SSNV230 - Validation of the law of behavior of steels 300 pennies irradiations in 3D

Summary:
These elementary tests aim to validate the law of behavior IRRAD3M steels under irradiations in $3D$, by activating the creep of irradiation and swelling.
It is about a case test of nonregression.

1 Problem of reference

1.1 Geometry

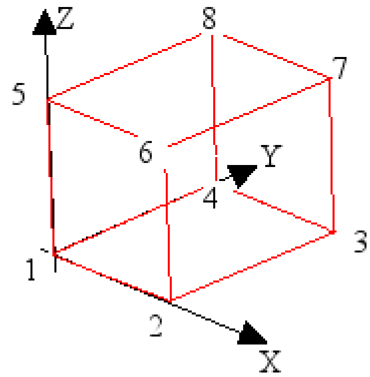


Figure 1.1-a : Geometry of the problem, cubes 1mm of with dimensions.

1.2 Material properties

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

The various properties materials are given below, with:

- T : temperature in $°C$
- $IRRA$: irradiation in dpa [R5.03.23]

Young modulus: $E=210000.0-30.0T$ in MPa
Poisson's ratio: $\nu=0.30+5.0\text{E-}05T$
Thermal dilation coefficient: $\alpha=(15.0+0.002)1.0\text{E-}06$

Plastic part

$\kappa=0.8$

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

$$R_{02}^{0}=270.0-0.65T+0.0010T^{2}$$
$$C_{w}\_R_{e}=1.0$$
$$I_{r}\_R_{e}=\left(4.0-3.0e^{\frac{-IRRA}{3}}\right)$$

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

$$R_{m}^{0}=600.0-1.5T+0.010T^{2}$$
$$C_{w}\_R_{m}=0.50$$
$$I_{r}\_R_{m}=0.005-0.0020\left(1.0-e^{\frac{-IRRA}{8.0}}\right)+e^{\frac{-IRRA}{3.0}}$$

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

$$\epsilon_u^0 = 50.0 - 0.15\,T + 0.007\,T^2$$
$$C_{w\_}\epsilon_u = 1.0$$
$$I_{r\_}\epsilon_u = e^{-IRRA}$$

Irradiation part

$A_{i0} = 3.0\text{E-}06\ \text{MPa}^{-1}\text{dpa}^{-1}$
$\eta_{is} = 1000\ \text{MPa.dpa}$

Swelling part

$R = 0.0020\ \text{dpa}^{-1}$
$\alpha = 1.0$
$\phi_0 = 45.0\ \text{dpa}$ or $\phi_0 = 1.0\ \text{dpa}$

1.3 Boundary conditions and loadings

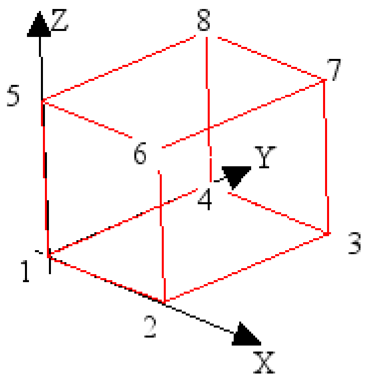
Modeling A

For nodes 1,2,3,4: $DX = DY = DZ = 0$
For nodes 5,6,7,8: $DX = DY = 0$
One applies moreover one linear slope of temperature having for maximum $400\,°C$ as well as a linear slope of irradiation having for maximum $140\,dpa$ (figure 1.3-a).
The characteristic materials for swelling are those of the lower limit.

