SSNA123 – Validation of the law of behavior of steels under irradiations into axisymmetric

Summary:

This elementary test aims to validate the law of behavior IRRAD3M steels under irradiations. Three modelings are present to validate each aspect of the law separately:

- modeling (A) concentrates on the plastic part of the law,
- modeling (b) on the irradiation part,
- modeling (c) on the swelling part.

1 Problem of reference

1.1 Geometry

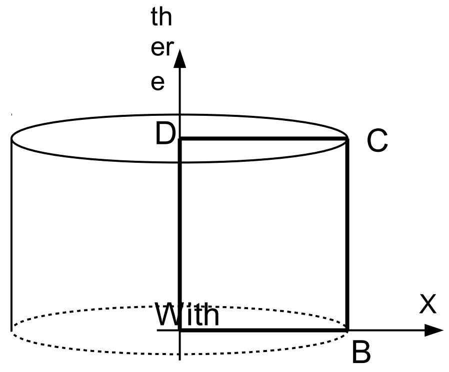

Figure 1.1-a : Geometry of the problem.

It is about a cylinder of ray $1\,mm$ and height $1\,mm$.
The square in fat corresponds to axisymmetric modeling.

1.2 Material properties

The properties materials are dependent on the type of modeling and functions of the temperature in $°C$ and of the irradiation in dpa (displacement per atom).

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

For all modelings
Young modulus: $E=210000.0-30.0\,T$ in MPa

Poisson's ratio: $\nu=0.30+5.0\text{E-}05\,T$.
Thermal dilation coefficient: $\alpha=(15.0+0.002\,T)\,1.0\text{E-}06$

For modeling has
Plastic part
$\kappa=1.0$

Elastic limit to 0.2% in MPa : $R_{02}=R_{02}^{0}.C_{w}\_R_{e}.I_{r}\_R_{e}$
with

$$R_{02}^{0}=270.0-0.65\,T+0.001\,T^{2}$$
$$C_{w}\_R_{e}=3.0$$
$$I_{r}\_R_{e}=\left(2.0-e^{\frac{-IRRA}{3}}\right)$$

Ultimate constraint in MPa : $R_{m}=R_{02(T,IRRA)}+(R_{m}^{0}-R_{02}^{0}).C_{w}\_R_{m}.I_{r}\_R_{m}$
with

$$R_{m}^{0}=600.0-1.5\,T+0.010\,T^{2}$$
$$C_{w}\_R_{m}=0.50$$
$$I_{r}\_R_{m}=0.25-0.10\left(1.0-e^{\frac{-IRRA}{10.0}}\right)+e^{\frac{-IRRA}{3.0}}$$

Lengthening distributed: $\epsilon_u = \ln\left(1.0 + \epsilon_u^0 . C_{w}\_\epsilon_u . I_{r}\_\epsilon_u * 1.0\text{E-}02\right)$
with

$$\epsilon_u^0 = 50.0 - 0.15\,T + 0.0007\,T^2$$
$$C_{w}\_\epsilon_u = 0.25$$
$$I_{r}\_\epsilon_u = e^{\frac{-IRRA}{2}}$$

Irradiation part
$A_{i0} = 0.0\,MPa^{-1}.dpa^{-1}$
$\eta_{is} = 1.0\text{E+}50\,MPa.dpa$

Swelling part
$R = 0.0\,dpa^{-1}$
$\alpha = 0.0$
$\phi_0 = 0.0\,dpa$

For modeling B
Plastic part
$R_{02} = 5.0\text{E+}09\,Mpa \quad R_m = 5.0\text{E+}09\,Mpa \quad \varepsilon_u = 0.0$

Irradiation part
$A_{i0} = 2.0\text{E-}06\,MPa^{-1}.dpa^{-1}$
$\eta_{is} = 1000.0\,MPa.dpa$

Swelling part
$R = 0.0\,dpa^{-1}$
$\alpha = 0.0$
$\phi_0 = 0.0\,dpa$

For modeling C
Plastic part
$R_{02} = 5.0\text{E+}09\,Mpa \quad R_m = 5.0\text{E+}09\,Mpa \quad \varepsilon_u = 0.0$

Irradiation part
$A_{i0} = 0.0\,MPa^{-1}.dpa^{-1}$
$\eta_{is} = 1.0\text{E+}06\,MPa.dpa$

Swelling part
$R = 0.0025\,dpa^{-1}$
$\alpha = 1.0$
$\phi_0 = 1.0\,dpa$

1.3 Boundary conditions and loadings

Modeling has

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 $400\,°C$.

