ANALYSIS OF THE PISC RESULTS IN VIEW OF IMPROVED NDE CODES, INDUSTRIAL PRACTICE AND TECHNOLOGY TRANSFER

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PISC (Programme for the Inspection of Steel Components) sponsored jointly by the EC (JRC) and OCDE (NEA), lasted for 20 years. All experimental work was terminated in 1993. Results of PISC I showed the need to reconsider NDE effectiveness for Reactor Pressure Vessel welds. PISC II identified the important parameters for RPV inspection. PISC III has introduced new detailed conclusions about pressure vessels and other components inspection: dissimilar metal welds with safe-end; primary piping welds; steam generator tubes. Conclusions are of general interest for the nuclear and non-nuclear industry involving heavy duty structural components. ENIQ (European Network for Inspection Qualification) received the legacy of PISC and issues the European Methodology for Inspection Qualification in 1995.

OVERALL EFFECTIVENESS OF INSPECTION TECHNIQUES OF REACTOR PRESSURE VESSEL WELDS

Overall NDT effectiveness evaluation in the PISC programme

The PISC programme (1) has the general objective of assessing procedures and techniques in use for the inspection of pressure components (in particular the vessel and piping). PISC (carried out since 1974 under the auspices of the CEC/Joint Research Centres and the OECD/Nuclear Energy Agency (NEA)) was a major international effort to better assess the effectiveness of non destructive inspection procedures used on structural components. Three projects were centred on the CEC, Joint Research Centre, Petten and Ispra Establishments which in their role as Operating Agent, Reference Laboratory and Referee Group managed the programme and provided, with the participants of EC countries, approximately half participating countries. The OECD/NEA provided the Secretariat of PISC.

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These series of collaborative exercises under PISC brought conclusions that were generally accepted. These conclusions induced code and standard bodies like ASME (American Society of Mechanical Engineers) to revise the corresponding procedures.

PISC II results, published in 1986 can be summarised as follows (2): procedures in the spirit of the ASME Code Section XI appeared to perform better if specific techniques were used for surface defect detection and if the recording level was low (high sensitivity).

The high performance of some procedures which were applied in PISC II has to be noted. These procedures were often complex combinations of standard and advanced techniques.

Sizing quality was dependent on the defect position in the thickness of the plate. Subsurface defects were, on average, oversized. The chances of undersizing defects were greater for defects located near the clad surface (3).

PISC III started in 1987; it was the third phase of the PISC series (4). It considered all major parts of the primary circuit of Light Water Reactors (LWR).

In Action No. 2 of PISC III (Full-Scale Vessel Tests) (5) results obtained by procedures in the PISC II exercise were confirmed in realistic inspection conditions. The installation existing at the Staatliche Materialprüfungsanstalt (MPA), Universität Stuttgart, Federal Republic of Germany was used. Validation of ASME type procedures and of some national procedures was conducted by an international team using an In-Service Inspection (ISI) mechanised scanner offered by RWE and MAN to PISC for the period of the exercise. Sizing results show that correct sizing on RPV can be achieved by several techniques, if the flaws are volumetric ones or discrete planar ones such as fatigue cracks. For complex flawed areas which combine volumetric and planar flaws, combinations of techniques are necessary to detect and characterise all individual components of the flawed area (6).

It appeared clear that the requirements of ASME XI, 1986, were not sufficient to detect crack like defects perpendicular to the scan surface. More clearly than was the case in PISC II, the need for specific and capable techniques was well established, e.g. for near surface cracks.

Effectiveness evaluation through the validation programme of the Inspection Validation Centre (IVC) (7) confirmed the PISC results. Most of the industrial countries developed verification exercises of the ISI capability of RPVs (8). Not all results were published but generally their conclusions agreed with the ones of the PISC exercise.

PRIMARY PIPING INSPECTION EFFECTIVENESS

From the safe-end weld to the pressure vessel nozzle up to the steam generator and back to the vessel, the pipe work of a reactor contains welds which connect various components, deviations and pipe sections made of different materials. Very often austenitic steels are present (e.g. 316L) which are manufactured by different processes: wrought steel, centrifugally cast steel, static cast steel. Often base and weld materials are very different and pose inspection problems.

Inspectability of Safe-ends

The PISC exercise (9) conducted on safe-ends and first homogeneous welds of the primary circuit led to results which highlight the difficulties of some situations. The conclusions of this PISC exercise are as follows:

- there is a general difficulty in detecting and evaluating flaws in the weld material;
- a large spread in flaw sizing is shown;
- high sensitivity is necessary and reliable detection is only achieved with a through-wall extent larger than 30% of the wall thickness; detection of flaws becomes uncertain for flaws smaller than 5%T;
- false calls are generally present mainly when mechanised scanners are used;
- difficult flaws for UT are also difficult ones for X-rays;
- the evaluation made at the level of individual UT techniques allows the conclusion that some techniques are capable of a high detection rate but that the overall performance given by a full procedure is generally not obtained by a single technique.

