SZLZ105 - Counting of cycles per RAINFLOW and computation of the Summarized

damage:

Transitory linear elastic problem quasi-static in structural mechanics.

Computation of the final damage in an element subjected to a cyclic loading, with a linear elastic behavior.

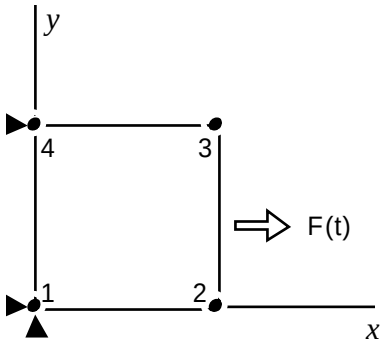
A modelization in plane stresses and a modelization in 3D.

This test validates the method of counting of cycles (RAINFLOW) established in operator CALC_FATIGUE as well as the méthode de calcul of the damage in imposed stress (curve of Wöhler) or imposed strain (curve of Manson-Whetstone sheath). The reference solution is an analytical solution.

It also validates the computation of the stresses and strains equivalent using options SIEQ_ELGA, SIEQ_ELNO, EPEQ_ELGA, EPEQ_ELNO, EPMQ_ELGA and EPMQ_ELNO.

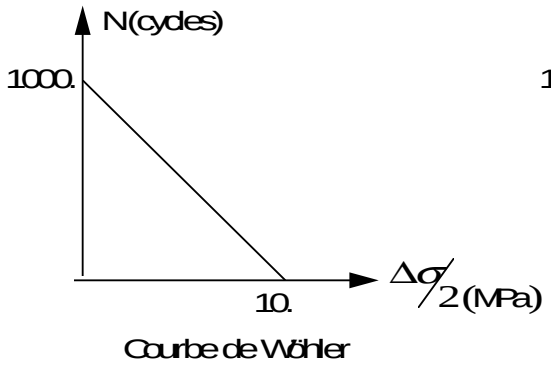
1 Problem of reference

1.1 Geometry

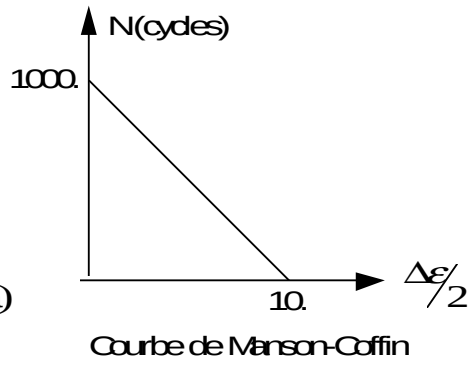


1.2 Material properties

linear Elasticity: $E=1.MPa \quad \nu=0.3$



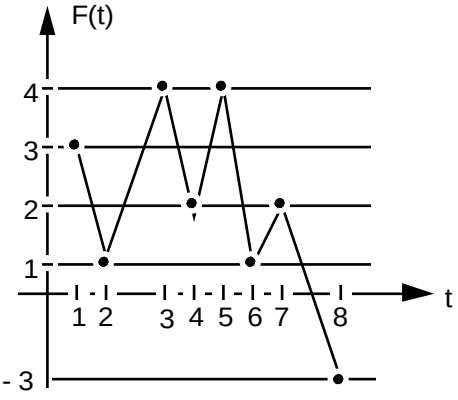
Courbe de Wöhler



Courbe de Manson-Coffin

1.3 Boundary conditions and loadings

- Blocked on face $1-4$ according to X - following 1 blocked node Y.
- In unit simple tension on the face $2-3$.
- Loading $F(t)$ in teeth of saw (according to the Article of Downing and Socie 1982) [bib1].



1.4 Forced

initial conditions and null strains.

2 Reference solution

2.1 Method of calculating used for the analytical reference solution

Solution

- computation of the stresses and strains. For a loading in simple tension, one point: obtains a homogeneous uniaxial stress state in all

$$\sigma=\begin{bmatrix}\sigma & 0 & 0\\ 0 & 0 & 0\\ 0 & 0 & 0\end{bmatrix} \text{ and the } \varepsilon=\begin{bmatrix}\varepsilon & 0 & 0\\ 0 & \gamma & 0\\ 0 & 0 & \gamma\end{bmatrix}$$

equivalent quantities are thus $\begin{cases}\sigma_{VMIS}=|\sigma|=\sigma_{TRESCA}\\ \sigma_{VMIS-SG}=\sigma\end{cases}$

and $\begin{cases}\varepsilon_{INVA-2}=\frac{2}{3}|\varepsilon-\gamma|\\ \varepsilon_{INVA-2\mathrm{SG}}=\frac{2}{3}|\varepsilon-\gamma|*sign\left[\frac{\varepsilon+2\gamma}{3}\right]\end{cases}$

- then manual computation of the cycles by the method of RAINFLOW, as well as amplitudes of loading ($\frac{\Delta\sigma}{2}$ or $\frac{\Delta\varepsilon}{2}$).

cycles	$\Delta\sigma/2$	$\Delta\varepsilon_{INVA-2}/2$
1	1.	0.8667
2	0.5	0.433315
3	1.	0.8667
4	3.5	3.03335

- finally carryforward of these values on the curves of Wöhler or Manson-Whetstone sheath to consider the damage unit at each cycle i, is $Du_i=\frac{1}{N_i}$ (N_i being the number of cycles with fracture for a given amplitude), as well as the cumulated damage $D=\sum_i Du_i$ (rule of linear office plurality TO MINE).

