SSNP163 – Validation of the law of behavior of steels under irradiations in plane constraints

Summary:
This elementary test aims to validate the law of behavior IRRAD3M steels under irradiations in plane constraints.
1 Problem of reference

1.1 Geometry

It is about a square plate of with dimensions 1 mm

![Geometry of the problem.](image)

1.2 Properties materials

The various properties materials are given below.

The parameters materials used in this case test do not have to be used to make studies. They do not correspond to real characteristics.

Young modulus: \( E = 210000.0 - 30.0 T \) in MPa

Poisson's ratio: \( \nu = 0.30 + 5.0E-05 T \)

Thermal dilation coefficient: \( \alpha = (15.0 + 0.002 T) \times 1.0E-06 \)

Plastic part

\( \kappa = 0.8 \)

Elastic limit with \( 0.2\% \) in MPa: \( R_{02} = R_{02}^0 \cdot C_w \cdot R_e \cdot I_{r-e} \cdot R_e \)

\[ R_{02}^0 = 270.0 - 0.65 T + 0.001 T^2 \]

\[ C_w \cdot R_e = 1.0 \]

\[ I_{r-e} \cdot R_e = \left(4.0 - 3.0 e^{-\frac{T}{3}}\right) \]

Ultimate constraint in MPa: \( R_m = R_{02}^{(T, \text{IRRA})} + \left( R_m^0 - R_{02}^0 \right) \cdot C_w \cdot R_m \cdot I_{r-m} \cdot R_m \)

\[ R_m^0 = 600.0 - 1.5 T + 0.010 T^2 \]

\[ C_w \cdot R_m = 0.50 \]

\[ I_{r-m} \cdot R_m = 0.005 - 0.002 \left(1.0 - e^{-\frac{T}{4.0}}\right) + e^{-\frac{T}{1.8}} \]

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Lengthening distributed: \[ \epsilon_u = \ln \left( 1.0 + \epsilon_u^0, C_w \epsilon_u, I_r \epsilon_u, 1.0 \times 10^{-02} \right) \]

with

\[ \epsilon_u^0 = 5.0 - 0.15 T + 0.0007 T^2 \]
\[ C_w \epsilon_u = 1.0 \]
\[ I_r \epsilon_u = e^{-I_{RA}} \]

Irradiation part
\[ A_u = 3.0 \times 10^{-06} \text{MPa}^{-1} \cdot \text{dpa}^{-1} \]
\[ \eta_u = 1000 \text{MPa} \cdot \text{dpa} \]

Swelling part
\[ R = 0.002 \text{ dpa}^{-1} \]
\[ \alpha = 1.0 \]
\[ \phi_0 = 40.0 \text{ dpa} \]

1.3 Boundary conditions and loadings

For the edges \( AB \) and \( DC \), \( DY = 0 \)

For the edge \( AD \), \( DX = 0 \)

One applies moreover one linear slope of temperature having for maximum \( 400 ^\circ C \) as well as a linear slope of irradiation having for maximum \( 140 \text{ dpa} \).
2 Reference solution

2.1 Results of reference

It is a case test of not-regression.
3 Modeling A

3.1 Characteristics of modeling

The modeling used in the case test is the following one: **Elements 2D 'C_PLAN' (QUA4)**

![Figure 3.1-a: Geometry and grid of modeling used.](image)

Cutting: 1 mesh QUAD4 according to the axis of $x$
1 mesh QUAD4 according to the axis of $y$

Nodes:
- $A$ : mesh $M1$ node $N1$
- $B$ : mesh $M1$ node $N2$
- $C$ : mesh $M1$ node $N3$
- $D$ : mesh $M1$ node $N4$

3.2 Characteristics of the grid

Many nodes: 4
Many meshes and types: 1 QUAD4, 3 SEG2.

3.3 Sizes tested and results

<table>
<thead>
<tr>
<th>Identification</th>
<th>Field</th>
<th>Size</th>
<th>Reference</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>t= 20 M1 Point 1</td>
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<td>SIYY</td>
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<td>1.0E-04%</td>
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</table>

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4 Comments

This case test makes it possible to make sure of the perenniality of the results resulting from the law from behavior IRRAD3M in plane constraints.