# Possibility of Using Nonmetallic Check Samples to Assess the Sensitivity of Penetrant Testing



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# Possibility of Using Nonmetallic Check Samples to Assess the Sensitivity of Penetrant Testing

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**Abstract.** Versions of check sample manufacturing for penetrant inspection are considered. A statistical analysis of crack width measuring for nonmetallic samples is performed to determine the possibility of their application to assess the penetrant testing sensitivity.

## 1. Introduction
Liquid penetrant testing (PT) is one of the most widely used nondestructive testing methods for detection of surface discontinuities in nonporous solid materials. It is currently most commonly used surface nondestructive testing method as it can be applied to virtually any magnetic or nonmagnetic material. Penetrant materials and check samples are the tools for PT.

The samples are used to estimate the performance of penetrant materials and to evaluate the sensitivity of the testing techniques. The paper aims to evaluate the discontinuity parameters, such as cracks, in non-metal samples to determine the feasibility of using these samples to assess the sensitivity of the testing technique.

## 2. Theory
Different check samples containing defects are used to perform penetrant testing. In particular, check samples in the form of plates with transverse cracks dissecting the surface from face to face and those with cracks radiating from the center are widely used. Widespread check samples are samples made of austenitic chromium-nickel steel with star-shaped cracks coated with chromium; samples of stainless steel of the martensitic class with single cracks; brass samples with transverse cracks in the nickel-chrome coating layer. Samples with surface hardened by thermochemical treatment – nitriding, cementation, cyanidation, aluminizing, thermodiffusion chromizing are well-known as well. For all the above check samples, cracks are formed through bending or stretching [1–7]. The authors proposed the techniques for manufacturing check samples of nonmetallic material with preset defect parameters, such as width, depth and length [8].

According to these techniques, crack width is measured by metallographic microscope. The defect dimensions are recorded in the check sample certificate.

Among various problems to be solved using check samples, the most important ones are identification of the penetrant materials efficiency and evaluation of the penetrant testing sensitivity.

The test material is estimated at the beginning of each shift or when changing it, i.e. to inspect a new batch of materials. One or two samples with cracks are used to perform estimation. The sample is tested by penetrant testing using the penetrant materials through the conventional technique. The penetrant material proves to be efficient if the crack is detected. The obtained indication pattern is compared with the flow pattern from the certificate for the check sample. The completeness of crack detection, pattern contrast and its sharpness are considered.

The sensitivity of the procedure is assessed with regard to the preset level of the procedure. Sensitivity is one of the parameters to indicate the technical efficiency of penetrant testing, which characterizes its ability to detect defects. When performing experiments to assess the sensitivity of penetrant testing, the probability of defect detection is taken equal to 0.9 at a confidence level of 0.95 [9].

## 3. Research

Samples from nonmetallic material manufactured according to the procedure in [8] were used to estimate their applicability for penetrant materials evaluation and assessment of penetrant testing sensitivity.

For the research, the samples were produced with a single crack corresponding to class III sensitivity. The crack width was measured using a measuring microscope MS 50 with a resolution of 1 µm.

According to the method described by Glazkov Yu. A. [9], the techniques used to measure the crack width during sample certification to evaluate the performance of penetrant testing materials are different from those used to evaluate penetrant testing sensitivity.

The measurements taken at 3–5 points along the crack length are sufficient to evaluate the performance of penetrant materials in sample certification. The final measurement result is presented in the form (equation 1)

$$B \pm \Delta b, P \tag{1}$$

where $\Delta b$ is the limit of the measurement error, [µm]; $P$ = 0.95 is the established probability of the measurement error within these limits.

The results are presented in table 1.

**Table 1**. Statistical processing of measurement results to evaluate the performance of penetrant materials on nonmetal check samples.

| Sample No. | Width, [µm] | | | | Variation coefficient, [%] |
|---|---|---|---|---|---|
| | Average opening width, [µm] | Standard deviation with the establ. probability $P$ = 0.95 | Min. | Max. | |
| 11f | 18.0 | 1.55 | 17.0 | 21.0 | 8.00 |
| 12f | 25.0 | 1.41 | 23.0 | 27.0 | 5.00 |
| 13f | 18.5 | 1.62 | 16.0 | 21.0 | 8.00 |

A more accurate value of the crack width is to be provided for samples intended to evaluate the threshold of testing sensitivity. Typically, cracks have small fractures, bends and variable width that affect the crack detectability. Therefore, a set of samples to evaluate testing sensitivity should contain samples of the same type with straight cracks.

The disadvantage of metallic samples is changing stresses in the sample which change the depth and width along the crack length. Sample bending under loading results in its curvature, and thus leads to the change in the width along the crack length and crookedness of the obtained defect, as shown in figure 1.

The nonmetal check samples obtained by etching [8] allow implementation of the defects with the desired parameters (opening width, length and depth), which can be seen in figure 2.

