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Monitoring of Penetration System Performance according to ISO 3452-1 by using Test Panels according to ISO 3452-3

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***Abstract* – Penetrant testing (PT) is one of the first ever industrial established non-destructive testing for detecting surface discontinuities. Because of its outstanding sensitivity as well as easy use this test procedure is even today widely used in various fields of industry. As example can be mentioned automotive industry or aerospace industry. PT also can be used for manually testing of single parts as well as automatically testing of repetition parts in serial production. Increasing of demands with respect to quality assurance aspects requires procedures to verify the test itself. Developing these verification procedures have been started by the 1970s whereas the actual verification procedure is described by standard ISO 3452-1.**

Alteration of penetration system performances is often known if the penetrant is used repeatedly or the penetrant is kept in open bins. Further aspects are subjected to the penetrants shelf life and other conditions of use as for example ultraviolet radiation, temperature, contamination or evaporation. So, the penetration system performance has to be monitored by the user periodically by using a »Test Panel Type 2« according to ISO 3452-3. Experiences have indicated further that the test panel itself and especially its artificial defects have to be inspected periodically. The artificial defects can appear less than original because of pollution. And it is also possible that the dimensions of these defects can increase by chemical strain or thermal stress. So, a calibration of test panels has to be done annually. Using test panels correctly enables the user to monitor the penetrant test in order with the technical standard as well as to guarantee a high performance in application.

MPA Hannover has a lot of long-lasting experiences in production and calibration of test panels for PT. From 1987 till 1995 »Test Panels Type B« according to DIN 54152-3 have been produced. Since 1995 »Test Panels Type 2« according to technical standard ISO 3452-3 are produced and delivered worldwide. On basis of the outstanding experiences MPA Hannover accredited according to ISO/IEC 17025 for verification of »Test Panels Type 2« according to ISO 3452-3. By this, MPA Hannover is a qualified partner for industrial customers.

Keywords – NDT Non-destructive testing, PT Penetrant Testing, ISO 3452, Test Panel, Calibration, Verification.

I. INTRODUCTION

Penetrant testing (PT) is one of the first ever industrial established non-destructive test procedure for detecting surface discontinuities. Because of its outstanding sensitivity as well as easy use this test procedure is even today widely used in various fields of industry. As example can be mentioned automotive industry or aerospace industry. PT also can be used for manually testing of single parts as well as automatically testing of repetition parts in serial production.

Increasing of demands with respect to quality assurance aspects requires procedures to verify the test itself. Developing these verification procedures have been started by the 1970s whereas the actual verification procedure is described by standard ISO 3452-1. Alteration of penetration system performances is often known if the penetrant is used repeatedly or the penetrant is kept in open bins. Further aspects are subjected to the penetrants shelf life and other conditions of use as for example ultraviolet radiation, temperature, contamination or evaporation. So, the penetration system performance has to be monitored by the user periodically by using a »Test Panel Type 2« according to ISO 3452-3.

II. HISTORY AND TECHNICAL STANDARDS FOR TEST PANELS

The »Test Panel Type 2« is described actually within standard ISO 3452-3 (since 1999). But this »Test Panel Type 2« has already replaced a former »Test Panel Type B« according to German standard DIN 54152-3 by issuing the European standard EN 571-3 in 1995. Both test panel types (»Test Panel Type 2« according to ISO 3452-3 resp. EN 571-3 as well as former »Test Panel Type B« according to DIN 54152-3) have been produced at MPA Hannover since 1987 until now and will be distributed worldwide. This »Test Panel Type 2« offers the user the possibility to monitor the test procedure in accordance with the standard which leads to an increase of application security of the test performance itself.

Penetrant testing is used to detect discontinuities, e.g. cracks, laps, folds, porosity and lack of fusion, which are open to the surface of the materials to be tested. The applicable technical standard for this test procedure is ISO 3452 which is subdivided by several parts. All parts are under the headline »Non-Destructive Testing / Penetrant Testing«. Part 1 of this standard contains the general principles whereas part 2 describes the testing of penetrant materials. Part 3 includes specifications for reference test blocks and part 4 for the equipment. Part 5 and 6 are giving requirements for using penetrant testing at temperature higher than 50 °C (part 5) respectively lower than 10 °C (part 6).

