About the limits of optical microscopy measurement for Al-fuel cladding thickness

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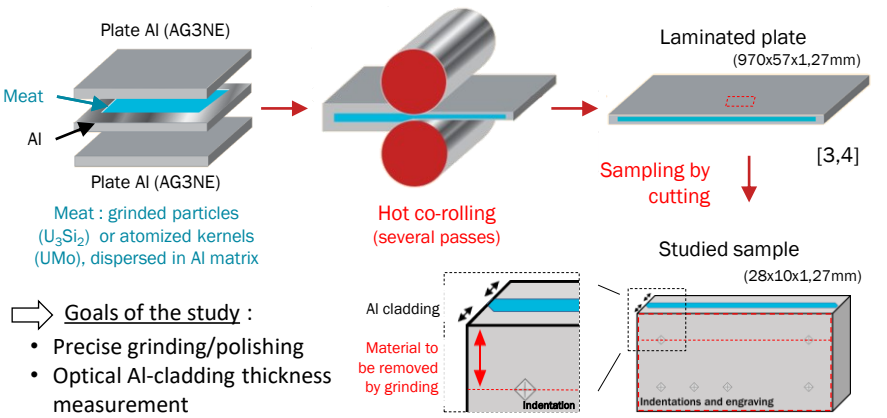
• Context and goal of the study

- The Al-based cladding is the only confinement barrier for research reactor fuels [1,2], so its integrity must be scrupulously preserved until the core assemblies are reprocessed. At each production stage stringent controls are carried out, such as dimensional examinations, visual inspections and a final blister test [3].
- In addition to these non-destructive tests, randomly selected fuel plates are also sampled for direct measurement of the cladding thickness. This additional control consists in taking cuts from specific areas of the fuel-plate which, once polished, are subject to a metrological measurement [3].
- This destructive examination, which is time and cost-consuming, would need to be replaced especially since optical measurements also have their own limits. In this work, we have attempted to stretch the limits of optical measurements to find the best compromise between high level of accuracy and effectiveness.

• Nuclear fuel fabrication stages

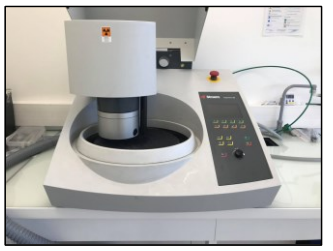


⇨ Goals of the study :
- Precise grinding/polishing
- Optical Al-cladding thickness measurement

• Methodology : Polishing procedure

❖ Abrasive polishing (A)
- Manual grinding with SiC (46 µm ⟶ 10 µm) with Al sacrificial plate + water (hand applied pressure)

❖ Finishing polishing (B)
- Manual polishing with diamond suspension (6 µm ⟶ 1 µm) with PVC transparent plate + lubricant (hand applied pressure)



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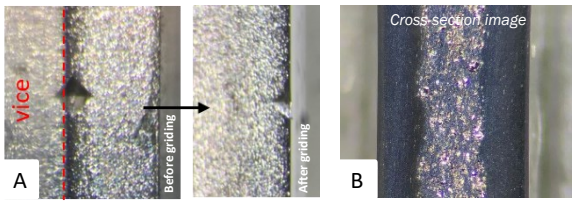
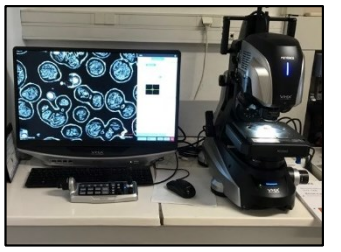


Sacrificial plates introduction to mitigate border effects :
- Al plates : abrasive step
- PVC transparent plate : final abrasive and finishing steps

• Methodology : Image acquiring and thickness measurement procedures

❖ Image acquiring
- 2 regular images of indentation locations, x40 lens, circular lightening (A)
- 3 reconstructed images, X300 lens, mixed lightening –circular and coaxial- (B)



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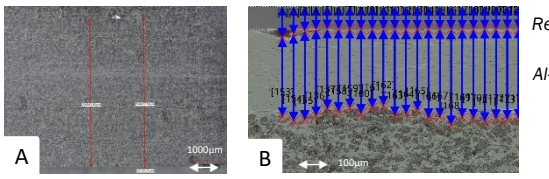
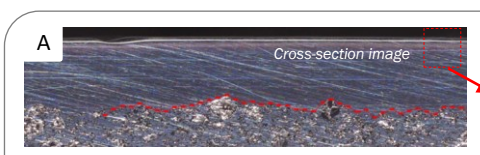
❖ Optical measurements
- 2 grinded indentation locations from above indentation (A)
- 400 Al-cladding thickness and 400 ref. line distances (B)



Data concatenation :
- Cross-section image
- Al-cladding depthline

• Result : Optimization the optical image quality



No sacrificial plate : Circular lightning needed
-> Difficulty to visualize sample border

No sacrificial plate

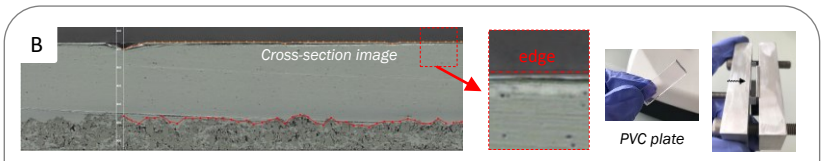
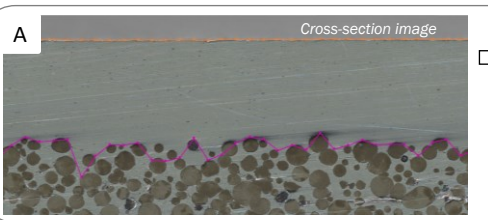


Plate introduction : Mixed lightning possible
-> Sample border and interface well visible

Al and PVC sacrificial plates

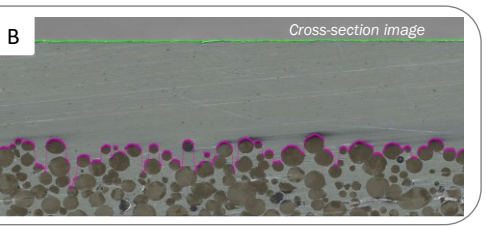
- **Without sacrificial plate in the vice, severe border effect observed leading to coaxial lightning not possible to be used, only circular lightning (not optimal)**
- Introduction of a sacrificial plate enable a mixed lightning (circular and coaxial) providing an accurate detection of sample border and meat/cladding interface

• Result : Decrease of the Al-cladding depth stepsize



⇨ **Step-size (A) : 50 µm**
- Time to completion : 2 h
- Mismatches occurring : some particles < 50µm appear undetected

⇨ **Step-size (B) : 5 µm**
- Time to completion : 8 h
- No mismatch : none undetected particles throughout the sample



- **Smaller stepsize increases the trustworthiness of the interface detection between the meat and the Al-cladding, no mismatch observed**
- Smaller stepsize increases also the time of completion of the measurements

• Conclusion

➢ In-house experimental methods managed to control the removal of the targeted amount of material during grinding to obtain a scratch-free cross-section surface after polishing, enabling Al-cladding depth measurement with sufficient accuracy and good efficiency.

➢ 10 trustworthy databases of optical cladding-depth measurement have been obtained for U_3Si_2 and UMo fuel type, which could be used as reference point.

➢ While a smaller stepsize of measurement allows a better detection of meat-cladding interface, it induces longer measurement completion time.

• References :

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