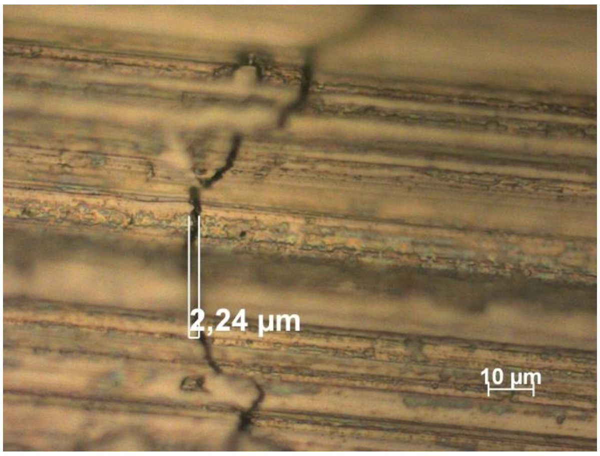


**Figure 1**. Crack in metal check sample.

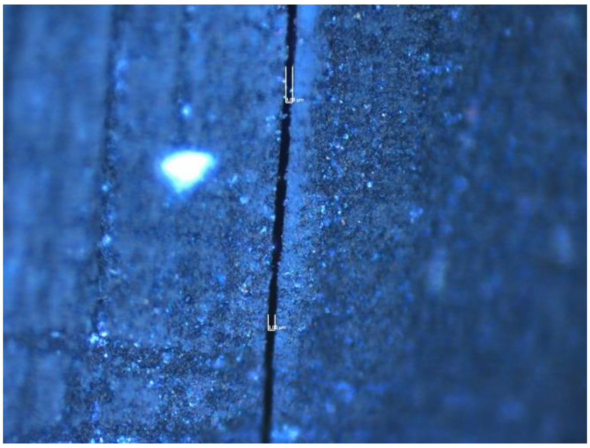

**Figure 2**. Crack in nonmetal check sample.

During sample certification, the crack width should be measured at 30–60 random points along the sample length.

The measurement results are statistically processed in order to:
- exclude the known systematic errors from measurement results;
- calculate the measured value;
- determine the RMS deviation of the measurement results;
- check for gross errors and eliminate the errors if needed;
- verify the hypothesis on correspondence of the measurement result to normal distribution;
- calculate the confidence limits of the residual estimation error for the measured value;
- calculate the confidence limits of the estimation error for the measured value [10].

The same samples were used for both the assessment of the penetrant materials performance and evaluation of testing sensitivity. Measurements taken at 50 points along the crack length were followed by statistical processing of the measurement results. The results are presented in table 2.

**Table 2**. Statistical processing of measurement results for the nonmetal check sample opening width to evaluate penetrant testing sensitivity.

| Sample No. | Width, [μm] | | | | Variation coefficient, [%] |
|---|---|---|---|---|---|
| | Average opening width, [μm] | Standard deviation with the establ. probability $P = 0.95$ | Min. | Max. | |
| 11f | 17.0 | 2.34 | 12.0 | 24.0 | 13.10 |
| 12f | 24.5 | 2.22 | 20.0 | 30.0 | 9.07 |
| 13f | 18.5 | 2.00 | 12.0 | 22.0 | 11.59 |

Measurements of opening width of check samples 11f, 12f, 13f presented on figure 3–5.

