FR0107074

QUALIFICATION OF NON-DESTRUCTIVE EXAMINATION FOR BELGIAN NUCLEAR REACTOR PRESSURE VESSEL INSPECTION

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INIS-FR--323

1. Introduction

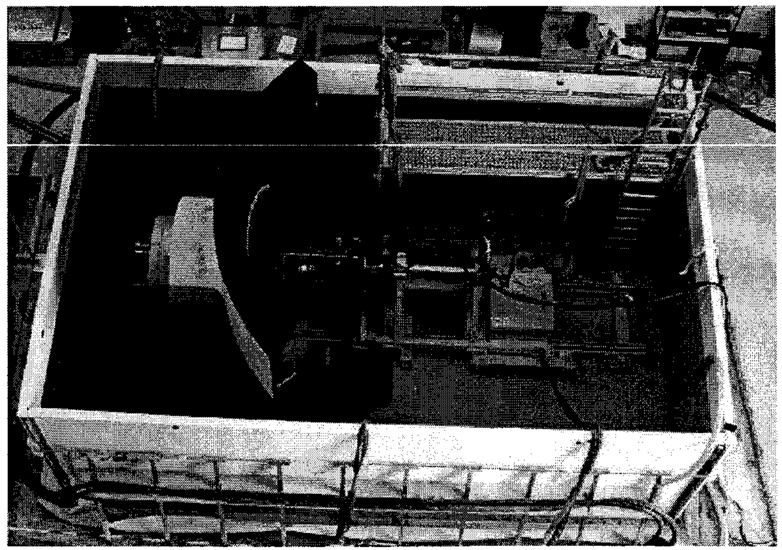
In-service Inspection participates in the continuous assessment of component integrity and the qualification process of Non Destructive Examination (NDE) techniques is essential to trust the reliability of the provided information.
When developing the strategy and the specification for inspection and qualification of the Reactor Pressure Vessel NDE system, Tractebel / Electrabel considered the ASME XI ed.92. requirements (Appendix VIII for qualification), amended by Belgian technical specifications and completed with the ENIQ "European Methodology for Inspection Qualification". The qualification was developed in close collaboration with Intercontrole, the NDE operator.
The exercise has shown that the qualification of the NDE technique must be demonstrated according to predefined objectives but it must also take into account feedback from on-site experience for final adaptation of the procedures.

2. Technical specification and Qualification

Definition of ISI objectives
ISI objectives, resulting from adequate safety considerations and leading to economically acceptable solutions, were based on a systematic analysis of all type of defects in all items of the vessel. Each type of defect is classified according to whether it has already appeared, it could appear or is highly unlikely to appear and to its potential impact on vessel safety.

Methodology for qualification
Different levels of qualification have been considered depending on ASME requirements on the applied NDE technique, and on the safety significance of the examined item. When a qualification dossier was required, the ENIQ Recommended Practices have been used as guidelines.
Qualification of NDE procedures
To demonstrate the effectiveness of NDE techniques, the procedures have been qualified for each item to be inspected. This covers :
- Application of ASME XI Appendix VIII or (when not covered) specific Belgian requirements .
- Determination of the NDE techniques : manipulator, probes, scanning patterns, data recording thresholds...
- Description of the qualification process, including characteristics of the test blocks.
- Technical Justification Dossier containing the summary of input data and the analysis of essential parameters.

Evaluation of the qualification process
Qualification was a rigorous work, but it has been shown that an optimised procedure can be obtained when inspection parameters are adapted (with justified reasons) during the qualification process, taking into account results from tests and reasoning.