Modeling B

Conditions in displacement
$DX = 0$, nodes: 1,4,5,8
$DY = 0$, nodes: 1,2,5,6
$DZ = 0$, nodes: 1,4,2,3

Nodes: 2,3,6,7
$DX = 0.0$ $t = 0.0\,sec$
$DX = 3.0\text{E}-03$ $t = 10.0\,sec$
$DX = 3.0\text{E}-03$ $t = 90.0\,sec$



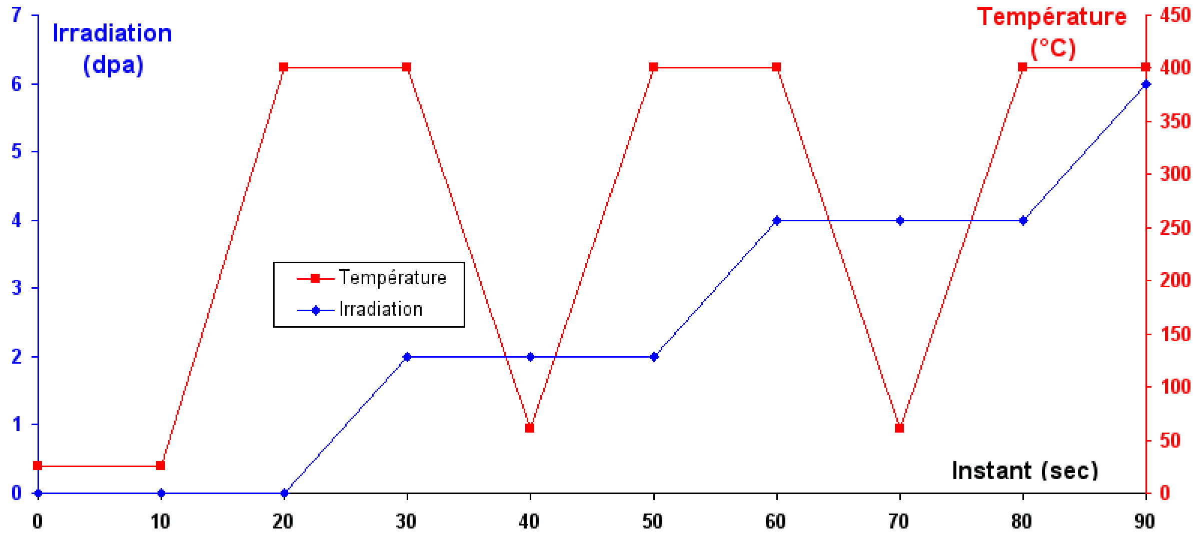


Figure 1.3-a : Conditions in temperature and irradiation with all the nodes according to time.

Modeling is made for the first time with the characteristics of swelling which correspond on the terminal higher then one second with the characteristics of swelling which correspond on the lower terminal.

2 Reference solution

2.1 Results of reference

Each modeling 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: **Element '3D' (HEXA8)**

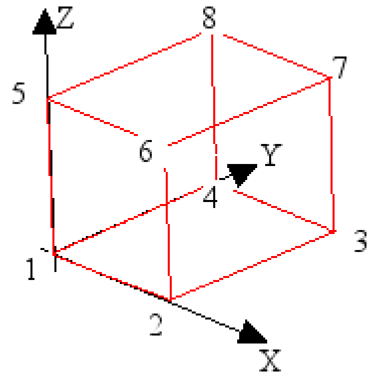


Figure 3.1-a : Geometry and grid of modeling used.

3.2 Characteristics of the grid

Many nodes: 8
Many meshs and types: 1 HEXA8, 2 QUA4.

3.3 Characteristics material

The characteristics of material are those which were indicated previously and $\phi_0 = 45.0\ \mathrm{dpa}$.

3.4 Sizes tested and results

Identification	Field	Size	Reference	Tolerance
t= 20s M1 Point 1	SIEF_ELGA	SIYY	-2,22679599E+02	1.00E-04%
t=100s M1 Point 1	SIEF_ELGA	SIYY	-2,02670376E+02	1.00E-04%
t=200s M1 Point 1	SIEF_ELGA	SIYY	-4,44447078E+02	1.00E-04%
t=100s M1 Point 1	VARI_ELGA	V1	1,12479090E-02	1.00E-04%
t=110s M1 Point 1	VARI_ELGA	V2	1,45524631E+03	1.00E-04%
t=200s M1 Point 1	VARI_ELGA	V2	4,26686655E+04	1.00E-04%
t=200s M1 Point 1	VARI_ELGA	V4	6,33333333E-02	1.00E-04%
t=110s M1 Point 1	VARI_ELGA	V3	1,36573893E-03	1.00E-04%
t=200s M1 Point 1	VARI_ELGA	V3	1,25005997E-01	1.00E-04%

