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Digital radiography – Preparation of the System for Tests

Abstract: Digital radiography is becoming increasingly popular in non-destructive tests of welded joints and castings, enabling the obtainment of a repeatable testing method and the minimisation of test time. However, the obtainment of proper test results requires the verification of quality levels (during tests of products) in accordance with a related standard concerning a given product or following the customer's specification. In terms of digital radiography, the process of preparation significantly affects test results. For this reason, the article discusses the calibration of a testing system, enabling the obtainment of enhanced detectability and the satisfaction of primary quality requirements.

Keywords: Digital radiography, non-destructive tests of welds

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Introduction

Increasingly high requirements concerning welded joints, such as satisfying the criteria of quality level B in accordance with PN EN ISO 5817 or B+ according to PN EN ISO 10902, necessitate the application of solutions enabling the precise analysis of entire joints. The appropriate selection of testing methods and techniques adapted to elements and material grades ensure the complete verifiability of a product in accordance with related requirements. Both at the stage of production and during diagnostic tests, the power generation or aviation industry require fast and precise tools enabling the verification and detection of any welding imperfections in the weld and adjacent heat affected zone. The use of poorly weldable and demanding materials, including austenitic steels, requires the repeatability and high quality of methods applied to test the quality of welds. The method which has dominated this area for many years is radiography. The radiographic method makes it possible to test elements characterised by complicated shapes, short diameters and varying thicknesses, i.e. where the alternative ultrasonic testing technique requires the application of special procedures in relation to objects of thicknesses below 8 mm. However, the radiographic method is not free from disadvantages. This method is definitely time-consuming and does not always enable the satisfaction of expected quality level-related requirements. The digital technique was developed in order to overcome at least some of the downsides of the radiographic method. Digital radiography has been successfully used in non-destructive tests and has become increasingly popular among users, also in Poland. The replacement of the X-ray film-based imaging with the digital matrix-based one translates into a reduced inspection time, the obtainment of a result on a real-time basis

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and certainty that obtained images meet quality-related requirements. However, to be effective, each testing technique must be prepared and calibrated to ensure the stability of tests at every stage. Digital radiography constitutes a set of two elements integrated into one whole and composed of a digital detector array (DDA) and a radiation source.

Selection of equipment

The present-day "NDT market" offers many digital radiography devices, the selection of which depends on the specification of a product, e.g. dimensions and thickness of an element to be tested and quality-related requirements which should be satisfied. An important aspect when selecting a digital detector array (DDA) is the size of a matrix pixel. The smaller the pixel, the greater the detectability, yet often at the cost of image quality induced by the reduced signal-noise ratio (SNRN). It should also be noted that each digital detector array is characterised by specific service life related to a specific number of working hours, i.e. exposure to radiation. Other parameters include the type of a scintillator (transforming radiation into visible light, the range of grey value, the range of applied energy and software provided by the producer. To this end, when selecting equipment it is necessary to compare available solutions and perform tests enabling the identification of strengths and weaknesses. Depending on a product subjected to a test, it is important to select the source of radiation, e.g. the power generation industry often uses isotopic sources Selen-75 or Iryd-192, whereas in cases of advanced applications such as aviation, microfocus lamps are used. Everything depends on requirements to be satisfied and the importance of their satisfaction to the user. Because of the fact that each producer of digital radiography equipment has their own approach and solutions and differently defines the preparation of the system for tests, it is immensely important to understand producer's guidelines and adjust the entire calibration procedure in order to obtain the best possible images of elements subjected to verification.