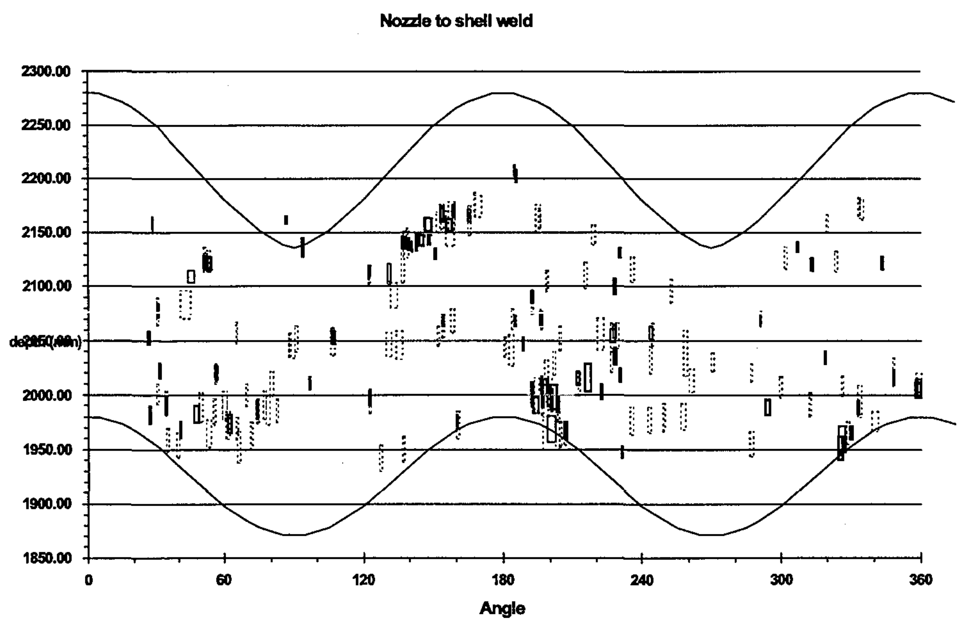


Examination of a Nozzle qualification test block

3. Site experience

The NDE procedure is the result of a compromise between two limitations : the degree of refinement of the specification and of the technical development (in order to fit as much as possible to the expected real conditions), and the effort that may be devoted to this process (in order to avoid unneeded excessive perfectionism).
Because the real condition of the inspected item is not completely known in advance, one must expect to discover new input information during the first on-site inspection, and use this feedback for final adaptation of the procedure.

On-site results
In 1999, some of the new qualified procedures were applied for examination of the Reactor Pressure Vessels of Doel and Tihange.
These procedures are successful regarding industrial efficiency. The inspection time is reduced by about 20% in comparison with previous procedures (conform to edition 80 of ASME XI). Inspection costs are reduced.
The detection capability has also been enhanced. Because of qualification requirements, the procedure sensitivity is relatively high. This means that a lot of defects are detected, including some with no impact on structural integrity (such as small fabrication defects).
Many indications were reported in some welds; most of them had not been detected with previous NDE techniques. For a correct interpretation of these results it was necessary to review the fabrication files. The existence of small acceptable fabrication defects (such as clusters of porosities) was clearly shown by the results from radiographic examination. Simulations and information contained in the technical justification of the procedure could explain why these indications were not detected with the previous NDE procedures.



