Creep model and experimental data for CrAl–ODS–Zr alloy ATF cladding

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** Introduction **

- CrAl–ODS–Zr alloy ATF cladding [1]
  - Surface modified Zr cladding concept in KAERI
    - CWSR Zry–4 cladding
      + Partial ODS treatment using Y_2O_3 particles by laser beam scanning (LBS) process
      + CrAl coating by arc ion plating (AIP) method

- Creep
  - One of the governing mechanisms inducing cladding deformation during the nominal LWR operation
  - Effect of improving the strength of the ODS layer greatly also in creased the creep resistance

- In this regard, the development of a creep law for CrAl–ODS–Zr alloy ATF cladding was based on experimental results obtained from tests by modification of FRAPCON creep model. Also, additional creep tests for CrAl–ODS–Zr–4 ATF cladding were performed and test results were compared with modified FRAPCON creep model.

** Experimental **

- Creep test
  - Test material: CrAl–ODS–Zr alloy ATF cladding
  - Internal pressurization method with 150–mm long specimens
  - 350 °C and 70/90/120 MPa of hoop stress for 3800 hours
  - Creep strain: from the average outer diameter measurement using a micrometer with a 0.0001–mm resolution

** Results and Discussion **

- FRAPCON creep model
  - given by Limbäck and Andersson
    (Thermal + Irradiation creep)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Values for Zry cladding</th>
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</thead>
<tbody>
<tr>
<td>a</td>
<td>MPa/°C</td>
<td>1.1898</td>
</tr>
<tr>
<td>T</td>
<td>°C</td>
<td>1200 ± 50</td>
</tr>
<tr>
<td>b</td>
<td>MPa</td>
<td>0.95 ± 0.20</td>
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<tr>
<td>n</td>
<td></td>
<td>12.4 ± 1.6</td>
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<tr>
<td>m</td>
<td></td>
<td>1.4 ± 0.2</td>
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<tr>
<td>C_a</td>
<td>cm²/yr</td>
<td>0.00015</td>
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<tr>
<td>C_b</td>
<td>cm²/yr</td>
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<tr>
<td>C_g</td>
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<td>C_m</td>
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<tr>
<td>T</td>
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<td>725 ± 10</td>
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<tr>
<td>t</td>
<td>h</td>
<td>1000 ± 100</td>
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</tbody>
</table>

- Modified FRAPCON creep model for ATF cladding
  - Modify FRAPCON creep model using existing data
    * 11.17 times lower than that of Zry–4
    * Greatly reduced compared with the uncoated Zry–4
    * Same trend to have same effects of temperature and stress with Zr–alloys are assumed due to limited data
  - Parameter "A" modified
  - Creep rate of CrAl–ODS–Zry–4 cladding at 180 °C for 1000 h in air [S]
  - Modified FRAPCON creep model for CrAlODS-Zry-4 cladding

- Creep model assessment for ATF cladding versus experimental data
  - Compared with additional test data
    - Scattered test data with very small strain
    - Good agreement with the trends and magnitude

** Conclusion **

- To evaluate creep deformation of CrAl–ODS–Zry–4 ATF cladding, the FRAPCON creep model for Zr–alloy cladding was modified based on the existing experimental data
- For a comparison, additional creep tests were performed and additional data are good agreement with the trends and magnitude of predictive curve, although measured data are widely scattered with large uncertainties

** Acknowledgments & References **

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- [3] FRAPCON 4.0, PNNL–19418 Vol.1 Rev.2