Radioscopy
The Prevalent Inspection Technique of the Future!?

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Trabalho apresentado no:
6º COTEQ – Salvador / BA – 19 a 21 de Agosto de 2002
Abstract

For the past twenty-five years, radioscopy has been employed by a steadily growing number of users. The high degree of flexibility and the potential for automation are the principal advantages of this testing method that enables a reliable and economically attractive materials evaluation. In fact, for the continuous inspection of light alloy metal castings no alternative is in sight. And even in the field of welded seam inspection, a marked tendency has been observed over the past few years to resort with increased frequency to the radioscopic technique.

The quality of radioscopic examination depends as much on what technology has to offer in terms of detectors and systems design as it does on the training level of the inspectors, a fact, by the way, that also is true of all other NDT fields. For some years now, attempts have been made to minimize the influences of possible human errors by training NDT personnel in a job-specific way. A two-level DGZfP course presents the physical and technical aspects of the inspection technique in RS-1 and the possible applications of digitized image processing in RS-2. The experience gained from this course since 1994 has been for the most part positive. Doubtless, it has led to an improvement of NDT personnel’s testing qualifications.

Constant innovations in system engineering enhance machine performance capability which in the case of continuous inspection implies a boost to specimen throughput coupled with a rise in cost effectiveness. Latest developments in system design prove that unattended, i.e. fully automated inspection, when supported by digitized image processing, constitutes state of the art in the automotive industry’s nondestructive testing of safety-relevant suspension parts. Yet even for these automated systems, operators with expert radioscopic knowledge are of the utmost importance when system settings are to be optimized to meet new set-ups for workpiece modifications. In the future, a new generation of detectors will enable further developments in system engineering. The many efforts taken over the years to draw up a radioscopy standard will in the near future come to a successful conclusion. This standard will firmly secure application fields so far existent while opening up new ones.

As computers have developed into more and more powerful and sophisticated tools over the years, it is by now possible to use them for even the most complicated computational processes. The 3D computed tomography e.g. is particularly suited to detect and characterize voluminous defects in materials and components, a fact that explains the importance it has come to assume in recent years.

Introduction

During the past few decades, radioscopy has firmly established itself in a wide range of industrial applications that of necessity depend on instant evaluation and - in the case of continuous inspection - also on a high degree of automation. In fact, radioscopy, in conjunction with digital image processing and automatic image assessment, constitutes state of the art by now as far as the continuous inspection of castings is concerned. This paper will discuss the issue of whether radioscopy can and will be, even in the future, a trend-setting and application-oriented inspection technique.
3 Radioscopy - State of the Art

Generally speaking, radioscopic systems are used in industrial applications for the continuous inspection of objects since these systems allow for flexible settings of the incident beam direction and the inspection perspective as well as for on-line viewing of the radioscopic image (Figure 1).

![Diagram of a Radioscopic System]

Fig. 1 - Schematic array of a radioscopic system

Roughly speaking, an X-ray image is created in a sequence of two steps:

- **Generation** of the attenuation image
- **Transformation** into a visible radioscopic image followed by image transfer

The X-radiation which is produced by the radiating unit passes through the object to generate an attenuation image of said object on the incoming screen of the detector. The geometric resolution or rather the resulting unsharpness in the radioscopic image is set by the Object-to-Detector distance. The relation between the Focus-to-Detector distance (FDD) and the Focus-to-Object distance (FOD) determines the geometric magnification of the image. An image sensor, e.g. an X-ray image intensifier transforms the attenuation image into a visible X-ray radioscopic image.

The transfer chain which is made up of a lens system, a camera and a monitor must then render the emergent image of the X-ray image intensifier visible on the screen so that the operator may view it. Digitization enables the transfer of the image to an image processor for **processing** or **evaluation** of the radioscopic image.

4 History

Already in the late thirties and early forties, **radioscopy with fluorescent screens** was widely known as a non-destructive test method. In the late forties, closed cabinets were used to examine aluminum castings for the automotive industry (Figure 2).
Fig. 2 - System for manual inspection of aluminum parts (about 1948)

In the mid-fifties, X-ray image intensifiers with a binocular were introduced to radioscopic inspection. Next to electrically powered object manipulators, the early sixties launched the image intensifier / TV camera chain which is common to this day, with the difference, however, that the formerly known analogue TV cameras have given way to CCD cameras.