4 Modeling B

4.1 Characteristics of modeling

The modeling used in the case test is the following one: **Elements '3D' (HEXA8)**

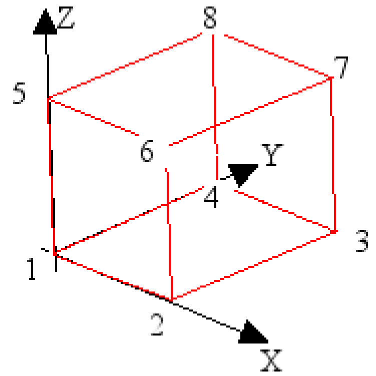


Figure 4.1-a : Geometry and grid of modeling used.

4.2 Characteristics of the grid

Many nodes: 8
Many meshs and types: 1 HEXA8

4.3 Characteristics material

The characteristics of material are those which were indicated previously and $\phi_0 = 1.0\,\mathrm{dpa}$

4.4 Sizes tested and result

Identification	Field	Size	Reference	Tolerance
t=10s Point 1	SIEF_ELGA	SIXX	2,53993074E+02	1.0E-04%
t=20s Point 1	SIEF_ELGA	SIXX	-1,85047588E+02	1.0E-04%
t=30s Point 1	SIEF_ELGA	SIXX	-1,85047588E+02	1.0E-04%
t=40s Point 1	SIEF_ELGA	SIXX	5,99759750E+02	1.0E-04%
t=50s Point 1	SIEF_ELGA	SIXX	-4,97991692E+02	1.0E-04%
t=60s Point 1	SIEF_ELGA	SIXX	-3,21076660E+02	1.0E-04%
t=70s Point 1	SIEF_ELGA	SIXX	7,75854613E+02	1.0E-04%
t=80s Point 1	SIEF_ELGA	SIXX	-3,30523956E+02	1.0E-04%
t=90s Point 1	SIEF_ELGA	SIXX	-9,98659764E+01	1.0E-04%
t=10s Point 1	VARI_ELGA	V1	1,78617408E-03	1.0E-04%
t=20s Point 1	VARI_ELGA	V1	5,56276438E-03	1.0E-04%
t=30s Point 1	VARI_ELGA	V1	5,56276438E-03	1.0E-04%
t=40s Point 1	VARI_ELGA	V1	7,14329016E-03	1.0E-04%
t=50s Point 1	VARI_ELGA	V1	7,14329016E-03	1.0E-04%
t=60s Point 1	VARI_ELGA	V1	7,14329016E-03	1.0E-04%
t=70s Point 1	VARI_ELGA	V1	7,19100378E-03	1.0E-04%
t=80s Point 1	VARI_ELGA	V1	7,19100378E-03	1.0E-04%
t=90s Point 1	VARI_ELGA	V1	7,19100378E-03	1.0E-04%
t=30s Point 1	VARI_ELGA	V2	3,70095175E+02	1.0E-04%
t=40s Point 1	VARI_ELGA	V2	3,70095175E+02	1.0E-04%
t=50s Point 1	VARI_ELGA	V2	3,70095175E+02	1.0E-04%
t=60s Point 1	VARI_ELGA	V2	1,29783675E+03	1.0E-04%
t=70s Point 1	VARI_ELGA	V2	1,29783675E+03	1.0E-04%
t=80s Point 1	VARI_ELGA	V2	1,29783675E+03	1.0E-04%
t=90s Point 1	VARI_ELGA	V2	1,68614985E+03	1.0E-04%
t=60s Point 1	VARI_ELGA	V3	8,93510262E-04	1.0E-04%
t=70s Point 1	VARI_ELGA	V3	8,93510262E-04	1.0E-04%
t=80s Point 1	VARI_ELGA	V3	8,93510262E-04	1.0E-04%
t=90s Point 1	VARI_ELGA	V3	2,05844955E-03	1.0E-04%

