SMOC

DIGITAL X-RAY INSPECTION SYSTEM

IMAGINERT

DRAWN UP BY A TEAM OF RESEARCHERS
FROM THE NATIONAL CENTER FOR NUCLEAR RESEARCH ŚWIERK

Introduction

Radiography examination is one of the most effective methods of non-destructive analysis. Widely used in defectoscopy, it can detect damage, leaks, material defects, etc. Typically X-rays and γ-radiation are used, with energies suited to the type and thickness of the tested objects.

The source of radiation can be X-ray tubes, radioactive isotopes, linear electron accelerators or betatrons with a conversion target. In case of objects with significant thicknesses, linear accelerators dominate due to high efficiency and high radiation energy. Traditionally used detector is a photographic film. Its advantages were and still are: the high resolution, low price and widespread availability. The disadvantages include the necessity of chemical processing and the associated costs, storage (catalogs, cabinets, warehouses), low image dynamics, the lack of computer methods for image correction and modification (contrast, brightness, summation, subtraction, etc.), lack of imaging in real-time and, for example, online observation and registration of occurring processes. Therefore, the natural way to improve the radiography is so-called digital radiography, when the image can be received on the computer screen.

The first possibility of digitizing the radiography is digitalization, i.e. scanning of the film, so that the result of the examination can be saved as a file in PC. Such solution enables image processing, efficient copying and archiving. However, the low dynamics of images still remain a disadvantage. The "overexposed" or "underexposed" film will remain so. The scan is a copy that does not reflect 100% of the image quality obtained on the film.

The second method available on the market is indirect digital radiography CR (Computer Radiography). It consists on the irradiation of reusable phosphor plates, which can then be read and simultaneously "erased" using UV light (or IR). CR plates offer high resolution and digital form of the examination. However, they show sensitivity to mechanical scratches. Also, they may be left with "ghosts" or remnants of previous pictures. Real-time imaging is not possible, since it is also an indirect test, i.e. to obtain an image, the CR plate must be taken from the test site. It may then turn out that the exposure time was, for example, too short, which requires repeating the entire test with the detector being placed back.

The third option is the direct digital radiography DR (Digital Radiography). It involves the use of electronic detectors displaying the image directly on the computer screen. These devices are free of the most inconveniences of X-rays films and CR plates. Only sensitivity to environmental conditions (e.g. temperature and humidity in field tests) can be mentioned, hard form (e.g. in tube testing, film flexibility is an advantage) and high price. For energy below 100 keV, CMOS technology dominates, for higher - amorphous silicon technology. The prohibitive price and the sensitivity of detectors to high doses of radiation cause that currently on the market of industrial radiography both in Poland and Europe, traditional X-ray films still play an important role. The goal of R&D activities performed at NCBJ was to develop an electronic detector that could be an alternative to X-ray film.

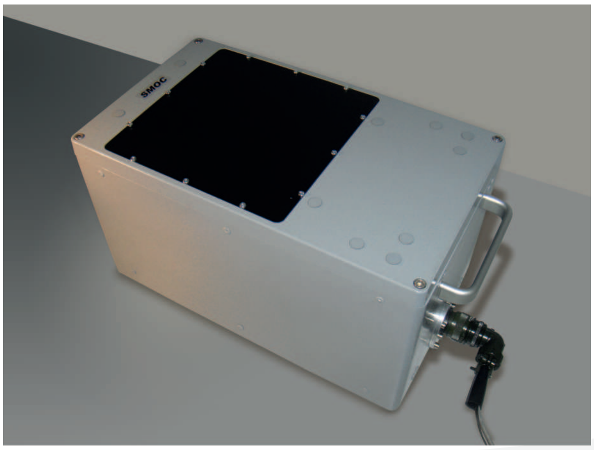

Fig. 1 Detector SMOC_STD.

The advantage of the device over other methods

In comparison to films

- image obtained immediately
- image in digital form
- possibility of improving image quality with digital methods
- no need to use chemical solvents, which in the long run translates into lower costs
- significant saving of time and workload
- lower archiving costs
- the ability to efficiently search and reproduce images with the information assigned to them
- no aging effect
- fast access to test results from many places by computer network

In comparison to CR detectors

- image obtained immediately without the necessity of indirect reading
- low sensitivity to mechanical damage (scratches, etc.)
- no "ghost" effect, i.e. remnants of the previous image
- no "fadding" phenomenon, i.e. disappearance of the recorded image between the acquisition of the CR plate and its reading by the scanner

In comparison to DR detectors based on amorphous silicon matrices

- greater resistance to radiation, which gives a longer life
- no effect of damaged pixels
- size of the detector adapted to the customer's needs

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Available options

keV energy range

In Fig. 1 the SMOC_STD detector is shown with 20cm x 20cm active area. It is adapted to work in the energy range corresponding to X-ray tubes and radioactive isotopes such as Ir-192 or Se-72. It is possible to manufacture the detector with other dimensions of the active area, tailored to the customer's needs.

