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Optimization of Digital Industrial Radiography (DIR) Techniques for Specific Applications: An IAEA Coordinated Research Project

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Abstract

In June 2007, the International Atomic Energy Agency (IAEA) convened a meeting of technical specialists from a dozen member states to initiate a coordinated research project (CRP) focussing on optimization of DIR techniques for specific applications. The objectives of this CRP are to test and validate simple and low cost DIR techniques and the optimization of X-Ray detector, detector source configuration, data processing and evaluation accuracy, spatial resolution and contrast sensitivity for steel and special light alloys. Participating organizations will evaluate both computed radiography (CR) and fluoroscopic techniques, based on scintillation screens beeing imaged with a digital CCD camera. The advance in PC-based computer technology and integrated data acquisition hardware for camera systems allows a low budget design of fluoroscopic DIR. New accumulation and calibration procedures enable the increase of contrast resolution, which will be comparable to modern detector systems. Digitised film radiographs, taken corresponding to USA and European standards, will be applied as reference in image quality. Comparative data will be collected for a series of test blocks, standard weld specimens and a variety of industrial castings. In this paper, the authors will describe the basis for the ongoing project, indicate the major milestones and suggest the probable outcomes when the project is completed in 2010.

1. Introduction

The International Atomic Energy Agency (the Agency) promotes the industrial applications of radiation technology which include Non-Destructive Testing (NDT) under its various programmes. One of the ways for promoting this technology is through coordinated research projects (CRPs) and research contracts. These are undertaken keeping in view the current status of the technology and the need for undertaking some research. Such research contracts and agreements can be worked out between the Agency and universities, colleges, research centres, laboratories and other institutions in Member States.

The IAEA is the only international organization having in its regular programme a continuous and effective transfer of NDT technology to developing countries. These efforts have led to a stage of maturity and self sufficiency in many countries, especially in the field of training and certification of personnel, and in the provision of services to industries. This has had a positive impact on the improvement of the quality of industrial goods and services.

NDT methods are primarily used for detection, location and sizing of surface and internal defects (in welds, castings, forging, composite materials, concrete and many more). Various NDT methods are also used in preventive maintenance (nuclear, aircraft, bridges). NDT methods are essential to the inspection of raw materials and half-finished products. They are applied for finished products and in-service inspection as well as for the design and development of new products and for plant life assessment studies.

The introduction of powerful computers and reliable imaging technology has had significant impact on the traditional nuclear based NDT methods. In particular, digitization of images provides economy of storage, efficiency of communication and increased speed of execution. NDT laboratories in developed countries are progressing rapidly with digitalization of NDT data. New imaging techniques have increased the capacity for visualization of defects and revealed new potential for accurate evaluation.

To review new developments in digital industrial radiology, a consultants meeting of experts from Canada, Germany, India, UK and the US was convened at IAEA in Vienna in November 2005. These specialists recognized the significant potential of DIR in the assessment of life expectation of components, facilities and products. The safe operation of nuclear and industrial plants and the protection of human life and resources benefit from the routine application of NDT. Advancement in radiological technology is rapid as new hardware and software tools become available (miniaturization of sensors, portable data acquisition systems, software for data processing and image creation, new ideas in methodology).

The meeting report prepared by this group provided their collective recommendations regarding identification of the status of digital radiography, the configuration of an affordable digital radiography system, a road map for the development of DIR systems by MS, a draft proposal for a CRP which is based on the participants' capacity to introduce DIR or to apply already existing systems, and the identification of possible future NDT projects.

Accordingly, the CRP was established with participation from Argentina, Canada, Brazil, Algeria, Malaysia, Israel, Syria, Uzbekistan, Uruguay, Germany, Pakistan and India. The first coordination meeting (CRM) for this programme was held in June 11th - 15th, 2007 at BAM in Berlin, Germany.

2. Scope

Digital industrial radiology, if affordable, offers significant potential for all MS to expand the application of radiation-based NDT techniques in construction and maintenance. The overall objective of this CRP is the development of an affordable DIR system that can be used for select industry applications, homeland security and training in

field of DIR. The information gained and technology developed will be disseminated to the MS.
The specific objectives of the CRP are to develop hardware and software for an affordable DIR system, prepare protocols on optimisation of detector-source configuration and procedures for use of affordable digital radiographs for online NDT inspection, adaptable by developing MS, to compare the performance of various digital systems and formulate standards for quality control and accreditation and to draft training manuals. Special attention will be paid to development of hardware, software, training and standards related to the digital industrial radiology.

