Fuel plate cladding thickness estimation thanks to acoustic microscopy

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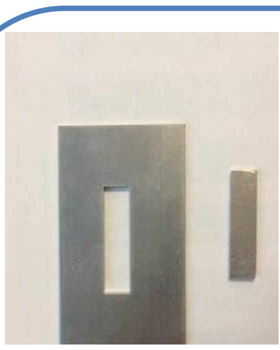
Introduction

The fuel cladding thickness is the first safety barrier. Currently, for research fuel plates, it is performed through destructive measurements. The project purpose is to replace the destructive measurements by non destructive measurements. The acoustic microscopy technics will be developed to measure the fuel plate cladding thickness.

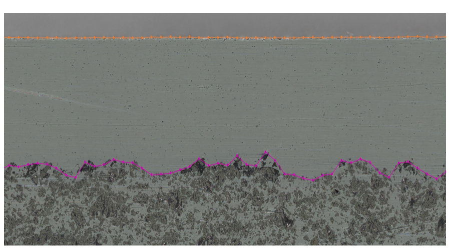
1. Current control of the fuel plates



1. Punching

2. Polishing

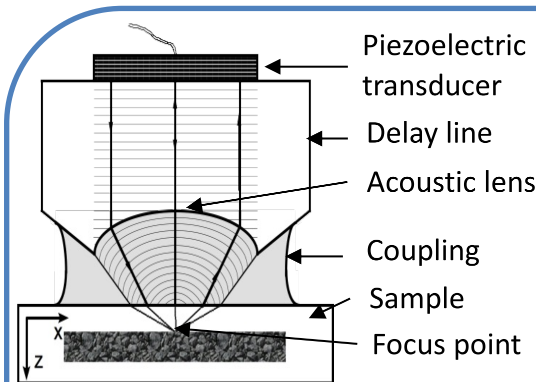
3. Optical measurement



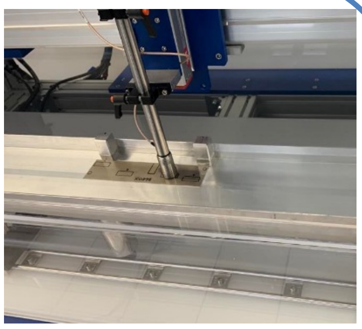
Optical thickness measurement

The optical measurement of the cladding thickness is done after that the plate has been cut and destroyed. The plate is punched at first. It is then polished in order to have a surface exploitable by the optical microscope. The optical measurements are finally carried out using the Keyence VHW optical microscope. These operations are performed manually.

2. Acoustic microcopy



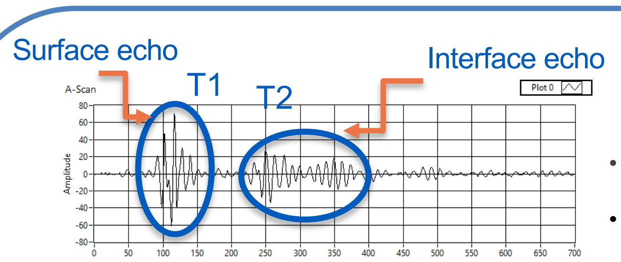
Principle of acoustic microscopy



NDT of a fuel plate by acoustic microscopy

A specific high frequency scanning acoustic microscope has been designed due to the fuel grains dimensions and the required resolutions to replace the current destructive control by a new non-destructive control.
The mechanics has been adapted for the step of the motors, the speed of acquisitions and the types of acquisitions.
The electronics has been adapted for the sampling frequency, the quantization and the analog filters.
The acoustics has been adapted for the frequency of the transducers, their focal distances and the remotes pulsers.

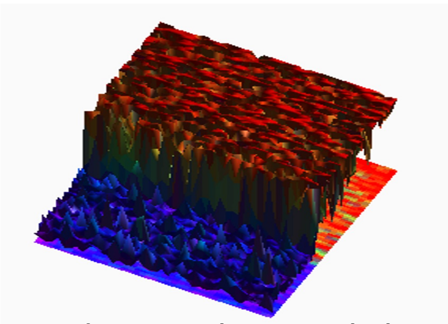
3. Signal processing



Ultrasonic signal

$$e = \frac{V * \Delta T}{2},$$

- V : Ultrasound speed in aluminum,
- ΔT : T2 – T1 (Time of flight).

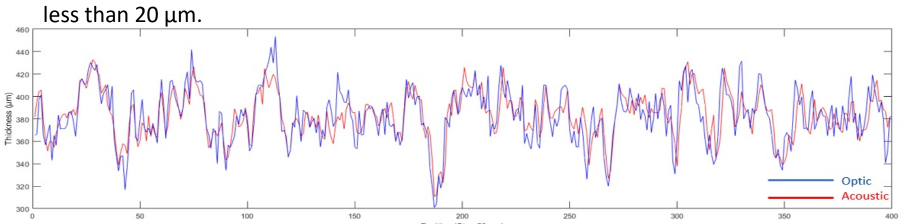


Two-dimensional acoustic thickness measurement

After the conception of the adapted acoustic microscope and the acquisition of the signals from the fuel plates, we extract the time of flight from the raw signals.
The time of flight extraction has a direct impact on the quality of the acoustic measurements.
For this purpose, new methods of identifying time of flight adapted have been developed and implemented.

4. Comparison of optical/acoustical thicknesses

We compare a 2 cm optical and acoustic measurement line. The average of the absolute differences of the two thickness curves on all the studied fuel plates are less than 20 µm.



Optical and acoustic thickness measurements on a 2 cm line

The table below shows the average of the absolute differences between the acoustic and optical measurements of the different coupons studied from 4 different types of plates.

Plate	Plate 1		Plate 2		Plate 3	Plate 4	
Coupon	A	B	A	B	A	A	B
Difference	11 µm	15 µm	12 µm	16 µm	17 µm	14 µm	15 µm

Conclusion

- ❑ High frequency ultrasonic microscope was designed in a way to allow non destructive measurement of the cladding thickness of nuclear fuel plates.
- ❑ High resolution measurements, frequency signal processing and adapted measurements of time-of-flight allowed the imaging of the interface rough surface.
- ❑ Ultrasonic measurements are in agreement with optical ones with less than 20 µm differences.

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