High energy range

For the high energy range, when a linear accelerator or betatron is used, SMOC_HE is the best choice. Due to the thicker scintillation screen and integrated covers which protect all sensitive elements, long- term and effective work in the energy range 1 - 15 MeV is possible. The active area of the detector can be adapted to the customer's needs and can even exceed 1m x 1m. The following versions of the SMOC_HE device have been manufactured so far: SMOC_HE_40x40, SMOC_HE_40x60 and SMOC_HE_50x60.

Resolution and precision of the SMOC detector

Detectors from the SMOC family achieve very good results of testing accuracy. In case of large, dense objects (Fig. 4-5), tested with linear accelerator, the accuracy of visible defects is approx. 0.5% in relation to the thickness of the detail. It means that for 100mm thick steel element, 0.5mm deep defect can be visualized with the SMOC detector (for example emptiness, crack, inclusions, etc.), while the standard accuracy of the radiographic method is estimated at approx. 2%.

Fig. 2. Detector SMOC_HE_40x40, active field 40 cm x 40 cm. (on a platform elevator)

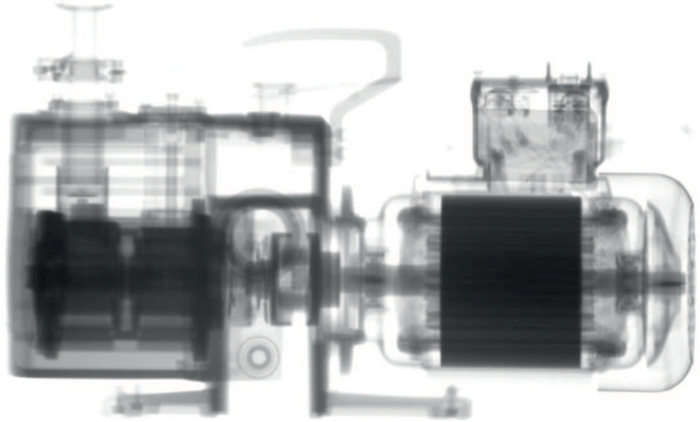

Fig. 3. Radiogram of the pump as an example of precise radiography of large and dense objects using the accelerator.

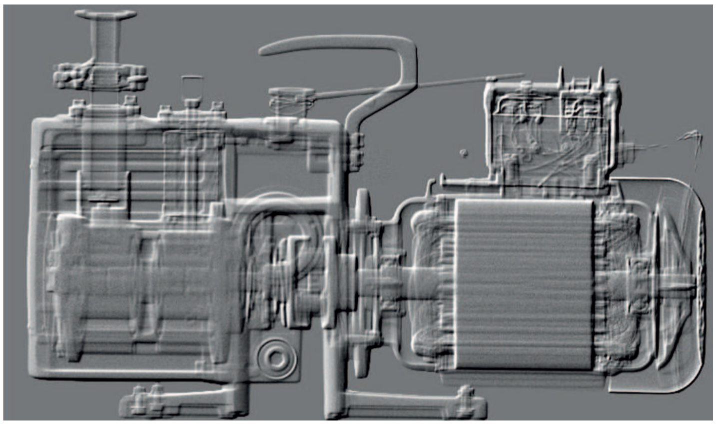

Fig. 4. The same radiogram of the pump with digitally improved parameters using the ImagineRT D-SMOC software, in this case the differential filter in negative is applied.

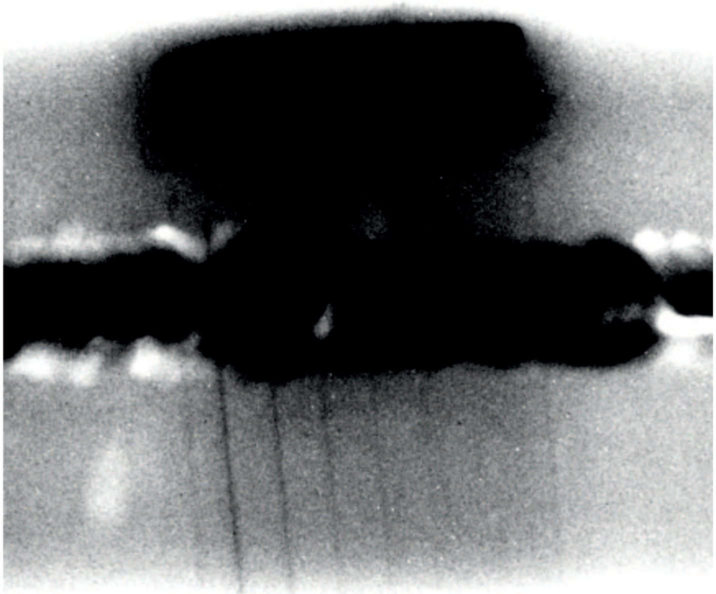

Fig. 5. Radiogram of the weld made with SMOC_HE_40x40 detector. Steel plates, 10mm thick, X-ray energy 220kV. Class B is achieved, bottom: details of the weld, top: zoom and brightness modification for penetrameter visibility.

