SZLZ105 - Counting of cycles by RAINFLOW and calculation of the damage

Summary:

Transitory linear elastic problem quasi-static in mechanics of the structures.

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

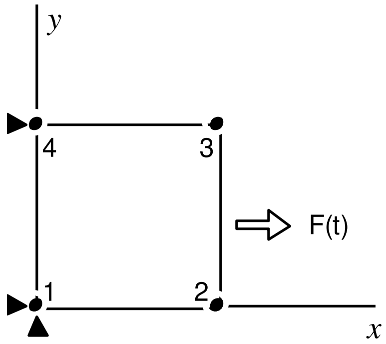
A modeling in plane constraints and a modeling in 3D.

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

It also validates the calculation of the constraints and deformations equivalent using the options SIEQ_ELGA, SIEQ_ELNO, EPEQ_ELGA, EPEQ_ELNO, EPMQ_ELGA and EPMQ_ELNO.

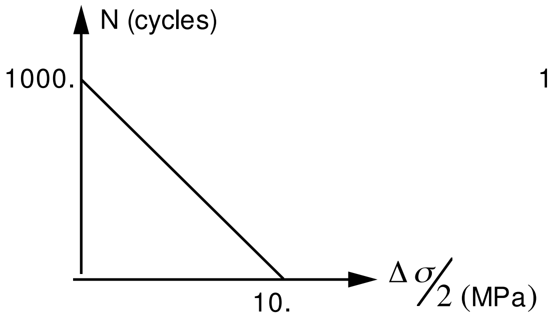
1 Problem of reference

1.1 Geometry

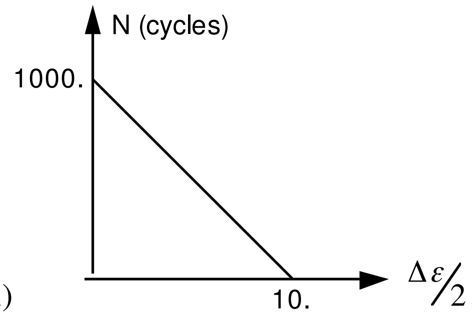


1.2 Material properties

Linear elasticity: $E=1.MPa$ $\nu=0.3$



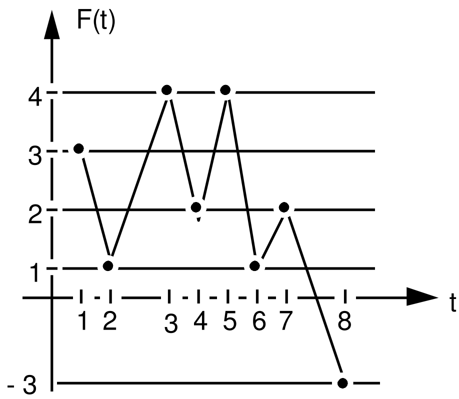
Courbe de Wöhler



Courbe de Manson-Coffin

1.3 Boundary conditions and loadings

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



1.4 Initial conditions

Worthless constraints and deformations.

2 Reference solution

2.1 Method of calculating used for the reference solution

Analytical solution

- calculation of the constraints and deformations. For a loading in simple traction, one obtains a homogeneous state of stress uniaxial in any point:

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

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

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

- then manual calculation 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 , that is to say $Du_i=\frac{1}{N_i}$ (N_i being the number of cycles with rupture for a given amplitude), as well as the cumulated damage $D=\sum_i Du_i$ (linear rule of office plurality TO MINE).

