# SZLZ111 - Damage of Lemaître-Sermage in postprocessing POST_FATIGUE

**Summary:**

The purpose of this test is calculation of the damage of Lemaître-Sermage "LEMAITRE"starting from a history of multiaxial loading unspecified and history of the cumulated plastic deformation.

One calculates the damage starting from the data of the tensor of the constraints and the plastic deformation cumulated in every moment $t_i$ (provided by the user).

The characteristics material $E$ (Young modulus), $\nu$ (Poisson's ratio) and $S$ (parameter of material) must depend on the temperature $T$. This one must thus be provided by the user at the same moments as $\sigma(t)$ and $p(t)$.

# 1 Problem of reference

One calculates the damage, $D(t)$ , starting from the data of the tensor of the constraints, $\sigma(t)$ , and of the cumulated plastic deformation, $p(t)$ .

$$\dot{D}=\frac{1}{(1-D)^{2s}}\left[\frac{1}{3\mathrm{ES}}(1+\nu)\sigma_{eq}^{2}+\frac{3}{2\mathrm{ES}}(1-2\nu)\sigma_{H}^{2}\right]^{s}\dot{p} \quad \text{if } p>p_d$$

$$D=0 \quad \text{if not}$$

$\sigma_{eq}$ is the equivalent constraint of von Mises
$\sigma_H$ is the hydrostatic constraint
$p_d$ represent the threshold of damage
$S$ is a characteristic materials ( $MPa$ )
$s$ is a characteristic materials

## 1.1 Properties materials

| $Temp(°C)$ | $E(MPa)$ | $\nu$ | $S(MPa)$ |
|---|---|---|---|
| 0. | 2.E+5 | 0. | 7. |
| 20. | 2.E+5 | 0. | 7. |
| 40. | 2.E+5 | 0. | 7. |

$p_d=0.02$

### 1.1.1 Modeling A

In this modeling, one checks the calculation of the damage of Lemaître-Sermage compared to the reference solution given daNS [V9.01.109]. Values of the exhibitor $s$ and of $S$ in the expression of the damage of generalized Lemaître are worth:

$s=1.0$ and $S=7.0$

### 1.1.2 Modeling B

In this second modeling, one checks the calculation of the damage of Lemaître-Sermage compared to an analytical solution obtained by applying the algorithms presented in the document of référencE [R7.04.01]. S values of the exhibitor $s$ and of $S$ in the expression of the damage of generalized Lemaître are worth:

$s=1.003$ and $S=7.0$

## 1.2 History of the loading

| $t$ | 43.11 | 100. | 1000. | 10000. | 20000. | 21000. | 22000. | 22200. | 22400. |
|---|---|---|---|---|---|---|---|---|---|
| $\sigma_{xx}(t)$ | 300. | 300. | 300. | 300. | 300. | 300. | 300. | 300. | 300. |
| $\sigma_{yy}(t)$ | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| $\sigma_{zz}(t)$ | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| $\sigma_{xy}(t)$ | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| $\sigma_{xz}(t)$ | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| $\sigma_{yz}(t)$ | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| $Temp$ | 20. | 20. | 20. | 20. | 20. | 20. | 20. | 20. | 20. |

| $t$ | $p(t)$ **(Cumulated Plastic deformation)** |
|---|---|
| 43.11 | 0.019996 |
| 100. | 0.046384 |
| 1000. | 0.46384 |
| 10000. | 4.6384 |
| 20000. | 9.2768 |
| 21000. | 9.74064 |
| 22000. | 10.20448 |
| 22200. | 10.297248 |
| 22400. | 10.390016 |

# 2 Reference solution

## 2.1 Method of calculating used for the reference solution

History of loading being very simple, results of reference EPuvent being obtained manually by applying the algorithms presented in the reference document [R7.04.01].

## 2.2 Results of reference

### 2.2.1 Modeling A

| $t$ | $D(t)$ **(Damage)** |
|---|---|
| 43.11 | 0. |
| 100. | 0.000848907 |
| 1000. | 0.014474925 |
| 10000. | 0.178374238 |
| 20000. | 0.524693005 |
| 21000. | 0.602827469 |
| 22000. | 0.73829052 |
| 22200. | 0.792149807 |
| 22400. | 0.967604351 |

### 2.2.2 Modeling B

The results of reference for the case test number 2 are got using a spreadsheet in which the expression of the damage of Lemaître-Sermage was established according to a diagram of digital integration identical to that used in the routine `POST_FATIGUE` of *Code_Aster*.

One initially checks that uncertainty on the results got for the value $s=1.0$ via the spreadsheet is acceptable:

| **Too bad (Excel calculation)** | **Too bad (reference solution)** | **Difference ( $\%$ )** |
|---|---|---|
| 0.0000000000 | 0.0000000000 | 0.00000% |
| 0.0008489062 | 0.0008489070 | -0.00010% |
| 0.0144749268 | 0.0144749250 | 0.00001% |
| 0.1783742841 | 0.1783742380 | 0.00003% |
| 0.5246932887 | 0.5246930050 | 0.00005% |
| 0.6028278917 | 0.6028274690 | 0.00007% |
| 0.7382915411 | 0.7382905200 | 0.00014% |
| 0.7921514337 | 0.7921498070 | 0.00021% |
| 0.9676720845 | 0.9676043510 | 0.00700% |

In the second time, one generates a reference solution for a value of $s$ = 1,003:

| $t$ | $D(t)$ **(Damage – Excel solution)** |
|---|---|
| 43.11 | 0.0 |
| 100. | 0.004742198 |
| 1000. | 0.083020455 |
| 10000. | 1.809947268 |
| 20000. | 2.003578566 |
| 21000. | 0.083020455 |
| 22000. | 0.178700399 |
| 22200. | 0.199207053 |
| 22400. | 0.220252827 |

## 2.3 Uncertainty on the solution

Analytical solution.

## 2.4 Bibliographical references

1.A.M. DONORE: Estimate of the lifetime in fatigue to great numbers of cycles and in fatigue oligocyclic. Note [R7.04.01] Index B.

# 3 Modeling A

## 3.1 Results of modeling A

| Identification | | Reference |
|---|---|---|
| Point 1 | Too bad | 0. |
| Point 2 | Too bad | 0.000848907 |
| Point 3 | Too bad | 0.014474925 |
| Point 4 | Too bad | 0.178374238 |
| Point 5 | Too bad | 0.524693005 |
| Point 6 | Too bad | 0.602827469 |
| Point 7 | Too bad | 0.73829052 |
| Point 8 | Too bad | 0.792149807 |
| Point 9 | Too bad | 0.967604351 |

# 4 Modeling B

## 4.1 Results of modeling B

| Identification | | Reference |
|---|---|---|
| Point 1 | Too bad | 0.0000000000 |
| Point 2 | Too bad | 0.0008401910 |
| Point 3 | Too bad | 0.0143249000 |
| Point 4 | Too bad | 0.1762380000 |
| Point 5 | Too bad | 0.5133290000 |
| Point 6 | Too bad | 0.5863320000 |
| Point 7 | Too bad | 0.7028150000 |
| Point 8 | Too bad | 0.7412430000 |
| Point 9 | Too bad | 0.7967720000 |

# 5 Summary of the results

Results provided by *Code_Aster* coincide with the values of reference.