shall find a minimum. Let M_i is a maximum, and m_i is a minimum on the length $[x_i, x_{i+1}]$ (the maximum M_i is reached at the point x_{i+1}). Let x_i^0 is the leftmost point on the length $[x_i, x_{i+1}]$ in which the minimum m_i is reached. Then the boundary contrast of the profile is the following value:

$$T = \frac{1}{n-1} \sum_{i=0}^{n-2} \frac{M_i - m_i}{x_{i+1} - x_i^0}$$

The quantity indicator characterizes the extent of diffuseness for indications. The more T value, the more probability of merging for the next indications and less reliability of the testing.

Calculating of all specified quality parameters was implemented in SPECTR PMS software application.

5. Comparison of two penetrant systems, example

Let the test-object is applied for comparison of two penetrant systems according to the JIS Z 2343. One plate (A) is processed consistently by two penetrant systems to be examined P_1 and P_2 according to manufacturer instructions is used for comparison.

The estimation of indication ability and comparison of penetrant systems is performed by comparison of quantity indicators N_1^j, N_2^j , S_1^j, S_2^j and T_1^j, T_2^j calculated according to the indication figures of the test-object processed by these systems (N_i^j, S_i^j, T_i^j is the number of connected peaks, contrast and threshold contrast of j -s' profile for i - penetrant system).

Before analyzing of the image the indications are preprocessed using noise-suppressing filters and conversion into to 256 greyscale format. In Fig. 1 the transformed images of indications received by means of penetrant systems P_1 (Fig. 1,) and P_2 (Fig. 1,) are shown.

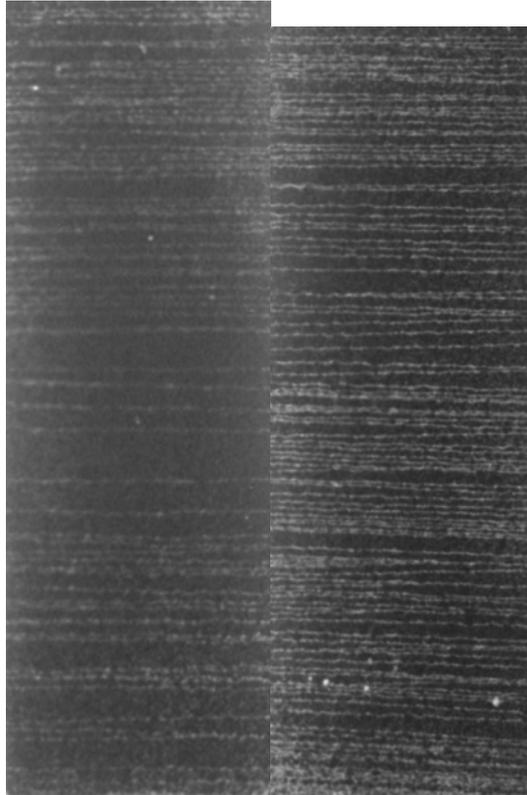


Fig. 1. JIS Z 2343 penetrant comparator set with indications; noise reduction and RGB-to-greyscale conversion applied/

Calculating of quality parameters is performed for five cross-sections (Fig. 2).

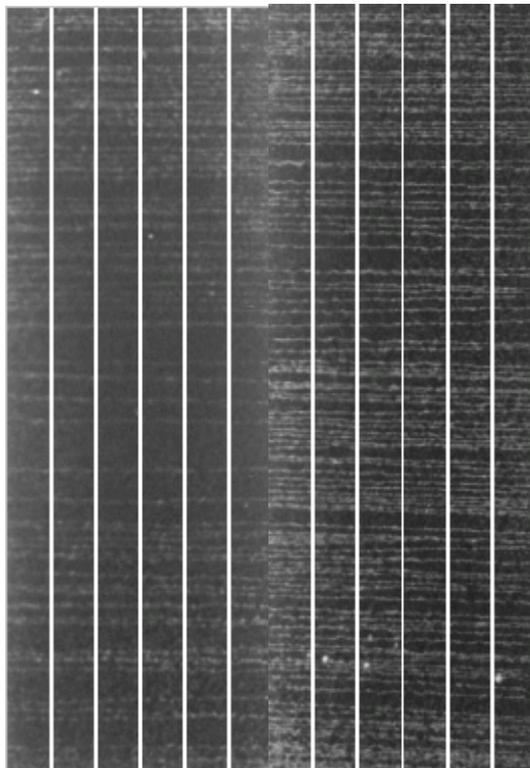


Fig. 2. JIS Z 2343 penetrant comparator set with indications; cross-section profile lines are generated

Table 1 contains values of parameter N (number of fixed indication lines for each of five profiles) for compared penetrant systems.