In the early seventies, continuing advancement of the imaging components and the inspection techniques led to a marked increase in the demand for radioscopic systems, especially for those that are intended for the examination of castings and welds. (Figure 3).

In the early eighties, digital image processing techniques were increasingly applied in radioscopy. Digital image processing for the purpose of image enhancement and automatic image assessment must nowadays be regarded as state of the art.

Fig. 3 - Inspection systems with image intensifier / TV camera chains for the examination of castings and welds (about 1970)

Drawing up of a Standard that governs radioscopy, Schooling and training of the NDT personnel and high-performance Systems designed for radioscopic inspection laid the foundation for the success of this examination technique and for a strong increase in applications. These “Three Important S” of radioscopy will continue to
determine the future success of this test method. They will be discussed in the following chapters.

5  The “Three Important S of Radioscopy

5.1  Schooling and Training

In the early nineties, the rising pressure exerted on users of radioscopic test methods to employ certified NDT personnel triggered an increased demand for the training of such personnel. Since 1994, a two-level training course, called RS 1 / RS 2, has been offered by DGZfP in cooperation with renowned manufacturers.

RS 1, a four-day training program, introduces the participants to the basics of radioscopic inspection and the characteristics of different types of imaging systems. Each day comprises four hours of theory and four hours of practice. Up to March 2000, 168 participants had enrolled in the RS 1 course. Figure 4 shows the percentage distribution of participants from different fields of application.

68% of the participants cover the light alloy metal casting industry. This is the largest group. 10% and 20% respectively represent weld inspection and various other applications fields. This participant distribution certainly reflects the application of radioscopy in the various industrial sectors. The large number of participants from the casting industry proves the validity of this training concept that was initiated by DGZfP together with leading manufacturers. The convincing success of the RS 1 course would have been impossible had it not been for the manufacturers’ direct approach of potential users with a keen interest in NDT training, the reason being that it is exactly the users in the casting industry who have no idea whatsoever about the responsibilities that DGZfP has assumed and about the opportunities that DGZfP offers.

Fig. 4 - Participant distribution for different application fields
Starting in 1996, the **RS 2 course** picked up momentum as well. It operates within the same time frame as the RS 1 course, but places its main emphasis on **digital image processing**. The 54 participants (until March 2000) who have enrolled so far demonstrate a noticeable shift toward NDT personnel from the field of seam weld inspection. This is a logical consequence of the fact that radioscopic weld inspection can only be performed successfully with the aid of digital image enhancement techniques. And it is exactly these techniques that are stressed in the RS 2 training course. But the course also features another topic of major importance which is the standardization of radioscopic inspection techniques.

### 5.2 Standardization

During the past few years, great efforts have been made to draw up a **radioscopy standard** /1/. It was in particular the International Institute of Welding (IIW) that made extensive contributions. The sub-commission V A working party in charge of “Radioscopic systems for weld inspection“ agreed to prepare a three-part standard resulting in **prEN 13068 draft European Standard “Radioscopic Testing Part 1-3”**.

**Part 1** of the standard defines the basic requirements that testing equipment has to meet as well as the approach on how to determine relevant parameters for the imaging system. These specific parameters serve to compare different radiosopic systems in terms of their component properties. Part 3 assigns these specific parameters to different classes of requirements so that each application is associated with certain minimum requirements that the imaging system in use must fulfill.

**Part 2** focuses on quality control and long-term stability of the imaging system. Generally speaking, the performance of a radiosopic system should always be checked with the aid of testing devices having natural flaws. For added comparability, standardised image quality indicators as in EN 462-1 and 5 must be used to monitor the principal image quality parameters such as spatial resolution or unsharpness and contrast sensitivity.

