



Faire avancer la sûreté nucléaire

NDE Challenges Faced by IRSN to Enhance Nuclear Safety: from Research to Expertise and Vice-versa


Lili Ducoussou-Ganjehi, Thierry Sollier
email: lili.ducoussoganjehi@irsn.fr

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« Challenges and Future Directions
in Nondestructive Examination »

Nuclear Safety Branch/ Division
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Equipment and Structure
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IRSN Identity

- ▮ A public body with industrial and commercial activities, is placed under the joint authority of the Ministries of Defense, Environment, Energy, Research, and Health.
- ▮ National public expert for research and technical support on radiation protection and nuclear safety risks.
- ▮ 1800 employees, including more than 1000 specialists: researchers, Ph.D. students, post-docs and engineers.
- ▮ A budget of €300 million, with 40% devoted to research.
- ▮ 8 establishments in France, including 3 major sites: Fontenay-aux-Roses, Cadarache and Le Vésinet.



IRSN Missions

- Support and technical assistance to the public authorities for civil or defense-related activities
 - ▮ Safety of basic nuclear installations
 - ▮ Safety of basic nuclear installations classified as secret and of nuclear defense systems
 - ▮ Safety of nuclear transport
 - ▮ ...
- Research and services of public interest, including public transparency
 - ▮ Research on nuclear safety and security an radiation protection
 - ▮ Monitoring of populations exposed to ionizing radiation
 - ▮ National accounting of nuclear materials
 - ▮ ...



NDE in Nuclear Safety

➤ To ensure the high quality of materials during the process of manufacturing

▮ Control of component manufacturing (Level 1 Defense-in-Depth)

- To check for flaws in semi-finished products (forging or plates) before they are assembled to a component and once welded.

➤ To ensure the normal operation of the Nuclear Facilities and the Integrity of components

▮ Preventive maintenance of the Nuclear Facilities

▮ In-service inspection (ISI) (Level 2 Defense-in-Depth)

- Any in-service inspection process shall be qualified, in terms of required inspection area, methods of non-destructive testing, defect being sought and required effectiveness of Inspections @WENRA Reactor Safety Reference Levels, January 2008).

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NDE in Nuclear Safety for PWR

➤ Qualified techniques (source: ENIQ)

▮ - 90 non-destructive testing qualifications on the primary and secondary circuits

- 38% ultrasound, 29% radiography, 18% electromagnetic, 15% other

➤ From Expertise to Research and vice-versa

▮ To improve the NDE performances and the reliability

▮ To take into account influent physical parameters

▮ To participate in the development of innovative methods

▮ In collaboration with research partners

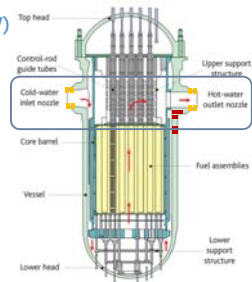
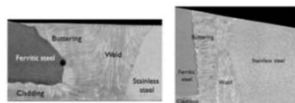
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Examples of NDE on PWR

➤ Reactor Pressure Vessel (RPV)

▮ Dissimilar Metal Welds (DMW)

- Liquid penetrant inspection for detection of surface defects such as Intergranular Decohesion (DIG)
- Ultrasound and radiographic inspection for detection of defects at the interface ferritic steel / buttering
- Radiographic volumetric inspection of the weld



@Georges Goué « Nuclear Power Reactor Core Melt Accidents »

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NDE in Dissimilar Metal Welds

➤ Expertise at IRSN

- What are the performances of NDE at the interface ferritic steel / buttering ?
- Does the NDE detection and/or characterisation of defect is reproducible ?
- What is the influence of the weld microstructure on NDE performances ?
- What is the influence of cladding on NDE performances ?

➤ Research works

- Development of simulation tools to take into account various factors (description of probes, metallurgical structure, couplant, ...)
- Validation of the simulation tools to verify its reliability for expertise
- In collaboration with the French Atomic Energy Commission's laboratories (CEA)

ON-GOING

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NDE in Dissimilar Metal Welds

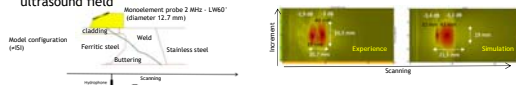
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➤ Research and Development

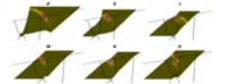
- Development of numerical tools to describe complex structure



- Development of semi-analytical model to describe the influence of DMW on the ultrasound field



- Development of semi-analytical model to simulate the NDE performances on DMW

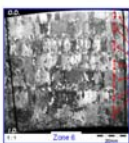


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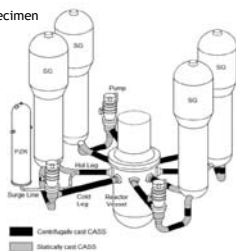
Examples of NDE on PWR

➤ Main coolant line (MCL)

- Centrifugally and Statically Cast Stainless Steel specimen
- Detection and sizing of manufacturing defect
- ISI to ensure the non-evolution of the largest defects located in the worst location
- Radiographic inspection



Multilayer, heterogeneous anisotropic and coarse-grained structure



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NDE in Cast Stainless Steel specimen

➤ Expertise at IRSN

- ▮ What are the performances of NDE through CASS specimens ?
- ▮ Does the NDE detection and/or characterisation of defect is reproducible ?
- ▮ What is the influence of coarse-grained structure and anisotropy on NDE performances ?
- ▮ What is the influence of the complex shape of component on NDE performances ?