Table 1. Number of fixed indication lines

The number of the profile	1	2	3	4	5
Penetrant system P_1	49	41	45	43	29
Penetrant system P_2	67	71	70	68	73

Table 2 contains values of parameter S (contrast of each of five profiles) for compared penetrant systems.

Table 2. Contrast values of profiles

The number of the profile	1	2	3	4	5
Penetrant system P_1	14.68	15.25	15.97	16.54	20.21
Penetrant system P_2	36.59	31.72	35.28	39.55	40.90

Table 3 contain values of parameter T (boundary contrast for each of five profiles) for compared penetrant systems.

Table 3. Boundary contrast of profiles

The number of the profile	1	2	3	4	5
Penetrant system P_1	1.25	1.65	1.63	1.4	1.88
Penetrant system P_2	4.46	3.7	4.02	4.47	4.55

Fig. 3-6 show images of profiles (1-5) for indication figures of penetrant systems P_1 and P_2 according to which the quality parameters were calculated. Each graph contain a profile of the penetrant system P_1 at the part above, and a profile of the penetrant system P_2 is at the part below.

According to the above tables containing calculated quality parameters and images of luminance profiles it is possible to conclude that the penetrant system P_2 of higher quality than P_1 system. Since contrast and threshold contrast of indication lines for the second system is higher, and because the more number of the lines were defined for the second system.