3. Background Analysis, Rationale and Problem Definition

Non-destructive testing (NDT) methods are largely used for detection, location and sizing of surface and internal defects (in welds, castings, forging, composite materials, concrete and many other materials). NDT methods are essential for the inspection of raw materials and semi-finished products. They are used for finished products and in-service inspection, as well as for the design and development of new products and for plant life assessment studies.

At present, over 90% of industrial NDT applying X and gamma rays is carried out using radiographic film as a recording medium. Although film radiography presents high-resolution images, it suffers from several major disadvantages, including low efficiency and sensitivity, cost of film and chemicals, delay between exposure and viewing of results, as well as environmental concerns due to chemical discharges. In short, the basic hardware and software facilities used in film-based radiography are inexpensive, but the operating costs are expensive.

New digital radiographic techniques being developed are replacing classical film-based radiography techniques in non destructive testing (NDT). Replacing film-based inspection processes with detector-based digital systems has enormous benefits. On-going development on digital X ray detectors could dramatically enhance the digital image contrast resolution. In many cases, X ray imaging systems can now meet and exceed the resolution provided by X ray film.

To review new developments in digital industrial radiology (DIR), a consultants meeting of experts from Canada, Germany, India, UK and the USA was convened at IAEA in Vienna in November 2005. The specialists have recognized the significant potential of DIR for applications by Member States in the assessment of life expectation of components, facilities and products, and they have recommended a coordinated research project (CRP) to address these needs.

Detector based digital radiography is now being applied to a broad range of X ray applications, including inspection of pipeline welds, castings, electronics assemblies, wheels, bridges and many other industrial uses. Increased emphasis on environmental safety, including concerns regarding the effects of radiation on workers and the requirement for the disposal of chemicals used to process film, have contributed to the growing need to replace conventional X ray inspections involving long film exposures.

From 1995 CMOS (complementary metal oxide semiconductors) detectors have been applying for X ray detection. Digital X ray detectors have improved dramatically with regard to image resolution. They can now meet or exceed the contrast resolution that X ray film provides. When needed, X ray sources with micro-focus beams can now be used to detect defects of less than 10 μm in size.

The major disadvantage of digital radiography for the time being is the relatively high cost of the detection system, in particular the manufacture of stable digital detectors that makes digital radiography equipment relatively expensive for most NDT laboratories in developing member states. Other problems to be resolved are the difficulty in scaling the hardware to fit vessels of different sizes, new radioisotope sealed sources and miniature X ray generators, complexity in image creation that requires highly qualified operators and experience in interpretation. In short, the digital radiography that is currently under development is expensive in terms of basic hardware and software facilities but inexpensive in terms of operational costs.

The research and development in digital radiography is being carried out mostly in NDT laboratories of developed countries. Digital radiography systems have already been introduced in industrial NDT inspections. New digital radiography systems are under development for routine services to industry. At present, the outlook for X ray digital radiography is bright. One of the oldest methods in NDT has found a new life in the future of industrial inspection.

A large number of developing member states have operational NDT laboratories, where film radiography is well established for routine inspection. There is a need to foster change to on-line digital radiography techniques for in-service inspection, plant life assessment and quality control. Digital industrial radiology, if affordable, offers significant potential for all member states to expand the application of radiation-based NDT techniques in construction and maintenance. One of the biggest advantages of the use of digital radiography is its ability to significantly reduce the radiation dose in comparison to film applications. Furthermore, using X rays instead of radioactive isotopes improves the level of radiation safety to operators dealing with the equipment. In addition, new imaging techniques have increased the capacity for visualization of defects and revealed new potential for accurate evaluation. Digital industrial radiography has been shown as competitive in terms of technical performance, quality control and quality assurance, cost-benefit analysis, end users' awareness, initial investment and payback.