ISO 3452-1 determines requirements for the test procedure. One of these requirements are those concerning monitoring the test procedure itself which are described in ISO 3452-1 annex B. These requirements are obligating the user to verify the process and penetrant system performance before start of each work period according to section B 3.2. Concerning this standard this has to be done by using a »Test Panel Type 2« according to ISO 3452-3. Alternative known defect standards may be used where authorized by a suitable qualified person, e.g. ISO 9712, level 3.

In ISO 3452-3 there are two different types of test panels described. »Test Panel Type 1« is used for verifying sensitivity levels within type test or batch test of the penetrant itself whereas »Test Panel Type 2« is used for routine monitoring of the penetration system performance.

III. PRODUCTION OF TEST PANELS

The »Test Panel Type 2« is produced by using stainless steel sheet which is nickel-chromium-coated. On one half of the reverse side five hemispherical indentations are created by using different loads. This leads to artificial crack areas with various dimensions at the opposite side. On the other half front side of the test panel there are four areas with various roughness which are used for checking the rinsability of penetrants. Figure 1 is showing a »Test Panel Type 2« in technical drawing and while using a fluorescent penetrant. Typical diameters of the crack areas are determined in ISO 3452-3 as given in table 1. The dimensional tolerances are +/- 10 % if nothing else is stipulated.

Table 1: Dimensions of crack areas

defect number	typical (diameter) dimensions [mm]
1	3
2	3,5
3	4
4	4,5
5	5,5

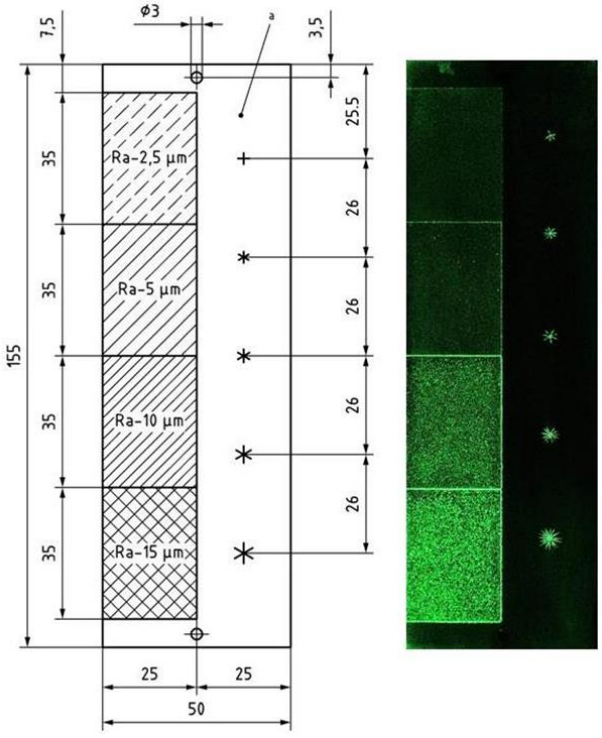

Fig. 1: »Test Panel Type 2« according to ISO 3452-3 (dimensions in mm according to ISO 3452-3 [left] and using a fluorescent penetrant [right])

The manufacturing steps are shown in figure 2. Because of the influence of several parameters the creating of artificial defects is relating to an imperative of wide experience. Variations concerning coating the steel plate or variations concerning the mechanical properties of stainless-steel material can be mentioned as having an important influence.

Often the determined dimensions of the defects can be obtained after loading for the hemispherical indentations

for several times. The test panel has to be dimensioned after each load as shown in figure 3 and figure 4. If one crack area is out of dimensional tolerance this means to refuse the test panel. The appearance of these artificial created defects differs widely. So, each test panel is unique and is marked by an individual serial number. Besides this each test panel is further marked permanently on reverse side by declaration of producer and technical standard. The effective size of the artificial defects is issued in a declaration stating the conformance 3.1 according to ISO 10474 resp. EN 10204. The dimensional measuring of each crack area is done by a special microscope including using a stage micrometre and a fluorescent product family according to ISO 3452-2 (I Aa level 2).