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The SMOC_HE and SMOC_STD detectors for double-wire method reach the level 7D (0.2mm) in accordance with the ISO 19232 standard. This method consists on the scanning of two identical thickness wires, whereas the distance between them is equal to the thickness of each of them (see Fig. 6). Achieving a given level of accuracy by the detector means that it shows both wires and the gap between them.

Fig. 6. Picture of double-wire pattern made with the SMOC_HR detector, where the resolution was 12D (0,063mm).

In case of smaller objects or made of less dense materials, tested with an X-ray tube (or other energy source) and SMOC_HE or SMOC_STD detector, **the accuracy from approx. 0.12 mm up to 0.05 mm can be achieved** (see Fig. 8-11). Even greater accuracy - approx. 0.063mm = 63um - is obtained with the SMOC_HR device, however, this applies only to elements with very low density (e.g. organic).

SMOC detectors software

SMOC detectors are equipped with dedicated ImagineRT D-SMOC software. It is the result of several years of software development for digital radiography. Its user-friendly interface (Fig. 7) has been refined for use in non-destructive testing and experiments.

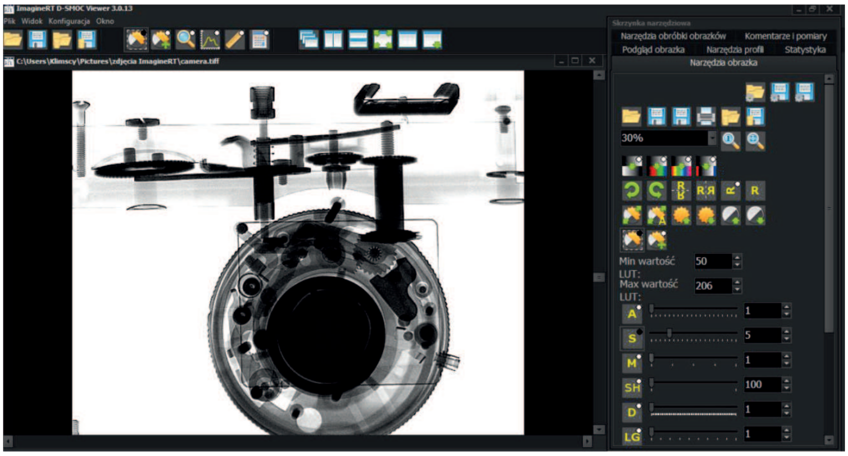

Fig. 7. ImagineRT D-SMOC software interface. In the main window radiogram of the camera is clearly visible.

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In addition to the standard display of images with a large depth, it is possible to process (and save) the radiograph using various types of filters. They often allow for better illustration of the examined objects' details, see Fig 9-11.

The ImagineRT D-SMOC software also includes tools for geometric measurements (such as length, width, angle), the ability to zoom-in, adjust brightness and contrast, rotate an object, make comments etc. The software can be operated in Polish, English or Italian language. The addition of another language version is also possible. The software reads most of the known graphic formats used in radiography (including HIF, DICOM / DICONDE, 16-bit TIFF), and allows recording in some of them, as well as in typical graphic formats, such as JPEG or BMP. In addition to detectors from the SMOC family, the software supports some of the DR detectors, so-called flat panels. Thanks to the D-SMOC software, it is possible to integrate few detectors with radiation sources (e.g. accelerators). The software is created in an open architecture, thus some new, non-standard functionalities can be prepared.

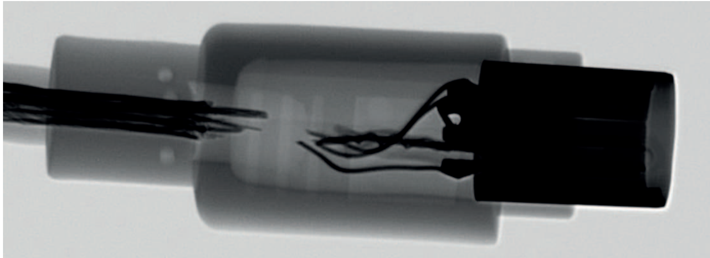

Fig. 9. The same picture using the sharpening filter. It allows for better contours illustration, show gaps or distances between elements. Here, for example, the individual wires and the space between them can be seen.