Preparation for calibration

Having completed a test set i.e. a digital detector array along with a radiation source, it is necessary to define the test system, parameters of exposure and quality requirements to be satisfied in order to consider a given image acceptable. The next step involves the performance of test exposure aimed to asses a welded joint through the verification of, among other things the value of SNRN. The value of SNRN should be measured in the weld area, in addition to IQI, in an area characterised by uniform thickness and homogenous grey value. Because of the fact that the weld area is not homogenous, the measurement of SNRN is usually performed in the base material, yet the aforesaid value should be multiplied by a factor of 1.4. An increase in SNRN is obtained by increasing the number of overlapping images, leading to improved image quality. The test-related standard do not define the grey value (GV) at which assessment should be performed, yet it is recommended to set the GV as close to 50% as possible. The application of higher GV is not recommended because of the fact that some pixels of the matrix indicate excessive saturation and, consequently, local image deficiency. It is also necessary to remember about the appropriate adjustment of the energy range and the level of detectability, simultaneously maintaining the compromise between the testing time and the efficiency of the testing technique. Once operation parameters, the test system and the settings of the detector are known it is necessary to perform the calibration procedure in relation to "offset" calibration (dark calibration) and "gain" calibration (bright calibration) as well as in relation to the correction of the map of bad pixels. The performance of calibration ensures an increase in detectability in relation to the model of a single IQI wire within the range of 1 to 3 levels of wires than that required by the test-related standard.

Calibration of background

Calibration concerns all active pixels of the matrix and is performed with radiation switched on. The purpose of calibration is to compensate for changes in pixel response intensity in relation to such settings as the size of a pixel, the number of frames per second or the sensitivity of the detector. The sensitivity of each pixel varies. Because of this, before the calibration of background it is advisable to wait approximately 30 minutes for the compensation of temperature and operational stability of the entire matrix. After the above-named time it is necessary to perform dark calibration following guidelines specified by the producer to obtain a homogenous black image indicating the proper compensation of pixels.

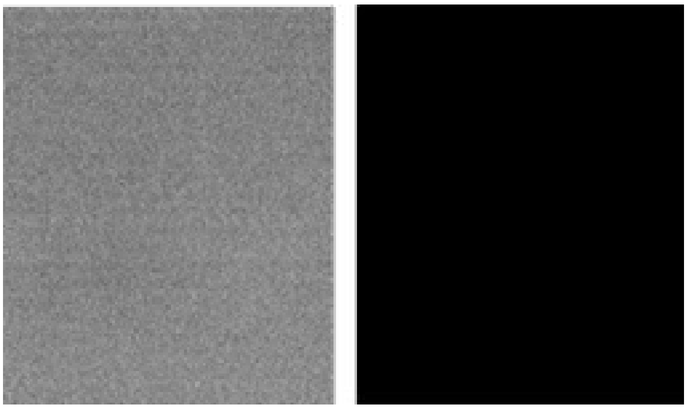

Fig. 1. Comparison of an image without the calibration of the background (A) and with the calibration of background (B)

Calibration of gain

Because of the fact that each pixel responds otherwise to the same dose of radiation, the calibration of gain consists in the adjustment of a pixel correction factor. The software programme automatically adjusts the value of the factor, multiplying it by the value of a dose reaching a given pixel (of the matrix) during exposure. As a result, obtained images are homogenous and free from bands or areas characterised by varying grey. The calibration of gain should always be carried out separately for each radiation source combined with the detector. At a later stage it is necessary to call (from a related software programme) calibration proper for the type of a radiation beam. Calibration should always be performed with radiation switched on, where the path between the detector and the source of radiation should remain undisturbed. As a rule, a distance between the detector and the source of radiation is restricted within the range of 850 mm to 1200 mm (in uniform lighting conditions). The setting of gain is usually performed in relation to one calibration point, yet it can also be performed for several points (depending on producer's recommendations). Some producers state that the performance of calibration for one point is sufficient, whereas others claim that a greater number of calibration points (usually restricted within the range of 3 to 5) guarantees an increase in image quality. In solutions presently available on the market, the entire process of the calibration of background and gain proceeds in a similar manner. However, the entire selection and process depend on the user and their individual preferences.