Modeling B

For the edge AB, $DY = 0$
For the edge AD, $DX = 0$
For the edge DC, application of a linear slope of linear forces of maximum value $FY = 200\ N/mm$
One applies moreover one linear slope of irradiation having for maximum $10\,dpa$ and a slope of temperature having for maximum $400\,°C$

Modeling C

For the edge AB $DY = 0$
For the edge AD $DX = 0$

2 Reference solution

2.1 Results of reference

Modeling has
It is a case test of not-regression.

Modeling B
It is a case test of not-regression.

Modeling C
It is a case test of not-regression.

2.2 Uncertainty on the solutions

Modeling has
It is a case test of not-regression

Modeling B
It is a case test of not-regression

Modeling C
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 $2D$ **'AXIS' (QUA4)**

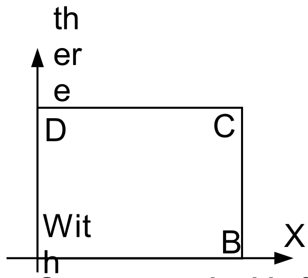

Figure 3.1-a : Geometry and grid of modeling used.

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 meshs and types: 1 QUAD4, 3 SEG2.

3.3 Sizes tested and results

Identification			Field	Size	Reference	Tolerance
$t=200s$	$M1$	Point 1	SIEF_ELGA	SIYY	-5,40000000E+02	1.00E-04%
$t=200s$	$N2$		DEPL	DX	4,11705882E-03	1.00E-04%
$t=200s$	$M1$	Point 1	VARI_ELGA	V1	4,32941176E-04	1.00E-04%
$t=400s$	$M1$	Point 1	SIEF_ELGA	SIYY	-6,15143448E+02	1.00E-04%
$t=400s$	$N2$		DEPL	DX	8,92077868E-03	1.00E-04%
$t=400s$	$M1$	Point 1	VARI_ELGA	V1	3,21321491E-03	1.00E-04%

4 Modeling B

4.1 Characteristics of modeling

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

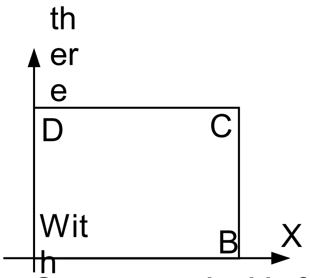

Figure 4.1-a : Geometry and grid of modeling used.

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 $N4$

It is about a test of creep to constant pressure on an axisymmetric element.

4.2 Characteristics of the grid

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

4.3 Sizes tested and results

Identification	Field	Size	Reference	Tolerance
$t=2000\text{s}$ $N4$	DEPL	DY	3,0101E-03	1.00E-04%
$t=2000\text{s}$ $M1$ Point 1	VARI_ELGA	V2	2,0000E+03	1.00E-04%
$t=2000\text{s}$ $M1$ $N2$	EPSI_ELNO	EPYY	3,0101E-03	1.00E-04%

5 Modeling C

5.1 Characteristics of modeling

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

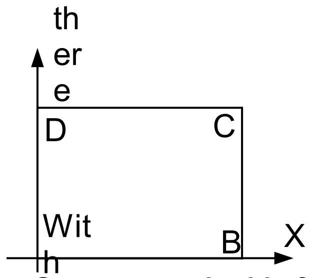

Figure 5.1-a : Geometry and grid of modeling used.

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 $N4$

5.2 Characteristics of the grid

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

5.3 Sizes tested and results

Identification	Field	Size	Reference	Tolerance
$t=0.1s$ $M1$ $N2$	EPSI_ELNO	EPYY	1,05722838E-02	1.0E-04%
$t=0.1s$ $M1$ Point 1	VARI_ELGA	V4	1,05722838E-02	1.0E-04%
$t=1s$ $M1$ $N2$	EPSI_ELNO	EPYY	1,15572282E-01	1.0E-04%
$t=1s$ $M1$ Point 1	VARI_ELGA	V4	1,15572282E-01	1.0E-04%

6 Comments

These cases tests make it possible to validate the law of behavior IRRAD3M in the elementary case into axisymmetric and activating for a given modeling only one part of the law (plasticity, irradiation and swelling).