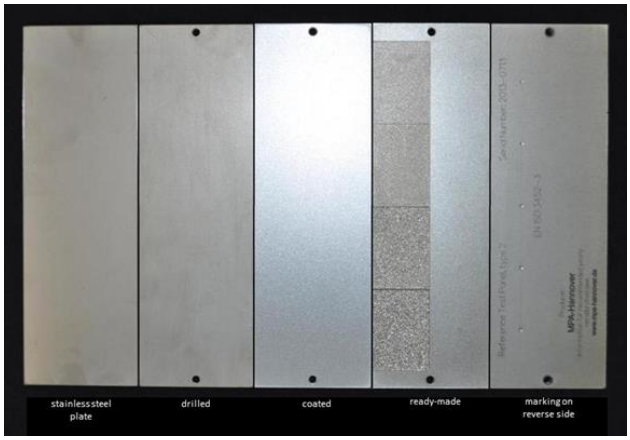

Fig. 2: Production steps

Fig.3: Dimensional measurements of artificial defects

IV. USE OF TEST PANELS

Checking the penetrant testing itself is necessary to assure the reproducibility of the penetrant test procedure. The main important check is verifying the visibility of the penetrant indications by using the test panels while monitoring the system performance. This performance may be altered for example if the penetrant is polluted or evaporated.

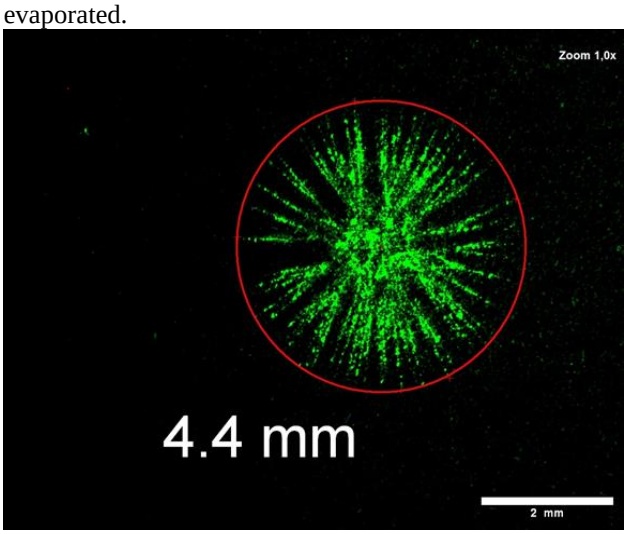

Fig.4: Typical indication of an artificial defect

This alteration may happen if the penetrant is used repeatedly and/or the penetrant is kept in open bins. But also, storage or other environmental conditions like UV-A radiation or temperature have a negative effect concerning the penetrant system performance. Basically, also penetrants which are used just for one time or delivered in aerosol containers are may be affected by these conditions. Because of this, monitoring the system performance by using a »Test Panel Type 2« is also recommended or even required sometimes for manual penetrant testing. Penetrants which are in accordance to ISO 3452-2 are marked with an expiry-date and by a batch-no. which enables traceability to relevant quality records.

The »Test Panel Type 2« has to be used for a first check with a fresh penetrant. This first check has to be done under same test and examination conditions as given for later regular tests. The examined results (quantity, detected discontinuities and level of background) shall be recorded, for example by a photograph on a scale 1:1 as possible. The quantity of detected discontinuities depends by the used penetrant system. It may be that not all artificial defects can be detected within the first check. It is not possible to realize a relation concerning the sensitivity level according to ISO 3452-2. The detected discontinuities should just be used as a basis of comparison for penetrant system performance.

In order to monitor the penetrant system performance periodically the actual results are related to above mentioned recorded first check. The detected discontinuities and the level of background shall be the

same. Otherwise the penetrant system shall be refreshed or other corrective action has to be taken. Of course, also the test panel itself may be out of tolerance. In this case the test panel has to be inspected and a re-calibration is recommended.

The »Test Panel Type 2« can be used with fluorescent penetrant as well as with colour contrast penetrant (figure 5). After using the test panel all penetrant and wash-fluid residues have to be removed completely. While not using the test panel it can be stored in a suitable solvent. But the solvent shall not effectuate any modification of the test panel.

