# SSNA124 – Simulation of the behavior of a screw subjected to an irradiation at strong temperature

**Summary:**

This case test aims to compare the integration of the law IRRAD3M via the simplified study of a screw into axisymmetric. At the time of this case test the phenomena of plasticity and creep under irradiation are activated. It is a test of not-regression.

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# 1 Problem of reference

## 1.1 Geometry

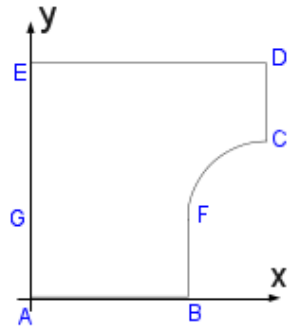


**Figure 1.1-a : Geometry of the problem.**

| Coordinates of the points | X-coordinate $(mm)$ | Ordinate $(mm)$ |
|---|---|---|
| $A$ | 0,00 | 0,00 |
| $B$ | 1,00 | 0,00 |
| $C$ | 1,50 | 1,00 |
| $D$ | 1,50 | 1,50 |
| $E$ | 0,00 | 1,50 |
| $F$ | 1,00 | 0,50 |
| $G$ | 0,00 | 0,50 |

## 1.2 Material properties

The various properties materials are 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.

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: $\alpha=(15.0+0.002\,T)\,1.0\text{E-}06$
Plastic part
$\kappa=0.8$

Elastic limit with $0.2\%$ in $MPa$ : $R_{02}=R_{02}^{0}.C_{w\_}R_{e}.I_{r\_}R_{e}$
with
$R_{02}^{0}=270.0-0.65\,T+0.001\,T^{2}$
$C_{w\_}R_{e}=3.0$
$I_{r\_}R_{e}=\left(2.0-e^{\frac{-IRRA}{3}}\right)$

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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

$$R_m^0 = 600.0 - 1.5\,T + 0.010\,T^2$$
$$C_{w\_}R_m = 0.50$$
$$I_{r\_}R_m = 0.25 - 0.10\left(1.0 - e^{\frac{-IRRA}{10.0}}\right) + e^{\frac{-IRRA}{2.0}}$$

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

$$\epsilon_u^0 = 50.0 - 0.15\,T + 0.0007\,T^2$$
$$C_{w\_}\epsilon_u = 0.25$$
$$I_{r\_}\epsilon_u = e^{\frac{-IRRA}{2.0}}$$

Irradiation part

$A_{i0} = 2.2\text{E-}06\,MPa^{-1}.dpa^{-1}$
$\eta_{is} = 700\ MPa.dpa$

Swelling part

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

## 1.3 Boundary conditions and loadings

For the edge $AB$, $DX = 0$ $DY = 0$
One applies moreover one field of temperature and irradiation with the evolutions presented below:

| Moment | Temperature [°C] | Irradiation [dpa] |
|---|---|---|
| 0,00 | 20,00 | 0,00 |
| 1,00 | 20,00 | 0,00 |
| 2,00 | 360,00 | 0,00 |
| 3,00 | 360,00 | 10,00 |

One proceeds to two types of calculation inside this case test. Initially, one subjects the structure to a linear pressure on the higher edge $ED$ of value $260\,N/m$. This pressure is applied as of the moment $t = 1$. Moreover, one imposes by connections between degrees of freedom that the edge $ED$ a displacement has according to $y$ identical (but unknown a priori). The objective of this first calculation is to evaluate the answer in creep of the structure.

Then, one carries out starting from the initial state a displacement imposed on the edge $ED$. The objective of this second calculation is to evaluate the answer in relieving of the structure.

In the case of relieving, the displacement imposed at the end of the rise in temperature ( $t = 2$ ) corresponds to that obtained with piloting in pressure for the same moment.
Imposed displacement is the following:

| Moment | Displacement [mm] |
|---|---|
| 0,00 | 0,00 |
| 1,00 | 3,77 |
| 2,00 | 17,25 |
| 3,00 | 17,25 |

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# 2 Reference solution

## 2.1 Results of reference

The results of references are got with another version of *Code_Aster*, it is thus a test of not-regression.