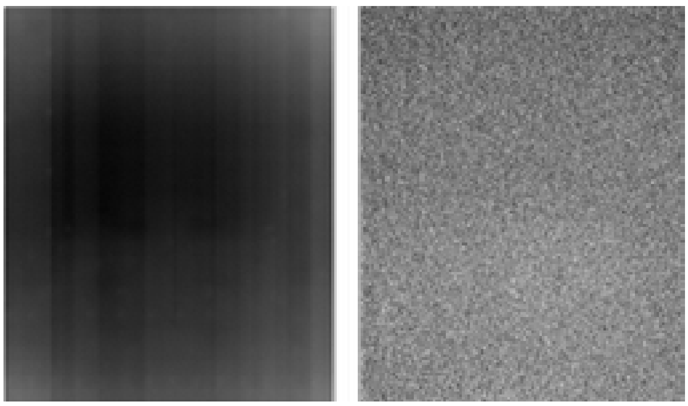

Fig. 2. Comparison of an image without the calibration of the background (A) and with the calibration of background (B)

Map of bad pixels

An indispensable element concerning the preparation of a system for tests and the stage of image assessment is the understanding and specification of requirements related to a map of bad pixels. For this purpose it is necessary to refer to the specification related to the production of digital detector array in accordance with standard ASTM E 2597, stating that each newly supplied detector should be provided with its individual map of bad pixels. To this end, to understand the above-named issues it is necessary to discuss individual definitions:

- bad (dead) pixel – pixel not reactive to any radiation dose;
- hyperreactive pixels – pixels, the grey scale values of which are higher than 1.3 times the mean grey value in relation to an area of minimum 21 × 21 pixels;
- hyporeactive pixels – pixels, the grey scale values of which are lower than 0.6 the mean grey value in relation to an area of minimum 21 × 21 pixels;
- noised pixels – pixels, the standard sequence deviation of which amounts to between 30 and 100 images without radiation and is six times greater than the standard pixel median deviation in relation to the entire detector system;
- heterogeneous pixel – pixel, the deviation of which exceeds the average value of 9 × 9 of the neighbouring pixel by more than ±1%. A test should be performed in relation to an image, the mean grey values of which amounts to 75% or more of the detector value (line— ar range);
- pixel afterglow/delay – pixels, the deviation values of which exceed by more than one the factor equal to two mid-values 9 × 9 of the neighbouring pixels in the first image after shutting down X-radiation and which exceed six times the mean value of noise in a dark image;
- bad neighbouring pixels – pixels, where all eight neighbouring pixels are bad pixels (also regarded as bad pixels).

In addition, the standards define groups and types of bad pixels:

- bad pixel – pixel not responding properly to radiation doses and having more than 5 good pixels in its neighbourhood. On the above-named basis it is possible to average collected data because of which a given area provides the complete range of information about the spot subjected to inspection;
- cluster of bad pixels – two more pixels connected with one another, having at least one common side. Also in the above-presented case, averaging guarantees the complete evaluability of areas.

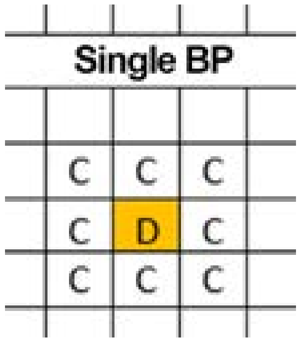

Fig. 4. Single bad pixel

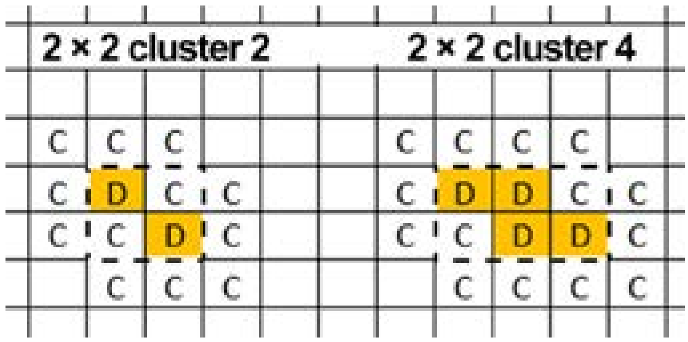

Fig. 5. Clusters of bad pixels

bad cluster – cluster kernel pixel (CKP), where bad pixels have less than five good pixels in its neighbourhood. As a result, such areas preclude interpolation and, consequently, create areas potentially containing welding imperfections which cannot be subjected to assessment. Because of this, it is not recommended to perform assessment in an area containing the CKP. Furthermore, a person carrying

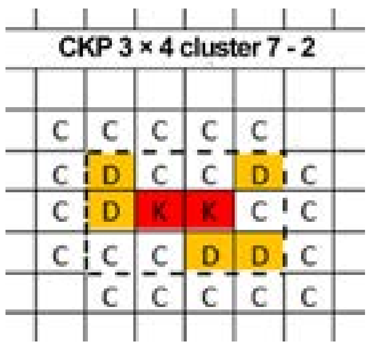

Fig. 6. CKP – cluster kernel pixel

out a test should record the presence of the above-named area and check, on a regular basis, whether such an area has not increased.