Over the years, the IAEA has contributed substantial funding and effort to industrial applications of NDT technology. As a result of several regional projects implemented in East Asia and the Pacific (RCA), in Latin America (ARCAL) and in Africa (AFRA) including dozens of national TC projects, hundreds of specialists have been trained in basic and advanced NDT techniques. Moreover, NDT laboratories equipped with basic facilities have been set up. The proposed CRP will address the needs of industry in developing countries and will take advantage of the infrastructure already available.

The CRP proposal on Digital industrial radiography was discussed and drafted by the participants of the consultants meeting. The CRP will focus on the designing,

developing, testing and validation of simple and low cost digital radiography techniques, in particular on optimization of the X ray detector, detector-source configuration, on data processing and on evaluation of accuracy, spatial resolution and contrast.

4. Objectives

The overall objective of the CRP is to design, develop, test and validate a simple, low cost and affordable digital radiography system for selected industrial applications, as well as homeland security.

Specific objectives of this project are:

- To design, build-up, test and validate simple and low cost DIR prototype system in each participating member states for specific industries like Welding, Light Alloys and Casting.
- Collecting of radiological images of a variety of objects, generating a catalouge for DIR applications.
- To compare the performance of DIR systems fabricated in participating member states through round robin tests, and to select the most affordable digital radiography instrument based on cost-quality-benefits aspects.
- To develop and test optimal source - digital detector configurations and validate them for different materials and defects.
- To develop training procedures and protocols of specific techniques and applications for each Industry for education and qualification of NDT personnel applying digital radiography in participating member states.

5. Expected Research Outcome

The main outputs of the CRP are envisaged as follows:

- A simple and low cost standard equipment package of a DIR prototype, which is affordable and suitable for developing countries usage.
- Procedures and protocols of testing for different materials (steel, light alloys, plastics) and different product forms (castings, welds) by using the simple and low cost DIR prototype system.
- DIR Hard- and Software for training, qualification and certification of NDT personnel in using this simple and low cost DIR system.
- Technical packages and guidelines for simple and low cost DIR applications in industry.

These outputs are expected to generate the following outcomes:

- Acceptance of the simple and low cost DIR technologies by the decision-makers and executives of the industry.
- Increased uptake and utilization of simple and low cost DIR techniques in industry.
- Reduced inspection time and radiation exposure of operators

- Development of a training manual for applications by Member States
- Increased awareness of the environmental protection and other benefits and the utilization of the DIR techniques by developing Member States.

Complementary benefits are related to training and qualification of NDT personnel and dissemination of the methodology and technology to developing Member States. Protocols and procedures will promote the simple and low cost DIR technology and its standardization and international harmonization.

The results will be disseminated through progress reports, meeting reports, inter-laboratory comparisons and technical reports.

At the end of the CRP, tested and validated protocols, procedures and software for using simple and low cost DIR for NDT for on-line plant life assessment will be ready in order to transfer the technology to end users.

10. Summary

Radiography is one of the oldest (over 100 years old) and the most widely used non-destructive evaluation methods, with applications in practically all industries. Conventional radiography utilizes the film/screen combination for recording the images.

New digital radiographic techniques are replacing classical film based radiography techniques in non destructive testing (NDT). Detector based digital radiography is now being applied to a broad range of X ray applications, including inspection of pipeline welds, castings, electronics assemblies, wheels, bridges and many other industrial uses for technical, environmental, safety and economic advantages. Increased emphasis on environmental safety, including concerns for the effects of radiation on workers and the requirement for disposal of the chemicals used to process film, have contributed to the growing need to replace conventional X ray inspections involving long film exposures. The relatively low operational cost of digital radiography and the possibility for online inspection are other major advantages of digital radiography.

The major disadvantage of digital radiography for the time being is the relatively high cost of the commercial hardware and software. There is sufficient evidence, when comparing film-based and digital radiography, that simple and low cost DIR technology is economically attainable and offers a very substantial advantage in many situations.

The objective of the proposed coordinated research project (CRP) is to design, build-up, test and validate simple and low cost digital industrial radiography (DIR) prototype systems for material and process inspection. The CRP will assist developing member states to introduce advanced digital radiography technology for online plant life assessment. An educational package will be prepared for training NDT practitioners in simple and low cost DIR experimental design, data processing and interpretation. The final goal of the CRP is the development of affordable digital industrial radiography systems mainly for developing member states.