**Part 3** of the radioscopy standard defines minimum requirements that all radiosopic systems must meet regardless of their specific technical application. As could be expected, this issue triggered off vehement discussions since such a common denominator in terms of application criteria for radiosopic inspection systems is difficult to establish when, in fact, these systems cover a diversity of industrial applications.

The performance of the entire system (imaging system and geometric imaging conditions) and its suitability for a certain inspection job are checked by means of **specified image quality indicators (IQIs)**, namely the DIN wire IQI (EN 462-1) and the platinum duplex wire IQI (EN 462-5). The use of these two indicators enables a nearly independent definition of geometric as well as contrast resolution. In analogy to radiography, two test classes are defined for each application: **a standard class SA** and a **more stringent class SB**.
Parts 1 and 2 of the standard have successfully passed all enquiries of CEN. The final vote for Part 3 is to be initiated still this year. Depending on the final vote of the CEN members, the availability of the long awaited radioscopy standard is now within reach.

5.3 Systems

The performance capability of a radioscopy inspection system (Figure 5) is judged first and foremost by the parts throughput, i.e. by the inspection rate.

**Schematic Inspection Sequence:**

Inspection of the object starts when the system, i.e. the mechanical manipulator is being charged. Immediately after having approached the first test position, fully automated systems will start with the exposure. The second position is being approached after image acquisition has been completed. While the object is being positioned, calculation of the test decision takes place. These steps will be repeated until all test positions have been executed and the object has been discharged.

![Fig. 5 - Fully automated inspection system](image)

A marked increase in the inspection rate and thus in the parts throughput depends very much on the concept of the inspection system. The times needed for the loading, unloading and changing of the object must be kept to a minimum. So-called twin-manipulators are ideally suited to handle these tasks (Figure 6).
Schematic Inspection Sequence with Twin-Manipulator:
The twin-mechanism of a parts manipulator enables parts transport into and out of the radiation protection cabinet with only minimum down-times. The loading and unloading of the parts manipulator takes place outside the radiation protection cabinet, parallel with the inspection.

Fully automated evaluation /2/, implying radioscopic image diagnostics with the aid of digitized image evaluation, constitutes by now an integral part of radioscopic inspection systems that are intended for the continuous testing of high-quality safety-relevant aluminium castings in the automotive industry. For economic reasons, such fully automated inspection systems are the only answer to ensuring both a high parts throughput and reliable test results.

Furthermore, late in the 90s, different X-ray sensitive panel-like digital sensors (flat panel detectors) found the way out of the development. An advantage compared to X-ray image intensifier / CCD camera systems is the low weight of such a flat panel detector. This offers the possibility to develop faster mechanical components for a further increase of throughput of fully-automated radioscopic inspection systems. But there is also a serious disadvantage of this flat panel detectors: most of them are not able to fulfill the video real-time requirements. This means, at least in the moment, a significant restriction for the applicability of flat panel detectors in the visual radioscopic inspection. Nevertheless flat panel detectors are highly suitable for the realization of three dimensional computer tomography.

As computer hardware has undergone rapid advancement in recent years, R&D centres are by now in a position to run highly complex, yet cost-effective computational processes when using their radioscopic equipment for three-dimensional computed tomography /3,4/. This method lets the object rotate in equidistant angular increments to mathematically reconstruct the X-rayed volume (Figure 7).

The 3D-CT technique allows an exact defect localization in the casting /5/. Thus it will be of great future importance in the design process of new castings and their moulds and dies. Consequently, the central issue already at the developmental stage
must be an optimization of both the casting design and the casting process so that a later emergence of defects can be prevented.

Fig. 7 - Schematic array of three-dimensional computed tomography (3D CT)

The reconstruction results shown below demonstrate the potential of 3D-CT for investigation of various components.

Fig. 8: Test object of Al and plastic (approx. 15 cm x 15 cm x 1 cm)
left: test object right: 2D CT

Figure 8 shows a test object consisting of aluminum and plastic blocks with a thickness of approx. 1 cm. In the blocks are bore holes drilled through and milling grooves of approx. 0.5 cm. The section image shows the plastic blocks darker than the aluminium blocks due to their lower density. Figure 9 shows the reconstruction of the test object volume.