Many producers of digital radiography systems offer tools for the editing and comparing maps of bad pixels, which quickly and easily enable the obtainment of information about changes occurring in the matrix. Each digital detector array contains bad (dead) pixels, i.e. pixels not reacting properly to radiation doses. The making of an ideal matrix is nearly impossible and, with the passage of time and as a result of the bombardment of the matrix by the electron beam, the efficiency of pixels decreases gradually, leading the reduction of matrix life. There is no standard defining the range where the level of bad pixels or cluster obliges the user to replace a detector. The only regulations concerning the area characterised by the presence of CKP (PN EN ISO 17636-2) state that the performance of tests in such areas is unacceptable. Furthermore, the aforesaid regulations state that other areas can be subjected to tests as long as the detector satisfies quality-related requirements in terms of the normalised SNRN or the detectability in relation to the quality indicator of IQI and IQI image of Duplex type.

Verification

Another stage involves the verification of calibration as regards the quality of the image of an object being examined and the reference to related standards or specifications, i.e. the qualification of a test system. It should be verified whether requirements are satisfied at least to a minimum extent, yet, because of the gradual burning of the lamp focus or a decrease in detector efficiency, it is advisable to obtain quality levels higher than recommended. Such an approach enables the performance of tests with a significant margin and certainty that an inspection will definitely enable the detection of any welding imperfections in a product. In cases where results do not satisfy related requirements, the entire procedure of the adjustment of testing conditions, including calibration, must be corrected and repeated so that it can meet customer's requirements and satisfy test-related standards.

Frequency of calibration

The standards do not define the frequency of calibration, neither dark nor bright. However, with the passage of time or in cases of changes in surrounding conditions, the detector responds otherwise than it did directly after calibration. Calibration can be performed in the event of artefacts appearing in an image or in cases of problems concerning the satisfaction of quality-related requirements. In addition, after a short period of tests, it is possible to specify the frequency of calibration ensuring the obtainment of the best test results. As a rule, it is assumed that dark calibration should be performed at least once a week, whereas bright calibration should be performed at least once a month. Where, within the above-named periods, symptoms indicating the deterioration of images appear sooner, the period within which calibration should be performed needs to be shortened.

Summary

The entire process of selecting an appropriate testing technique and quality-related requirements are described in the following standards concerning non-destructive tests:

– PN EN ISO 17636-2 Non-Destructive Testing of Welds – Radiographic Testing - Part 2: X and gamma-ray techniques with digital detector,
– PN EN ISO 12681-2 Founding – Radiographic Testing – Part 2: Techniques with Digital Detectors.

However, neither of the above-named NDT-related standards contains clearly specified criteria in relation to a calibration procedure, frequency of calibration and requirements concerning the applicability of a detector in relation to the map of bad pixels. To this end, personnel performing digital radiographic tests should develop their own procedures, clearly and precisely describing all performed activities and ensuring the repeatability as well as the proper methodology of tests. It is in the laboratory's best interest to protect itself against deviations or divergence (as regards related standards) in the testing procedure, which should be approved by the ordering party.

References

[1] PN EN ISO 17636-2 Badania nieniszczące spoin - Badanie radiograficzne - Część 2: Techniki promieniowania X i gamma z detektorami cyfrowymi.
[2] E2597 Praktyki w zakresie właściwości produkcyjnych dla detektorów cyfrowych.
[3] Mackiewicz S.: Badania złączy spawanych technikami radiografii cyfrowej w świetle wymagań normy EN ISO 17636-2, KKBR, Popów 2013.