Inspectability of wrought stainless steel primary piping

The PISC III Action on primary piping contained 3 capability studies characterised by three materials type combinations: wrought -to-wrought, cast-to-cast and wrought-to-cast welded assemblies.

The wrought-to-wrought capability study involved piping welds, typical of BWR primary piping (10).

The best results for detection, correct classification and false calls were very similar to those of the exercise on safe-ends.

In conclusion, good capability exists to inspect these assemblies but sizing performance can be quite poor though the teams that were able to detect crack tip diffraction did well.

In the other capability studies cast-to-cast and wrought-to-cast welds typical of PWR primary piping were studied.

In general one can conclude that the performance, especially for the rejectable flaws was good. The depth sizing performance was often poor again.

The PISC Action 4 on austenitic steel testing provides thus an excellent data base for useful insights into the inspection capabilities of artificial and real flaws in wrought and cast stainless steel piping.

STEAM GENERATORS INSPECTION EFFECTIVENESS

The PISC III programme (11) involved an important round robin test on steam generator tubes containing realistic and artificial flaws of the corrosion and fatigue crack type. The trends shown by the evaluation of results of this exercise are as follows:

- in general the probability of flaw detection does not reach 80%, where results from ultrasonic testing (UT) or from eddy current testing (ET) can be the best or the worst in several particular situations; combined procedures often gave results in the upper range of capability;
- dispersion of results is very high;
- corrosion defects were generally safely detected if the through thickness depth was greater than 40% of the wall thickness;
- IGA (intergranular attack) type defects are never safely detected;
- presence of fatigue defects in areas of denting is often not detected;
- deposits have a negative influence on detection of defects;
- flaw depth sizing results show large dispersion and no specific techniques showed particular capability;
- flaw length sizing also showed a large dispersion except for deep flaws or inside surface flaws;
- improvements are necessary in view of the correct application of generally accepted plugging criteria.

QUALIFICATION OF INSPECTION PROCEDURES

Methodologies for demonstrating effectiveness of ultrasonic techniques have been developed in the UK and the USA (7) (12) (13).

The US and UK approaches have much in common, though there are important differences and a great deal has been learned in both countries about the difficulty, time and cost of implementation. Many other countries with nuclear plants are currently considering their own approach to inspection qualification and are carefully assessing experience to date before making a decision on the type of qualification procedures to use.

A European methodology was developed by the European Network on Inspection Qualification (ENIQ) using all the experience of PISC (14) (15). The general objective of this network is the coordination and management at European level of expertise and resources for the assessment and qualification of NDE inspection techniques and procedures primarily for nuclear components. The ultimate goal is to support International Codes & Standards bodies by making available the results (state-of-the-art), technical tools, expertise and performance capabilities demonstration exercises that can be sponsored and managed at the European level. As a consequence, ENIQ helps in establishing a European attitude about inspection qualification in general.

ENIQ is guided by the European plant operators and operated by the JRC-IAM.

This European Qualification Methodology developed by ENIQ contains guidelines for the qualification of non-destructive tests. Qualification as defined in this document is a combination of technical justification which involves assembling all supporting evidence for test capability (results of capability evaluation exercises, feedback from site experience, applicable and validated theoretical models, physical reasoning) and test piece trials using deliberately defective test pieces.

The methodology relates to all those aspects of tests which can influence a successful outcome, that is procedures, equipment and personnel.

The European methodology developed by ENIQ is not intended to be a code or standard but it is hoped that Codes and Standards Bodies will make use of its recommended practices for the satisfaction of national regulations.

CONCLUSIONS

In Service Inspection can often be effective and reliable. It is fair to consider that Inspection is able to play an important role in the Structural Integrity Assessment scheme. Inspection techniques are, or soon will be, able to furnish in a reliable way the information needed on the "Status of the structure" as far as the presence and location of defects in view of plant life management is concerned. Sizes and characteristics evaluations are often characterised by uncertainties.

However, new damage mechanisms are appearing in old plants and some materials are not transparent.

Much has to be done to establish procedures for a better assembling and evaluation of all techniques contribution to express the final procedure results.

The effectiveness and reliability of inspections depends very much on the way in which qualification is applied as an effectiveness assurance tool and as a harmonisation process in Europe. The first ENIQ success: the establishment of a European Methodology is an important step.

The networks such as ENIQ and PISC generated information suitable for an effective improvement of structural integrity assessment in practice, for a better evaluation of margins of failure, for optimisation of ISI and thus for economy at equivalent Safety level. Better transfer of detailed information is however necessary. This technology transfer has to be organised as PISC or ENIQ were organised and has to be based on up to date information technologies.

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