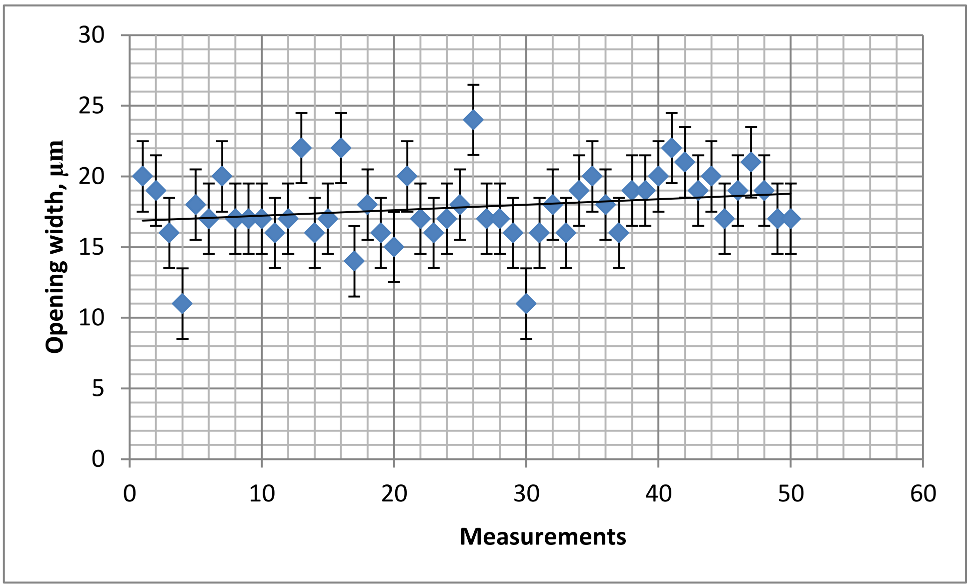


**Figure 3**. Check sample 11f.

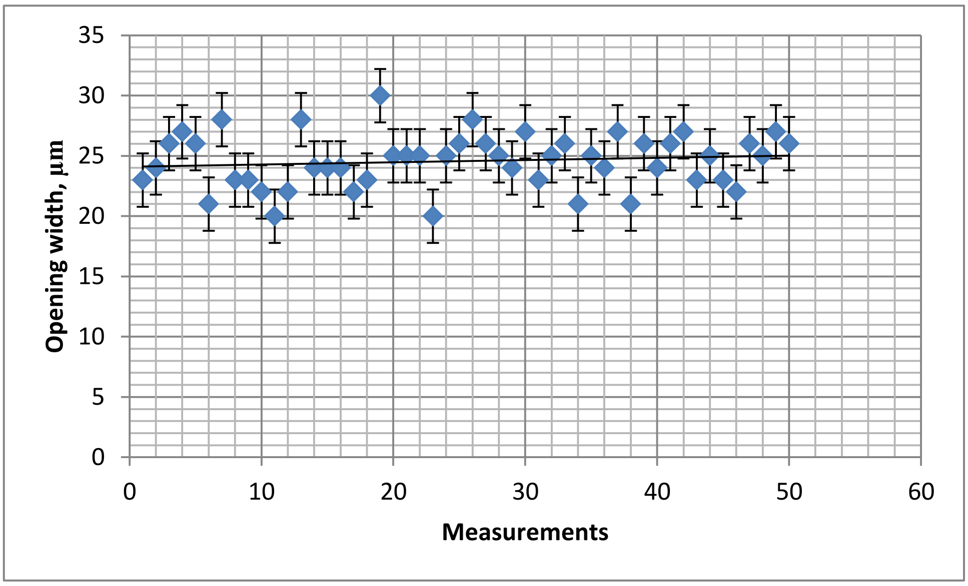


**Figure 4**. Check sample 12f.

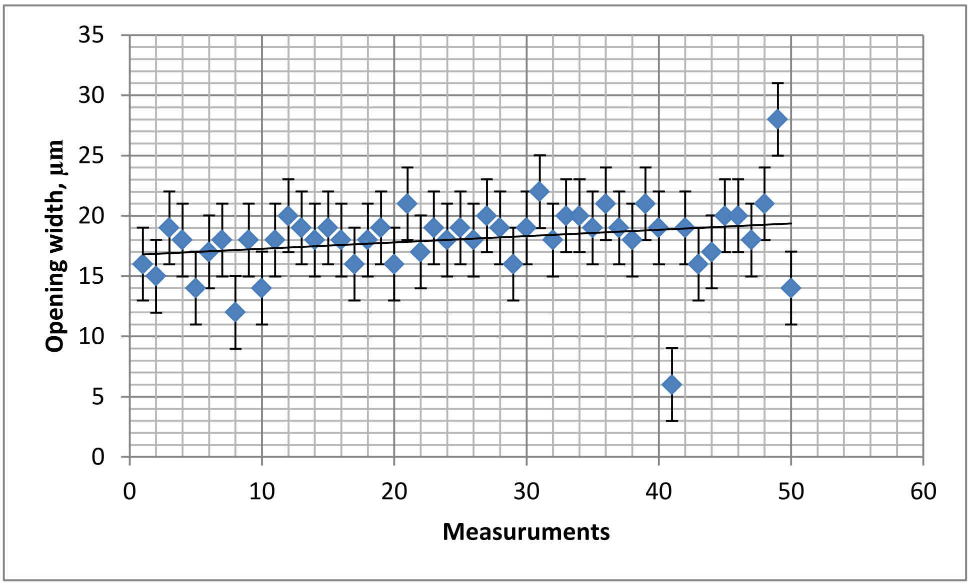


**Figure 5**. Check sample 13f.

## 4. Summary

Manufacturing check samples made from metallic and nonmetallic materials used in penetrant testing has been considered.

Metallic samples are less advantageous since cracks vary in their depth and width, and sample bending during manufacturing distorts the crack, which hinders their use for evaluation of penetrant testing sensitivity.

The conducted studies showed that manufacturing the control samples of nonmetallic material through etching provides one-type samples as the width parameters along the crack length are. These samples can be used to estimate both the performance of penetrant materials and to assess penetrant testing sensitivity since the cracks are virtually straight.

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