Developments of U-Mo monolithic plates with gradient foils

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CONTEXT :

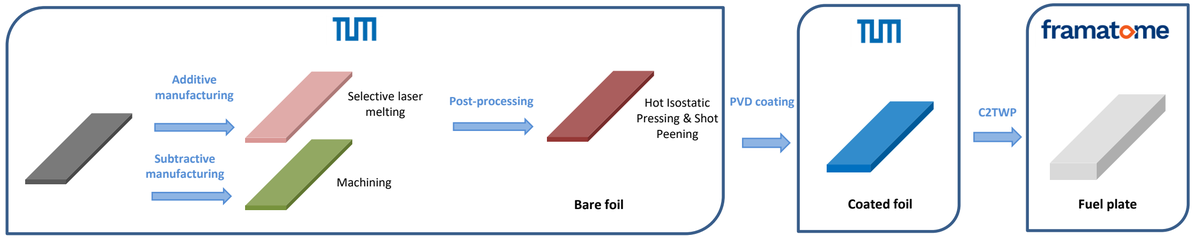
- To convert the European High Performance Research Reactors (EUHPPR), the European consortium HERACLES supports R&D efforts on UMo monolithic and dispersion LEU fuels.
- In the framework of the HERACLES consortium, Framatome - CERCA™ and Technical University of Munich (TUM) are developing U-Mo monolithic fuel.
- A pilot line of U-Mo monolithic fuel manufacturing and inspection is currently implemented in Framatome-CERCA™'s R&D laboratory, CRIL (CERCA™ Research and Innovation Laboratory).
- Funded by the European Commission through the H2020 project LEU-FOREvER.

1. Manufacturing project

- ❑Two fuel variants based on uranium-molybdenum (UMo) alloys: dispersed and monolithic.
- ❑Collaboration between TUM and Framatome - CERCA™ for the development of a European chain for the fabrication of U-Mo monolithic fuel plate.
- ❑High-performance research reactors, like TUM's FRM II reactor, may require U-Mo foils with varying thickness, so-called gradient foils.
- ❑TUM develops the coating process while CERCA™ develops C2TWP plate fabrication process.

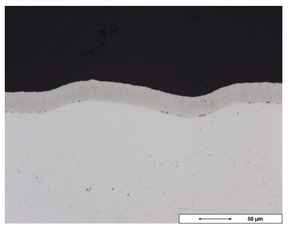
2. R&D process

- ❑Evaluation in inert material to test robustness of the process before switching to U-Mo gradient foils and plates.
- ❑Research is shared between TUM and CERCA™.



3. Preparation and C2TWP processing

Cross-section of a Zr-coated HPM foil



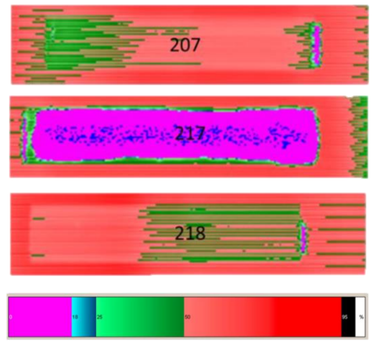
Cross-section of a Zr-coated SLM foil

Number of trial	N°Inert GRADIENT Foil	Foils manufacturing process	Parameter 1	Parameter 2
1	#207-SS316L-SLM	SLM + Shoot peening	C2TWP 1	P1
2	#217-SS321-M+	Machining	C2TWP1	P2
3	#218-SS321-M+	Machining	C2TWP2	P2

Fabrication and C2TWP parameters of the 3 mini-size inert foils

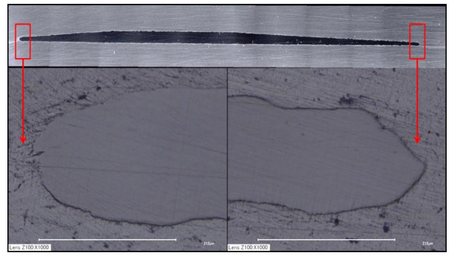
- ❑Machining foils present a smooth surface and regular Zr layer.
- ❑Machining induce material loss during process.
- ❑SLM foils shows irregular surfaces despite post-processing and small bending in large design.
- ❑SLM have better yield than machining but 3 steps process.

4. C2TWP results



Results of UT analysis on inert gradient mini-size foils

- ❑Full decohesion on plates 217 with set of parameters C2TWP and P1.
- ❑Radial decohesion on the end of foils 207 and 218.
- ❑No decohesion between foils/clad and between clad/clad on plates 207 and 218.
- ❑C2TWP parameters and cladding preparation could be optimized to remove end gap.
- ❑Check of the bonding quality by metallography on SLM based plate.
- ❑Ultrasonic and X-Ray test successfully passed.
- ❑The cross section of the plate 207 highlights a good bonding.
- ❑The surface of the SLM + Shoot Peening foils are acceptable for C2TWP.
- ❑Good enclosure of gradient foil in aluminum cladding by C2TWP.



Optical micrograph of a cross section of the plate 207

Conclusion :

- ❑Feasibility of the C2TPW process to produce the cladding on the inert mini-size gradient foils has been demonstrated.
- ❑Optimization of the C2TWP process should be conduct to solve the residual defects of bonding at the fuel plate ends.
- ❑The SLM process to produce the gradient foils seems to be compatible with the C2TWP process.
- ❑The "Shoot peening" surface finishing after the SLM process seems to be sufficient to ensure a good bonding in the C2TWP process.
- ❑Development on full-size inert gradient foils are required before tests and validation on DU-Mo coated mini-size gradient foils on DU-Mo coated full-size gradient foils.