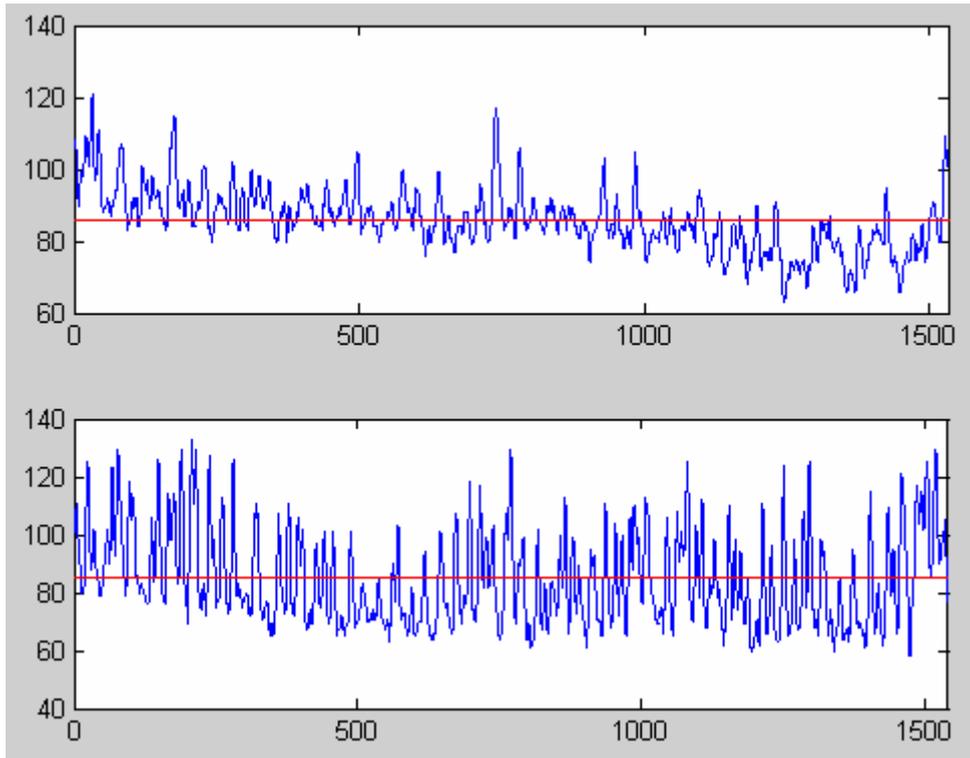


Fig. 3. Comparison of two panels by luminance profiles

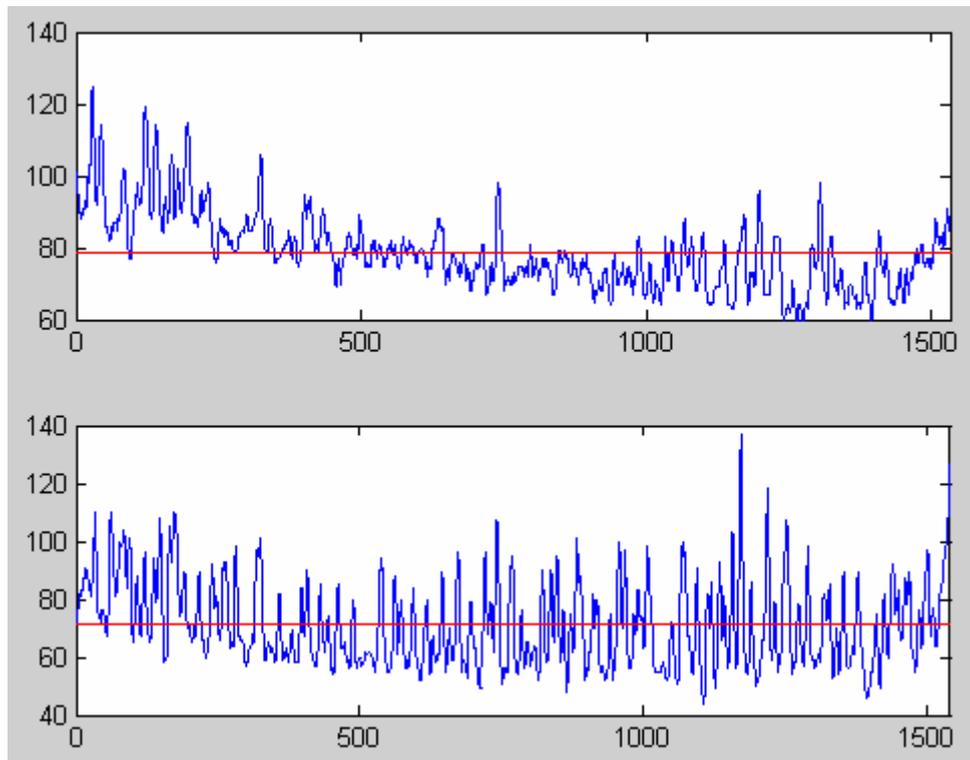


Fig. 4. Comparison of two panels by contrast profiles

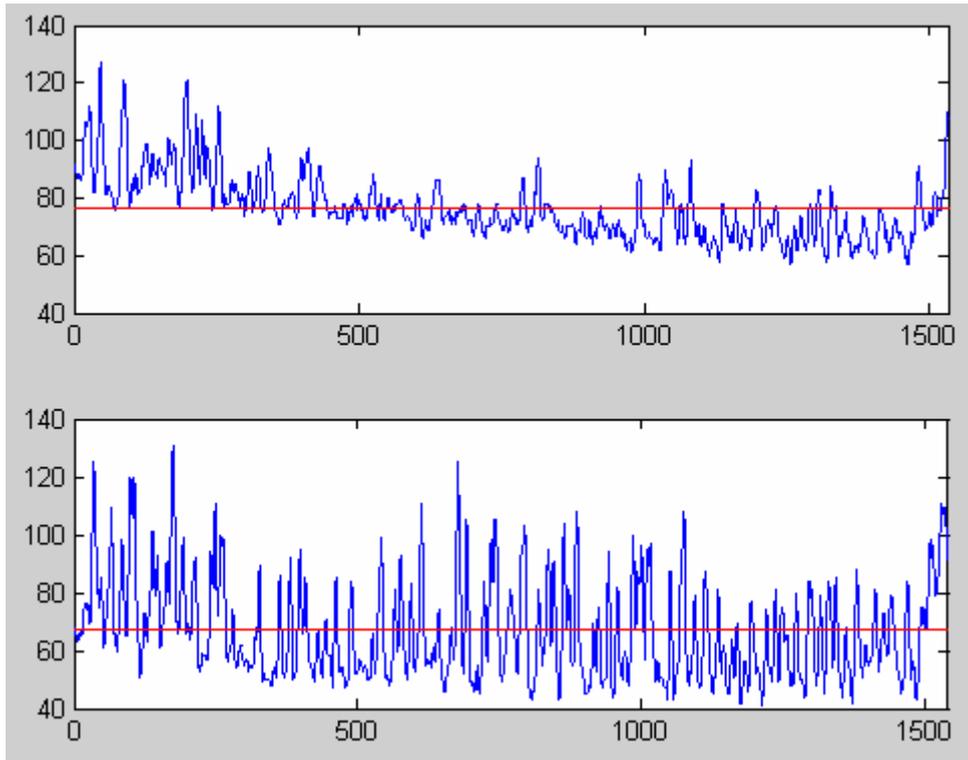


Fig. 5. Comparison of two panels by boundary contrast profiles

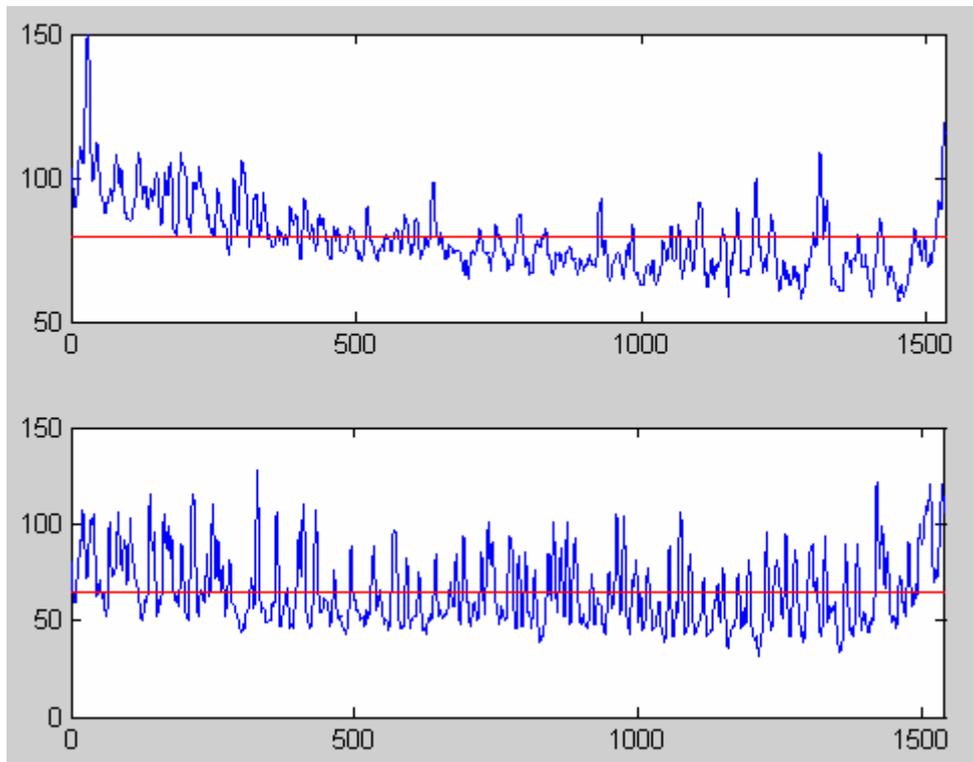


Fig. 6. Comparison of two panels by indication-to-noise threshold level

Conclusions

On the basis of the experimental examination it is possible to conclude that the shown quantity indicators of quality can be applied successfully to comparison of penetrant systems. And the options of computer processing for images of test-object indication figures (for compensation of noise) using automatic calculating of the specified quality parameters allows increasing reliability of comparison for penetrant systems.

References

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- [2] Measurements. Testing. Quality. Nondestructive testing. - M.: IPK Publishing House for standards, 2002.