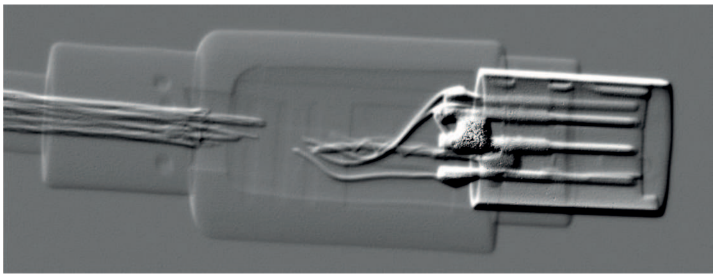

Fig. 10. The differential filter gives three- dimensional features to 2D image. It allows for clear visualization of some emptiness's, texture differences of internal elements. Here, for example, a clearly visible solder structure.

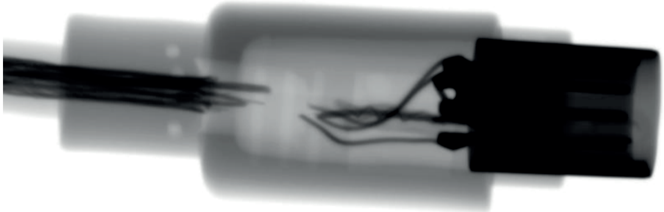

Fig. 8. A standard digital x-ray image of a plug with defects.

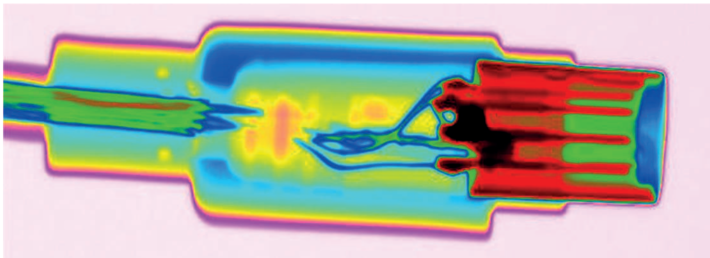

Fig. 11. The use of pseudo-colors allows to see more details of the object in comparison to classic grey levels in B&W image. In this case, for example, differences in density between metal elements, especially on the right side of the image are visible.

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Connection of the device

The SMOC detector has a Gigabit Ethernet interface for PC connection. Thanks to active amplifiers and/or LAN type transfer, it is possible to move the test site from the operator's PC to a considerable distance - even several hundred meters (40m as a standard). It is possible to power detector from a battery, accumulator or a standard 230V power supply. The SMOC detector can optionally be equipped with WiFi interface, enabling wireless connection to PC.

In Fig. 13 interior of the X-ray laboratory bunker equipped with electron linear accelerator and SMOC_HE_50x60 detector is shown.

Weight and dimensions of the device
To achieve resistance to long-lasting work with high energies, lead shields were used to protect electronic components against harmful radiation. Hence, the weight of the SMOC_HE_40x40 device (Fig. 2) is approx. 200kg. Detectors with a different active field size weigh more or less, respectively. The dimensions of the SMOC_HE_40x40 detector are 700/700/700 mm.

Dynamic tests
ImagineRT has introduced X-ray dynamic imaging. Frame rate of 25 fps with Full-HD quality enables the eicient imaging where the rotation or movement of the object takes place.

Special applications ImagineRT offers dedicated custom solutions, such as a detector for radiography of welded joints in configuration: radiation source outside the pipe, detector placed inside. Due to its small size, it allows for testing of longitudinal welds in pipes with a diameter of min. 170mm (Fig. 12).

Fig. 12. SMOC_L detector, 300mm x 80mm active area.

Warranty and service

As standard, we offer a 12-month warranty with possible extension to 36 months.
The manufacturer's service offers a free installation and user training at the recipient's laboratory. Service offers an assistance within 24 hours after reporting a defect.

Technical Specification

Energy range	SMOC_STD from 40 keV do 500 keV SMOC_HE from 100 keV do 15 MeV
Detector sensitive area	from 200 x 200 mm to 1000 x 1000 mm and more (individual request possible)
Image sensor	CMOS/CCD
Grey scale	16-bit (65536 shades of gray)
Image dynamics	65,000 (16 bits)
Size of the pixel	≤ 150µm for the imaging field 400 x 400 mm
Number of pixels	min. 36 Mpx
Time to prepare for work	< 1min.
Single frame acquisition time	from 0.01 to 300sec.
Communication protocol	Gigabit Ethernet, Wi-Fi (optionally)
Power supply	230V battery (optionally)
Cable length detector - PC	40 m (standard) possibility of extension / shortening (optionally)

Fig. 13. Detector SMOC_HE_50x60 in the laboratory of the Wrocław Technology Park.

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