EDF Non Destructive Testing R&D Programs An Overview

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SUMMARY

This paper presents some advanced NDT technologies used during in-service inspection and shows how the Research and Development programs bring the necessary complements in order to increase safety, availability and life duration of EDF's nuclear power plants.

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THE NUCLEAR POWER PLANTS MAINTENANCE ACTIVITIES

80 % of the electricity produced by EDF come from nuclear power plants (PWR) :

34 plants 900MWe,
20 plants 1300MWe,
4 plants 1450MWe.

These 58 plants are quite new : the oldest plant has been on duty for 20 years.

The new french nuclear regulation has enhanced the requirements for in-service inspection using Non Destructive Testing in the framework of plant maintenance.

Regarding the preventive maintenance: it is the most important part of the maintenance activities. The aim of NDT is to check, that there are no fabrication or in service induced flaws.

Regarding the curative maintenance : The aim of NDT is to determine by sizing if a flaw detected in a component – the fabrication or in-service induced flaw – can be accepted based on mechanical calculations or if the component has to be repaired or removed from service.

The aim of the following overview is to present some advanced NDT technologies already used during in-service inspection and shows how the Research and Development programs bring the necessary complements in order to increase safety, availability and life duration of EDF's nuclear plants.

This presentation is divided in 4 parts :

1. The NDT methods and the new french regulation
2. The industrial solutions for in-service inspection
3. The complementary role of NDT R&D programs
4. Conclusions and perspectives

1. THE NDT METHODS AND THE NEW FRENCH REGULATION

For nuclear power plant primary and secondary circuits, the French order of november 1999 [1] requires :

- to identify the sensitive zones of these circuits and to check that their flaws have acceptable brittle fracture margins regarding the new regulation require-ments,
- to check on each of those zones that the NDT detection performances are in accordance with these acceptable flaws sizes,
- for all the NDT methods used :
  - ⇒ *qualify them and demonstrate their performances where flaws have been observed or may be suspected,*
  - ⇒ *qualify them and evaluate their performances in other cases,*
  - ⇒ *attest these qualifications by an entity accredited and recognized as technically competency and independence [2].*

2. THE INDUSTRIAL SOLUTIONS FOR IN-SERVICE INSPECTION

Searching for small size flaws has yet led to use advanced NDT techniques, for example :

- multifrequencies Eddy current rotating coil technique to detect at least 0,5 mm depth intergranular stress corrosion cracks in steam generator tubes (40 % of wall thickness),
- focalized ultrasonics beam technique to detect and size at least 6x20 mm undercladding cracks in pressure vessel,
- another ultrasonic diffraction technique to detect at least 2x10 mm thermal fatigue cracks in the Residual Heat Removal System.

All these NDT techniques have been qualified and their perfomances demonstrated.

About 80 NDT methods have to be qualified.

3. THE COMPLEMENTARY ROLE OF NDT R&D PROGRAMS

The objectives :
In addition to the industrials solutions, these projects allow to :

- solve physical complex issues resulting from the new zones inspections : for UT complex geometries, anisotropic structures ...
- enlarge qualification limits in terms of sizing accuracy, smaller flaws detection in sensitive zones.

The programs organization :

- generally 3 years projects for optimising the NDT performances for a given inspection zone,
- in partnership with EDF R&D, Commissariat à l'Energie Atomique (CEA) and Universities laboratories,
- an important part of the global annual budget is allocated both to austenitic pipes inspection and more generally to contribute to EDF's effort to be in conformity with the new regulation.

The programs orientations :
More generally the R&D programs address different plants issues :

A. safety oriented programs :
   - Simulation tool for radiography,
   - NDT methods to inspect pressurizer surge line,
   - Extension to the inspection of other pipe mixing areas.

B. Availability :
   - Eddy current characterisation method.

C. life duration :
   - Radiographic inspection of the primary circuit elbows,
   - UT sizing for pressure vessel inspection.