4.5 Sizes tested and results

Identification	Field	Size	Reference	Tolerance
t=10s Point 1	SIEF_ELGA	SIYY	2,53993074E+02	1.0E-04%
t=20s Point 1	SIEF_ELGA	SIYY	-1,85047588E+02	1.0E-04%
t=30s Point 1	SIEF_ELGA	SIYY	-3,17047588E+02	1.0E-04%
t=40s Point 1	SIEF_ELGA	SIYY	5,97508271E+02	1.0E-04%
t=50s Point 1	SIEF_ELGA	SIYY	-5,00132868E+02	1.0E-04%
t=60s Point 1	SIEF_ELGA	SIYY	-4,10813416E+02	1.0E-04%
t=70s Point 1	SIEF_ELGA	SIYY	6,91429029E+02	1.0E-04%
t=80s Point 1	SIEF_ELGA	SIYY	-4,10813416E+02	1.0E-04%
t=90s Point 1	SIEF_ELGA	SIYY	-2,76944958E+02	1.0E-04%
t=10s Point 1	VARI_ELGA	V1	1,78617408E-03	1.0E-04%
t=20s Point 1	VARI_ELGA	V1	5,56276438E-03	1.0E-04%
t=30s Point 1	VARI_ELGA	V1	5,56276438E-03	1.0E-04%
t=40s Point 1	VARI_ELGA	V1	6,48743752E-03	1.0E-04%
t=50s Point 1	VARI_ELGA	V1	6,48743752E-03	1.0E-04%
t=60s Point 1	VARI_ELGA	V1	6,54594319E-03	1.0E-04%
t=70s Point 1	VARI_ELGA	V1	6,54594319E-03	1.0E-04%
t=80s Point 1	VARI_ELGA	V1	6,54594319E-03	1.0E-04%
t=90s Point 1	VARI_ELGA	V1	6,54594319E-03	1.0E-04%
t=30s Point 1	VARI_ELGA	V2	4,81325700E+02	1.0E-04%
t=40s Point 1	VARI_ELGA	V2	4,81325700E+02	1.0E-04%
t=50s Point 1	VARI_ELGA	V2	4,81325700E+02	1.0E-04%
t=60s Point 1	VARI_ELGA	V2	1,51649548E+03	1.0E-04%
t=70s Point 1	VARI_ELGA	V2	1,51649548E+03	1.0E-04%
t=80s Point 1	VARI_ELGA	V2	1,51649548E+03	1.0E-04%
t=90s Point 1	VARI_ELGA	V2	2,17700281E+03	1.0E-04%
t=60s Point 1	VARI_ELGA	V3	1,54948645E-03	1.0E-04%
t=70s Point 1	VARI_ELGA	V3	1,54948645E-03	1.0E-04%
t=80s Point 1	VARI_ELGA	V3	1,54948645E-03	1.0E-04%
t=90s Point 1	VARI_ELGA	V3	3,53100844E-03	1.0E-04%
t=30s Point 1	VARI_ELGA	V4	6,66666667E-04	1.0E-04%
t=40s Point 1	VARI_ELGA	V4	6,66666667E-04	1.0E-04%
t=50s Point 1	VARI_ELGA	V4	6,66666667E-04	1.0E-04%
t=60s Point 1	VARI_ELGA	V4	1,82355044E-03	1.0E-04%
t=70s Point 1	VARI_ELGA	V4	1,82355044E-03	1.0E-04%
t=80s Point 1	VARI_ELGA	V4	1,82355044E-03	1.0E-04%
t=90s Point 1	VARI_ELGA	V4	3,12896911E-03	1.0E-04%

5 Comments

These cases tests make it possible to validate the law of behavior IRRAD3M by not-regression.