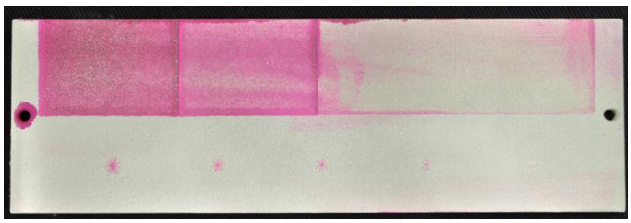

Fig. 5: »Test panel type 2« (with colour contrast penetrant)

While using the »Test Panel Type 2« various application errors can occur. This may lead that indications of the discontinuities cannot be detected or the detectability of the defects may be reduced significantly. Possible application errors are for example:

- Using the wrong side of the test panel, because the indentations are misinterpreted as defects
- Exorbitant excess penetrant removal which leads to no indication of discontinuities
- Incorrect penetrant removal after use or incorrect storage of test panel with residues in crack areas
- Executing the first verifying check by using other test or viewing conditions than for regular monitoring use

The »Test Panels Type2« are often used in various industries like aviation industry, railway industry or automotive industry.

A very high level of safety is required in aviation industry with respect to extremely mechanical and thermal stress while use and dramatic effects in case of failure of safety relevant components. Because of this, non-destructive testing is used often while production or maintenance of aircraft components. A lot of these components are made of non-ferrous metal as for example aluminium alloy, magnesium alloy or titan alloy. Figure 6 shows an aircraft wheel rim (inboard rim made of aluminium alloy). Within the penetrant testing using a fluorescent penetrant an unacceptable linear detection was indicated. The penetrant system performance has been monitored while this test by using a »Test Panel Type 2«. Also, other components of aircrafts as for example fixing brackets for seats are tested by penetrant testing mostly directly at the job shops.

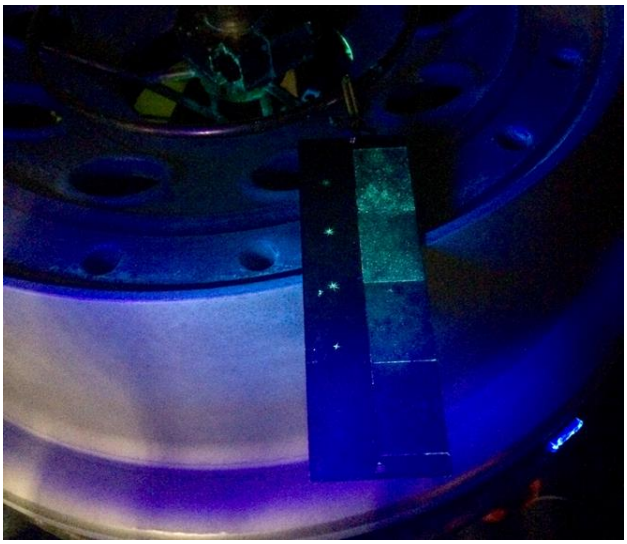

Fig. 6: Aircraft wheel rim including »Test Panel Type 2«

Another example for the use in aviation industry is the use while maintenance of turbo-jet engines. These engines are disassembled for inspection in regular intervals. Concerning to the used materials and the required detection limit it is necessary to use fluorescent penetrants with a high sensitivity level and longer penetration time as well as longer development time. Even if an automatic or a manual penetrant test procedure will be done the penetrant system performance will be monitored by test panels at begin and end of work period respectively while shift changeover (Figure 7).

Fig. 7: Penetrant test processing line for turbo-jet engine components

Also, in railway industry non-destructive testing is an essential element of quality assurance. Because of dynamical stress of components while train operation it may happens that operational failures occur. These failures are often repaired by using welding procedures. The quality of the welding seams has to be proved by non-destructive testing. Typical components which are tested by using the penetrant test are welding seams of frames and bogie frames or welding seams of bumpers or coupling rods. The monitoring of the penetrant system performance by using a »Test Panel Type 2« and requirements for documentation of quality records are given in standard operation procedures issued by various railway traffic companies. For example, in Europe the standard VPI 09 (issued by German Association of Freight Car Owners) is used usually and requests that at least 4 of 5 crack areas shall be detected by using the »Test Panel Type 2«.

In automotive industry a lot of safety relevant components will be produced and assembled in cars. A lot of these components are tested and the tests are documented in quality records. Examples for these components are chassis components, engine blocks, valves, steering gear cases etc. These components are often produced by light metal casting or by drop-forge procedures with corresponding surfaces and a complex geometry. Therefore, the penetrant test in combination with an automatic processing is an appropriate procedure. Testing of several thousands of components per day is a normal quantity. The use of test panels in order to monitor the penetrant system performance and the documentation of this verification is obligatory recommended in quality standards of automotive industry.