A. THE SAFETY ORIENTED PROGRAMS

A simulation tool for radiography :

It has been developped to build the qualification dossiers required by the regulation and to limit the number of mock-ups and experimental trials.
The aim is to establish the performances and to define the limits of the radiographic methods :

- defining the detection criteria : optic density contrasts,…
- determination of the influent parameters : crack width, wall thickness gradient ...

NDT methods to inspect the pressuizer surge line [3]

- <u>First objective</u> is to check that no fatigue crack is growing in the different temperature water mixing areas of the surge line.
  Due to the perturbation induced by the austenitic structure on the UT beam, detection is performed by radiography (Ir 192) and sizing by an UT diffraction technique.
  Fatigue cracks greater than 5 mm can be sized by using a signal proccessing technique based on an "a priori" decon-volution method.

- <u>Second objective</u> is to improve the knowledge of the metallurgical structure influence on ultrasonic behaviour in aus-tenitic welds.
  A simulation tool based only on macros-copic knowledge of the weld structure has been developped.

The beam spliting and deviation can be foreseen.

Extension to the inspection of other pipe mixing areas :

Different programs have been launched to benefit from the previous results for more complex issues occuring in the pipe inspection of other pipe mixing areas by :

- checking the spliting and deviation in other austenitic weld (other welding conditions...),
- coupling the metallurgical **structure** and real **geometry** effects (internal and external geometry of the component, surface finish, …),
- coupling the **geometry** and the **defect** effects (planar, volumetric, fatigue crack in a crazing area, …).

B. THE AVAIBILITY ORIENTED PROGRAMS

In some cases, ultrasonic false calls lead to remove pipes in areas where no replica is possible.
The program objective is to differentiate the small depth acceptable surface irregularities (local coarse surface finish, scratches…) from the 2 to 3 mm deep flaws like thermal crazing, which are not always a priori acceptable.
An eddy current characterization method is therefore under development.

C. THE PLANT LIFE EXTENSION ORIENTED PROGRAMS

Generally, these programs are developped for circonstances where the material aging phenomena and the flaws occur on the same component.

⇨ *A radiographic inspection for the primary circuit elbows* [4] :

Some duplex stainless cast elbows are sensitive to thermal aging. In case of shrinkages, the margins for brittle fracture must be checked.
Due to difficulties for ultrasonic inspection all the elbow material is inspected by radiographic examination (Ir 192).
An innovating expertise method has been developped in order to measure the depth extension by contrast analysis on digitalized radiograms. It has been checked that the flaws are acceptable.

⇨ *An ultrasonic sizing technique for pressure vessel inspection* [5] :

Some pressure vessel material is sensitive to irradiation aging. In case of undercladding cracks, the brittle fracture margins have to be checked like in previous example.
The undercladding crack sizing accuracy is dependant on the surface finish : about ± 2 mm for the older plants coarser states.
The sizing accuracy improvement will contribute to justify plant life extension beyond 40 years.

4. CONCLUSIONS AND PERSPECTIVES

Industrial in-service inspection already uses advanced NDT technologies such as UT Phased-Array transducers, time of flight diffraction (TOFD) and focussing techniques .

R&D NDT programs bring the necessary complements :

- to prepare realistic technical specifications for contractualization,
- to improve the in-service performances.

In the future, UT improvements are expected to address more complex issues, such as the interaction between UT beam and :

- irregular component surface finish,
- non volumetric flaws (fatigue cracks, …)
- anisotropic and hetrogenous metallurgical structures (austenitic welds).

Some austenitic welds inspection is a real challenge which can be solved by using advanced technologies (phase-array, TOFD, …) but also signal processing and ultrasound modelling.

To succeed, a good knowledge of flaws geometries and macroscopic structure of the inspected zone is needed, as well as a good knowledge of the ultrasonic propagation and interaction in heterogeneous media.

These efforts in the industrial and R&D field contribute to enlarge the limits of qualified NDT techniques and to prepare the coming 10 years inspections that will open the way to safe plant operation beyond 40 years.

References

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