High frequency acoustic microscopy imaging of Pellet/Cladding interface in nuclear fuel rods

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Outline

- Presentation of IES
- General context of this work
- Working principle
- First results
- Conclusions & perspectives
Group M²A: Materials, Micro-sensors and Acoustics

- Synthesis of functional materials,
- Characterization,
- Integration into (micro- and macro-) devices.
Image of the pellet/cladding interface as a function of the burnup

Better knowledge of the morphological evolution of the pellet-cladding interface throughout the life of the rod
Non-destructive method
Acoustic Microscopy High Frequency

X Destructive examinations

✓ Non-destructive method

Sample cutting
Preparation in hot cell
Limiting the number of tests

Several tests on irradiated rods
Better knowledge of the pellet/cladding interface

Ultrasonic imaging pellet/cladding mechanical interaction (PCMI)

Initial Gap

Reduction of the gap

Closed pellet/cladding gap

High frequency acoustic microscopy

- Visualization of structures in opaque materials,
- Very high-frequency ultrasound (> 100 MHz),
- The wave beam is highly focused.
Ultrasound imaging system

Circular acoustic imaging system of a cladding

- Mechanical system
- Control system (Made in IES)
- Electronic system
Mechanical bench

- Adjustment system
- Micrometer screw
- Sensor
- Cladding
- Linear micrometer system
- Rotation system
• Reflection-mode acoustic microscope
First results
Acquisition along a generatrix of the cladding

Acquisition along a generatrix of the cladding

2D Echogram

B-Scan

Inner face

Outer face

Grayscale encoding

A-Scan

Time

Acquisition
Polar representation

2D Polar Echogram

Outer face
Inner face

Echo of the inner face

Outer face Echo

Time (µs)

Amplitude (V)
The external and the inner image of the cladding

Amplitude (V)

Time (µs)

Image of the outer face

Image of the inner face

Outer surface echo

Inner surface echo

HOTLAB 2016
Images of outer surface and the inner surface of the cladding including a glue layer

Variation of the reflection coefficient

Amplitude (V) vs. Temps (µs)

Cladding/Air interface

Cladding/Glue interface

Glue

X (cm)

Amplitude (V) vs. Temps (µs)
Images of the inner face of the cladding (Engraving)

Aluminium tube (Length= 20 cm, Ø= 10mm, Thickness= 1mm)

- Imaging from the outer face of the cladding
- Variation in the state of the surface studied
- Engraving IES inside the tube

Ability of the system to detect:
- Interface modifications in terms of contact,
- Defect identifications.
Conclusion

- Acquisition system of the outer and the inner surface of the fuel rod.
- Development of the system (Analysis of the alignment constraints and Improvement of the mechanical bench).

PhD Perspectives

- Optimizing Signal Processing.
- Improving the interpretation of the ultrasonic images and extraction of the important data.
- Real-time data acquisition.
- System modeling.
- Simulation of the pellet-cladding interface with materials simulating the fuel.
Perspectives after this thesis

- Adaptation of the ultrasonic system designed for the irradiated cladding investigation.
- Adaptation of the system on the existing bench (MEGAFOX) in LECA STAR at CEA CADARACHE

MEGAFOX bench for irradiated fuel rod
Thank you for your attention