V. VERIFICATION OF TEST PANELS

Quality standards as ISO 9001 or ISO/IEC 17025 request to calibrate or verify test equipment in periodic intervals. The characteristics of the test panels are may altering by use which effects the test results. The artificial defects can appear less than original due to pollution. And it is also possible that the dimensions of these defects can increase by chemical strain or thermal stress. Figure 8 shows a »Test Panel Type 2« which is corroded heavily compared with origin conditions according to ISO 3452-3. A detection of the artificial defects within the crack area is for this corroded test panel not possible anymore.

ISO 3452-1 recommends a calibration of the test panels annually. The calibration should be done by an accredited laboratory or the producer of the test panel in accordance to ILAC P10. Also qualified personnel (e.g. in accordance to ISO 9712 level 3) is permitted by ISO 3452-1 to verify alteration in order to take corrective actions.

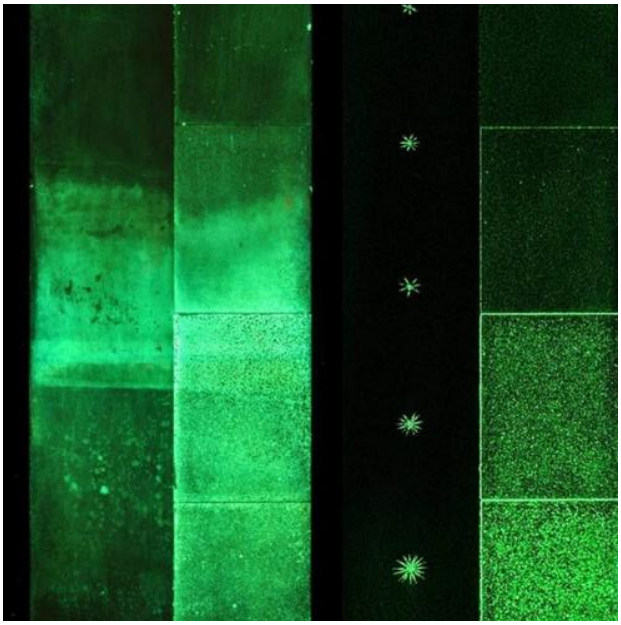

Fig. 8: »Test Panel Type 2« (left: coating corroded / right: origin condition)

During the re-calibration the first activity is an extensive pre-delivery check. After a visual reception control a penetrant test will be done according to ISO 3452-1 using a fluorescent penetrant according to ISO 3452-2 (I Aa level 2). The detected discontinuities are measured dimensionally in same way as it was done for the first calibration before delivering the »Test Panel Type 2«. The measured results are compared with the requirements given in ISO 3452-3 and will be recorded. With respect of a lot of experience in re-calibration it was realized that for a lot test panels the effective size of the indication of crack areas are reduced and out of the dimensional tolerances. Just in some cases an increasing of the indication size was identified.

If the results fulfil the requirements given in ISO 3452-3 a new declaration stating the conformance will be issued. In this new declaration the actual effective sizes of indication of the artificial defects are documented. If the results are out of the dimensional tolerances it depends if the effective sizes have been decreased or increased. If the effective sizes have been increased and the results are out of dimensional tolerances these test panels have to be substituted and the customer gets a notification including a test record with the negative results. If the results of the effective sizes have been decreased but out of dimensional tolerances a special

multi-level cleaning treatment of the crack areas will be done. In most cases the sizes of indication of the artificial defects are in accordance to the dimensional tolerances after this treatment. In that case the declaration stating the conformance documents the results before and after the cleaning treatment.

VI. SUMMARY

Using test panels correctly enables the user to monitor the penetrant test in accordance with the technical standard as well as to guarantee a high performance in application. Experiences have indicated further that the test panel itself and especially its artificial defects have to be inspected periodically. So, calibration of test panels has to be done annually. MPA Hannover has a long-lasting experience in production and calibration of »Test Panel Type 2« according to ISO 3452-3 (Figure 9). Further MPA Hannover is accredited according to ISO/IEC 17025 for verification of »Test Panel Type 2« according to ISO 3452-3. Due to this competence and long-lasting experience MPA Hannover is a qualified partner for penetrant test panels.

Fig. 9: »Test Panel Type 2« in storage box