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# 3 Modeling A

## 3.1 Characteristics of modeling

The structure is modelled in elements $2D$ axisymmetric.

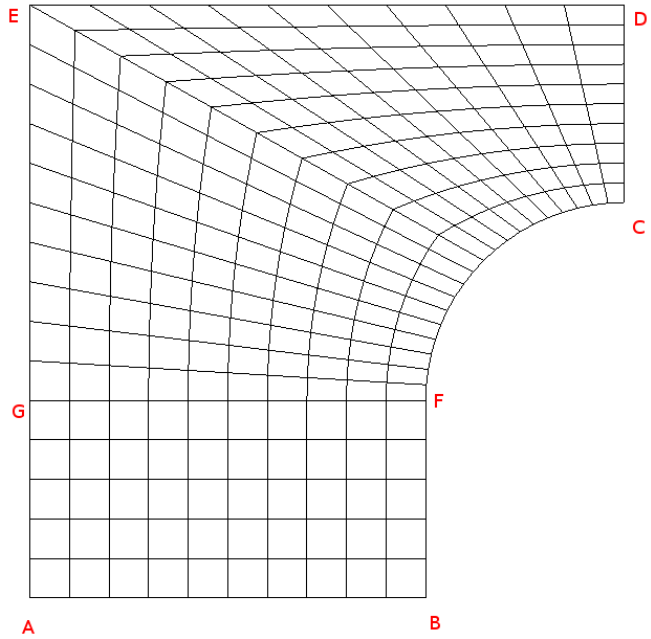


**Figure 3.1-a : Grid.**

## 3.2 Characteristics of the grid

Many nodes: 286
Many meshs and types: 250 QUAD4, 45 SEG2.

## 3.3 Sizes tested and results

Answer of the structure in creep: calculation number 1.

| Identification | Field | Size | Reference | Tolerance |
|---|---|---|---|---|
| $t=2.0\text{s}$ Not $E$ | DEPL | DY | 1,40067962E-02 | 1.0E-04% |
| $t=2.1\text{s}$ Not $E$ | DEPL | DY | 1,40157903E-02 | 1.0E-04% |
| $t=2.5\text{s}$ Not $E$ | DEPL | DY | 1,75889819E-02 | 1.0E-04% |
| $t=3.0\text{s}$ Not $E$ | DEPL | DY | 2,22867046E-02 | 1.0E-04% |
| $t=2.0\text{s}$ Not $E$ | VARI_NOEU | V1 | 2,82155486E-03 | 1.0E-04% |
| $t=2.1\text{s}$ Not $E$ | VARI_NOEU | V1 | 2,82155486E-03 | 1.0E-04% |
| $t=2.1\text{s}$ Not $E$ | VARI_NOEU | V2 | 5,70139195E+02 | 1.0E-04% |
| $t=2.5\text{s}$ Not $E$ | VARI_NOEU | V3 | 5,06944859E-03 | 1.0E-04% |
| $t=3.0\text{s}$ Not $E$ | VARI_NOEU | V3 | 1,27185952E-02 | 1.0E-04% |

Answer of the structure in relieving: calculation number 2.

| Identification | Field | Size | Reference | Tolerance |
|---|---|---|---|---|
| $t=1.0\text{s}$ Not $E$ | SIEF_NOEU | SIYY | 5,68228889E+02 | 1.0E-04% |
| $t=2.0\text{s}$ Not $E$ | SIEF_NOEU | SIYY | 5,05515873E+02 | 1.0E-04% |
| $t=2.1\text{s}$ Not $E$ | SIEF_NOEU | SIYY | 5,03413238E+02 | 1.0E-04% |
| $t=2.5\text{s}$ Not $E$ | SIEF_NOEU | SIYY | 1,05182782E+02 | 1.0E-04% |

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# 4 Comments

This case test makes it possible to validate the law of behavior IRRAD3M in a simplified study of what is its most current use with knowing a behavior in extreme request of irradiation like temperature. The results got by this case test of nonregression make it possible to validate the law in a nonelementary case.

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