Note:

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

2.2 Results of reference

- Being given the values of the parameters of loading 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 calculation of the damage, one obtains:

$$D_{Wöhler}=4{,}8133\,.\,10^{-3}=\sum_{i=1}^{4}Du_i$$

$$D_{Manson}=4{,}67\,.\,10^{-3}=\sum_{i=1}^{4}Du_i$$

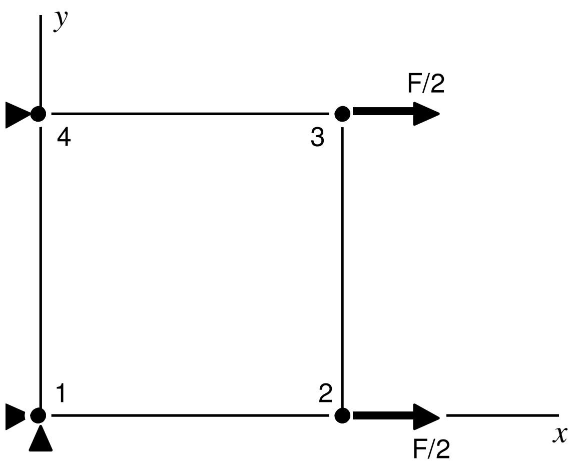
2.3 Bibliographical references

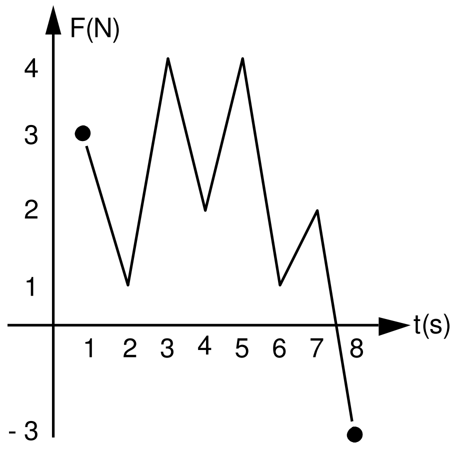
1. DOWNING and SOCIE, 1982. “Simple Rainflow counting algorithms”. Int. J. Tiredness, January 1982 (p. 31).

3 Modeling A

3.1 Characteristics of modeling

Modeling in plane constraints:





3.2 Characteristics of the grid

1 mesh QUAD4.

Square width = 1
thickness = 1

3.3 Sizes tested and results

Identification	Reference
in all nodes at the end of the loading in constraint or deformation	
Wöhler damage	$4.8133\ 10^{-3}$
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
ε_{INVA-2}	2.6
$\varepsilon_{INVA-2}SG$	-2.6

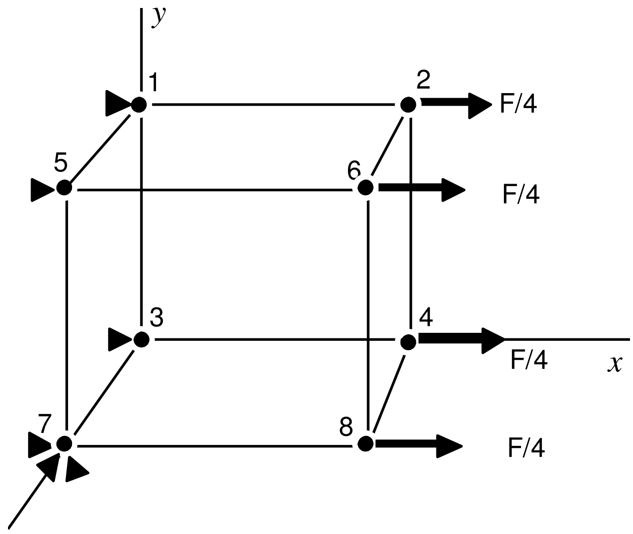
3.4 Remarks

Fast test in time calculation.

4 Modeling B

4.1 Characteristics of modeling

Modeling in 3D :



4.2 Characteristics of the grid

1 mesh HEXA8.
cubic of width = 1

4.3 Sizes tested and results

Identification	Reference
in all nodes at the end of the loading	
Wöhler damage	$4.8133\ 10^{-3}$
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
ε_{INVA-2}	2.6
$\varepsilon_{INVA-2} SG$	-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 constraints.

5 Summary of the results

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

Results of *Code_Aster* are identical to those obtained analytically.