➤ Research works

- ▮ Development of method and simulation tools to predict the signal to noise ratio
- ▮ Validation of the simulation tools
- ▮ Development of innovative methods to improve the accessibility of inspection
- ▮ In collaboration with the French Atomic Energy Commission's laboratories (CEA)

ON-GOING

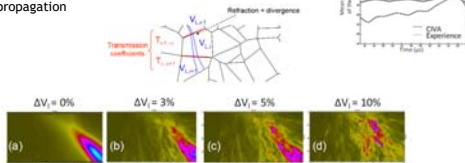
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NDE in Cast Stainless Steel specimen

➤ Research and Development

- ▮ Development of semi-analytical model to predict the signal to noise ratio of a planar defect in a equivalent simplified medium

- ▮ Simulation of the influence of the elastic properties on UT propagation



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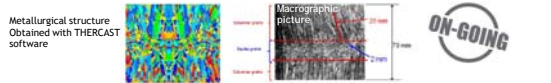
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research

NDE in Cast Stainless Steel specimen

➤ Material characterization

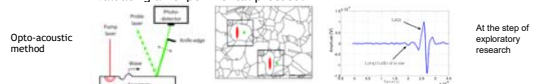
- ▮ Reliable NDE simulation models are based on material knowledge.
- ▮ Various applications: CASS, DMW and also Concrete (see presentation "Odobas project")
- ▮ To determine the material properties of the specimen:

- Directly from a modelling approach



ON-GOING

- Evaluating an experimental protocol



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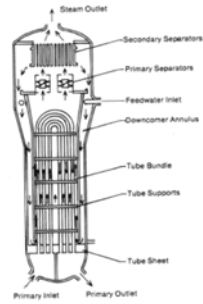
At the step of exploratory research

Examples of NDE on PWR

➔ Steam Generator (SG)

U-Bends

- To ensure tube integrity
- To detect and size cracks in the U-Bend region of tubes
- Eddy-Current inspection
- Collaboration NRC/TIP-5 (Tube Integrity Program)



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NDE in U-Bend

➔ Expertise at IRSN

- ▮ What are the performances of NDE by taking into account the bobbin position in the U-bend and geometrical deformation of the tube?
- ▮ What is the signal to noise ratio as a function of probes ?
- ▮ What is the influence of the complex shape of component on NDE performances ?

➔ Research works

- ▮ Development of simulation Eddy-Current tools on bobbin coil in U-Bend
- ▮ Evaluation of a metric for Eddy-Current performances evaluation (SNR, POD)
- ▮ Evaluation of signal processing enhancement on detection
- ▮ In collaboration with the French Atomic Energy Commission's laboratories (CEA)

ON-GOING

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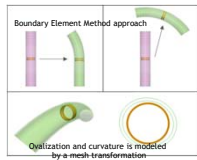
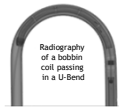
NDE in U-Bend

list research

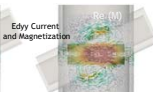
➔ Research and Development

U-Bend inspection modeling

- Boundary Element Method approach (BEM)
- Deformation of the tube section



Wear under AVBs (anti-vibrating)



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NDE in Complex shape components

Advances in phased array techniques and signal processing

The fixed shape of the wedge cannot match to all inspected zones

Flexible ultrasonic arrays answers to the lack of adaptability to geometry



	Dual element PA 500 kHz	Flexible 500 kHz
Detector capabilities	80° to 80° angle inspection S/N > 12 dB 0.1 (20mm) * 0.8mm 0.2 (20mm) * 0.8mm 0.3 (20mm) * 0.8mm 0.4 (20mm) * 0.8mm 0.5 (20mm) * 0.8mm	80° to 80° angle inspection S/N > 12 dB 0.1 (20mm) * 0.8mm 0.2 (20mm) * 0.8mm 0.3 (20mm) * 0.8mm 0.4 (20mm) * 0.8mm 0.5 (20mm) * 0.8mm
Characterization capabilities	40° to 80° angle inspection S/N > 7 dB 0.1 (20mm) * 0.8mm 0.2 (20mm) * 0.8mm	Yes

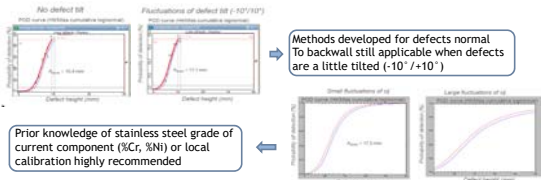
NDE and Statically analysis

Probability of Detection (POD)

The POD curves measure the probability of detecting a defect by taking into account the Statistics of fluctuations of influent parameters

Characteristic parameter: height of notch

Influence parameters: Specimen, Transducer positioning, Tilt or skew of defect, Metallurgical structure (grain size, shape, elastic constants,...)

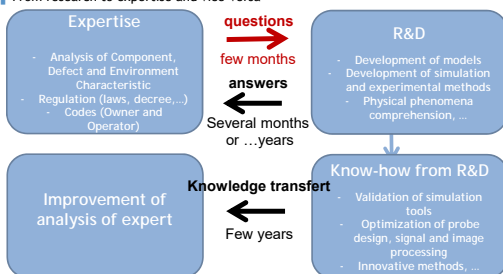


@IRSN and CEA communication at 7th European-American Workshop on Reliability of NDE, Poitiers, September 2017

Conclusion

An NDE analysis approach

From research to expertise and vice-versa



Thank you for your attention

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