Note:

One will use as equivalent stress $\sigma_{VMIS-SG}$ and equivalent strain $\varepsilon_{INVA-2\mathrm{SG}}=\frac{2}{3}|\varepsilon-\gamma|\times sign\left[\frac{\varepsilon+2\gamma}{3}\right]$.

2.2 Results of reference

- being given the values of the loading parameters used, one obtains simply at the end of the loading (increment 8) $\sigma=-3.\ \ \varepsilon=-3.\ \ \gamma=0.9\ \ \varepsilon_{INVA-2}=2.6$.
- For the computation of the damage, one obtains:

$$D_{Wöhler}=4{,}8133.10^{-3}=\sum_{i=1}^{4} Du_i$$

$$D_{Manson}=4{,}67.10^{-3}=\sum_{i=1}^{4} Du_i$$

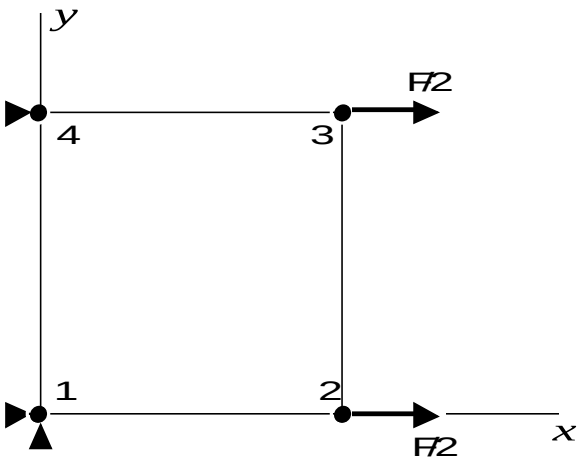
2.3 Bibliographical references

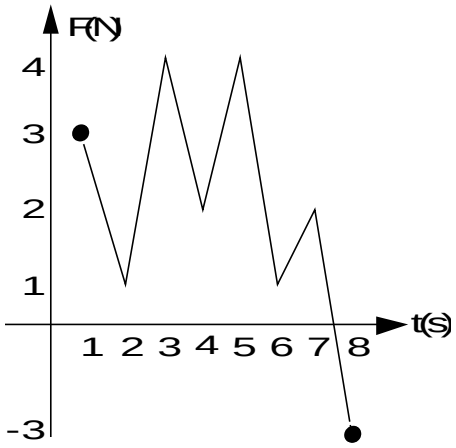
1.DOWNING and SOCIE, 1982. “Simple Rainflow counting algorithms”. Int. J. Fatigue, January 1982 (p. 31).

3 Modelization A

3.1 Characteristic of the modelization

Modelization in plane stresses:





3.2 Characteristics of mesh

1 nets QUAD4.

Square width = 1
thickness = 1

3.3 Quantities tested and results

Identification	Reference
in all nodes at the end of the loading in stress or strain	
Damage Wöhler	4.8133 10-3
Damage Manson-Whetstone sheath	4.6705 10-3
σ	-3.
σ_{VMIS}	3.
σ_{TRESCA}	3.
$\sigma_{VMIS-SG}$	-3.
ε	-3.
γ	0.9.2.6
ε_{INVA-2}	
$\varepsilon_{INVA-2}SG$	-2.6

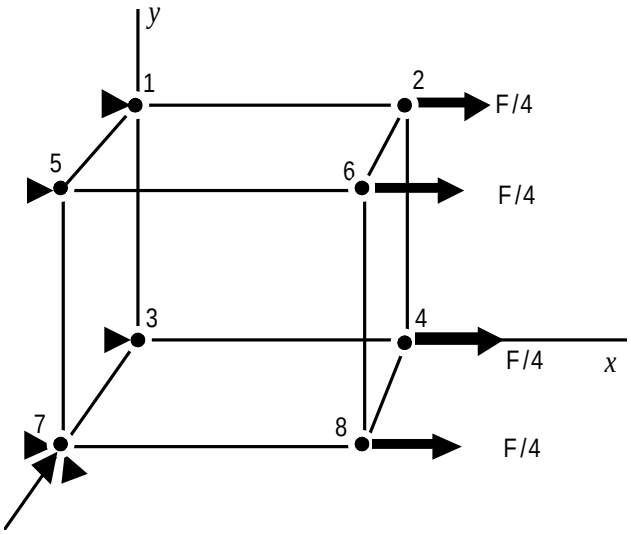
3.4 Remarks

fast Test in time computation.

4 Modelization B

4.1 Characteristic of the modelization

Modelization in 3D :



4.2 Characteristics of mesh

1 nets HEXA8.
cubic of width = 1

4.3 Quantities tested and results

Identification	Reference
in all nodes at the end of the loading	
Damage Wöhler	4.8133 10-3
Damage Manson-Whetstone sheath	4.6705 10-3
σ	-3.
σ_{VMIS}	3.
σ_{TRESCA}	3.
$\sigma_{VMIS-SG}$	-3.
ε	-3.
γ	0.9.2.6
ε_{INVA-2}	
$\varepsilon_{INVA-2}SG$	-2.6
$(\varepsilon-\varepsilon^{th})_{INVA-2}$	2.6
$(\varepsilon-\varepsilon^{th})_{INVA-2}SG$	-2.6

4.4 Remarks

Same results and reference that in plane stresses.

5 Summary of the results

This test validates the method and the computation of the damage of Wöhler and Manson-Whetstone sheath.

The results of *Code_Aster* are identical to those obtained analytically.