Creep and relaxation testing at Studsvik
Cecilia Janzon
Rikard Källström
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Presentation content

Basics in Creep and Relaxation testing

Experimental test equipment
  Specimens
  Test Cell
  Supply system
  Diameter measurement
  Temperature verification

Test results
Basics in Creep and Relaxation testing
Basics

Creep testing

Increased Diameter

Constant pressure

Relaxation testing

Constant diam.

Decr. pressure

Month

Days

Ramp Relax. Unload.
Creep Phases

- Primary creep
- Secondary creep
- Tertiary creep

Secondary creep rate = 0.12 %/day
Relax test basics, Stress / Strain curve

- **Constant diam.**
- **Decr. pressure**
- **Days**

**Graph:***
- **Max stress** $f(T, \varepsilon\text{-rate material})$
- **Relaxation** $f(T, \varepsilon\text{-rate material})$
- **Residual strain** $f(\text{Temp})$

<table>
<thead>
<tr>
<th>Hoop Stress [MPa]</th>
<th>Hoop Strain [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>0,0</td>
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<td>400</td>
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<tr>
<td></td>
<td>0,9</td>
</tr>
<tr>
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<td>1,0</td>
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</tbody>
</table>

**Axes:**
- **X-axis:** Days
- **Y-axis:** Hoop Stress [MPa]
- **Legend:**
  - Ramp
  - Relax.
  - Unload.
Profilometri before and after relaxation test

Residual strain = \( \frac{0.07}{9.49} \times 100 = 0.68 \%
\)
(acc. to relaxation-test 0.75%)
Experimental Specimens
Test specimen

Before mounting the support rings

- Upper end plug
- Upper support ring
- Cladding
- Lower support ring
- Bottom end plug
- Welds
Experimental
Test cells
Test Cells
Test Equipment
Transfer of sample to test cell
Test Cells
Creep test setup

System allows supervision of

• Pressure
• Strain (diameter)
Relaxation test setup

System allows control of

- Pressure
- Strain (diameter)
Test Cells

Agilent logger and Eurotherm control system

Pressurizing system
Experimental
Diameter measurement
Check of diameter measurement stability at 400°C

Therm exp.: 26 µm

20 h stabilizing
Instrumental setup

- Laser Emitter
- Glass block
- Sample
- Furnace
- Isolation
- Metal shielding
- Laser Receiver
Diameter meas. sensitivity of lateral movement

![Diameter control](image)

![Graph showing apparent diameter vs. horizontal position](graph)

- Apparent diam. [mm]
- Horizontal position [mm]

-9,090 to 9,120
-9,090 to 9,120
Experimental
Temperature verification
Temperature verification
Some results
Creep testing
Relaxation testing of unirradiated cladding

![Graph showing pressure and hoop stress over time with different rates.](image)

- **Pressure [bar]**
  - 0 to 600 bar
  - Time [h]: 0 to 96

- **Hoop stress [MPa]**
  - 0 to 0.8 MPa
  - Time [h]: 0 to 96

- **Diameter [mm]**
  - 9.5 to 9.8 mm
  - Time [h]: 0 to 96

- **Hoop Strain [%]**
  - 0 to 0.8%
  - Time [h]: 0 to 96

**Rates:**
- **medium rate**
- **low rate**
- **high rate**
- **medium rate** (for each test period)
Relaxation testing of unirradiated cladding

![Graphs showing hoop stress and strain over time for different rates.]

**Residual strain:**
0.55%, 0.54%, 0.52%, 0.52%
Total: 2.12%

Total residual strain according to Prof.: 2.19%