Raw UT information : detection of many indications

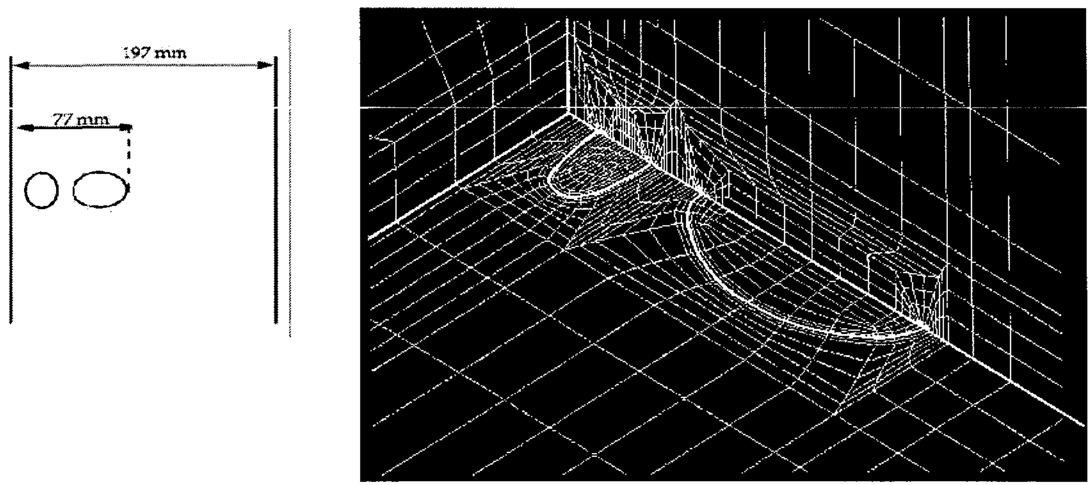
The presence of acceptable fabrication defects has no consequence on the structural integrity of the vessel. However, the ASME code requires following some conservative rules for characterisation and evaluation of indications. When the results of the examination are detailed, due to the required high sensitivity of the NDE procedure, the strict application of these flaw characterisation rules leads to formally consider very large defects (artificial construction) that are not acceptable according to "acceptance standards" of ASME and difficult to justify.

Feedback on procedure and on qualification

The field experience confirmed the ability of the technique to detect the defects aimed at. However, the tools used for evaluation of results (NDE analysis and ASME rules) did not allow an easy interpretation of the information.
Based on the better knowledge of the weld actual conditions, both ISI and qualification requirements were refined. The detection of defects significant for structural integrity is still required, but the "reference defects" are defined more accurately: the acceptable size is calculated through a "defect tolerance analysis" adapted to each specific case (position of the defect, design and material of Belgian RPVs, operation conditions, etc...).
Moreover, new requirements are defined for classification of the defects. The NDE procedure must identify and eliminate innocuous indications.
Each class of defects is defined in function of the characteristics of the defects : size, planar or volumetric, position,... For each class, there are different requirements regarding qualification of the procedure, detection and sizing capabilities, reporting, grouping of the defects and analytical evaluation.
The NDE procedures are then adapted to fulfil these objectives. The acquisition and the setting of the sensitivity are not modified when the qualification showed their necessity for detection of the "worst case defect". Different analysis tools are developed to determine more accurately the characteristics of the indications. Sorting criteria, based on clear characteristics, are designed to establish a correct and quick classification of all detected indications.
The aim is to identify rapidly the defects significant to structural integrity, if any, and to give a useful characterisation of the state of the inspected item. This information is then forwarded on-line to structural integrity experts, who will be able to define the operational conditions of the reactor. All these operations are performed in a very short time, as the results are needed before restarting the reactor after refuelling.

In parallel with NDE procedure optimisation, alternatives to the ASME rules are developed for defect evaluation. Calculation tools, based on finite element analysis, provide a justification tailored to each specific defect, avoiding the conservatism of a general solution.

All these optimised tools have been applied with success at Doel 2 RPV inspection in May 2000. Results from 1999 are also reviewed with the optimised procedures.



Specific defect evaluation using alternative calculation

Lessons learnt

Through this experience, we have learnt that NDE procedure development and qualification is a necessary but long process, which must include feedback from industrial application to achieve optimisation of the technique.

A detailed technical justification helps to focus efforts and costs and to provide more rigorous qualification.

The qualification is an iterative process of "validation of performance" and "improvement of procedure". The systematic review of parameters influence and the quantitative assessment of performance lead to identification of the weaknesses of the NDE procedure or to elimination of unnecessary sophistication. From there, the procedure is improved, and once again validated.

Finally, it is necessary to adapt the evaluation standard to the performance of the NDE technique. Analytical evaluation of defects and qualification of the NDE procedure are linked and must be approached in a global strategy, by a multi-disciplinary team.