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Characterization of fresh EMPiRe and SEMPER FIDELIS plates with PVD-coated U(Mo) particles

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CONTEXT AND GOAL OF THE STUDY
Two irradiation programs are currently in progress:
- EMPiRe, on mini-plates, in ATR reactor (USA),
- SEMPER FIDELIS, on full-size plates, in BR2 reactor (Belgium).

In both experiments, U(Mo)/Al plates are tested under aggressive irradiation conditions.

Seven fresh plates (5 EMPiRe ones and 2 SEMPER FIDELIS ones), manufactured with atomized U(Mo) particles from RAED, whether or not heat treated at 1000°C for Mo homogenization, all ZrN-coated by PVD, are examined mainly by SEM.

A particular attention is paid to the integrity of the ZrN coating and to the U(Mo) particles microstructure, in the different types of plates.

PLATES MAIN CHARACTERISTICS

<table>
<thead>
<tr>
<th>Plate designation</th>
<th>Mo homogenization</th>
<th>U(Mo) particles sphericity</th>
<th>ZrN coating thickness (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMP-717 (mini-plates)</td>
<td>No</td>
<td>Defined by the squared ratio between the width and the thickness</td>
<td>EMP-717</td>
</tr>
<tr>
<td>EMP-717 (full-size plates)</td>
<td>No</td>
<td>Defined by the squared ratio between the width and the thickness</td>
<td>EMP-717</td>
</tr>
</tbody>
</table>

EXPERIMENTAL DETAILS (for quantified results)
ZrN layer thickness:
- Measured by image analysis on 30 particles per plate
- Particles with continuous coatings
- 100 measurements per particle

Mo content analysis by EDS:
- On at least 15 different particles

SF-402 FULL-SIZE PLATE, MADE WITH AS-ATOMIZED PARTICLES

ZrN coating damages

SF-202 FULL-SIZE PLATE, MADE WITH HOMOGENIZED PARTICLES

ZrN coating damages

SF-202 FULL-SIZE PLATE, MADE WITH AS-ATOMIZED PARTICLES

ZrN coating damages

SF-202 FULL-SIZE PLATE, MADE WITH HOMOGENIZED PARTICLES

ZrN coating damages

ZrN particles sphericity:
- Related to the metallurgical state, in EMPiRe mini-plates (excepting EMP-189), systematically lower in SEMPER FIDELIS plates.
- Mean Mo content of U(Mo) particles: identical in all plates.

CONCLUSION
EMPiRe mini-plates and SEMPER FIDELIS full-size plates have very similar microstructural characteristics.

- Fuel core thickness and U(Mo) particles distribution: slightly more irregular in EMPiRe mini-plates.
- U(Mo) particles microstructure: similar in both types of plates, depending on the heat treatment.
- ZrN layers damages: 4 types identified in all plates:
  - Delaminations: preferentially observed in plates made with as-atomized particles, more marked in EMPiRe mini-plates.
  - Radial cracks: related to the layer thickness, which varies between 1 and 2 µm in both types of plates.
- Damages linked to contacts: high in all plates.
- Coating loss of adherence linked to powder oxidation: greater in plates made with homogenized particles, and especially in EMPiRe ones.