SZLZ107 - Criteria of starting in fatigue under multiaxial loadings for a localization criticizes structure

Summarized:

The purpose of this test is the multiaxial computation of the criteria of fatigue for the periodic loadings and NON-periodicals by means of **POST_FATIGUE** for a critical localization of structure. The purpose of this benchmark is to find same the computation results got by CALC_FATIGUE.

modelization A	criteria CROSSLAND, DANG VAN-PAPADOPOULOS and formulates modelization
of it B	criteria in formulas (to find the results of benchmark SSLV135D), "MATAKE_MODI_AC", DANG_VAN_MODI_AC (to find the results of benchmarks SSLV135A) ;
modelization C	criteria in formulas (to find the results of benchmark SSLV135E) ;
modelization D	criteria in formulas (to find the results of benchmark SSLV135F);
modelization E	criteria in formulas, "MATAKE_MODI_AV", DANG_VAN_MODI_AV, FATESOCI_MODI_AV (to find the results of benchmarks SSLV135B)
modelization F	criteria MATAKE_MODI_AC , DANG_VAN_MODI_AC, MATAKE_MODI_AV, DANG_VAN_MODI_AV, FATESOCI_MODI_AV. One tests the change of the direction of the critical plane on which the damage or the shears is maximum

results provided by the operator POST_FATIGUE are completely satisfactory.

1 Problem of reference

1.1 Modelization To

the analysis consists in determining the criterion of CROSSLAND and the criterion of DANG VAN - PAPADOPOULOS in a point of a structure subjected to a radial periodic multiaxial loading.

Criterion of CROSSLAND:

$$\tau_a + a\,P_{max} - b \leq 0 \text{ where:}$$

$$\tau_a = \frac{1}{2}\underset{0\leq t_0\leq T}{Max}\;\underset{0\leq t_1\leq T}{Max}\left\|\tilde{s}(t_1)-\tilde{s}(t_0)\right\| = \frac{1}{2}\underset{0\leq t_0\leq T}{Max}\;\underset{0\leq t_1\leq T}{Max}\sqrt{\frac{1}{2}\left(\tilde{s}_{11}^2+\tilde{s}_{22}^2+\tilde{s}_{33}^2+2\tilde{s}_{12}^2+2\tilde{s}_{13}^2+2\tilde{s}_{23}^2\right)}$$

amplitude de scission avec $\tilde{s}$ déviateur du tenseur des contraintes σ

$$P_{max} = \underset{0\leq t\leq T}{Max}\left(\frac{1}{3}trace(\sigma)\right) = \text{ maximum hydrostatic pressure}$$

$$a = \left(\tau_0 - \frac{d_0}{\sqrt{3}}\right) / \frac{d_0}{3} \text{ and } b = \tau_0$$

with τ_0 = limit of endurance in alternate pure shears
d_0 = limit of endurance in alternate pure traction and compression

the criterion is: $Rcrit = \tau_a + a\,P_{max} - b$

If $Rcrit$ is negative or null, there is no damage. If $Rcrit$ is positive, there is likely to be damage.

Criterion of DANG VAN-PAPADOPOULOS:

$$K^* + a\,P_{max} - b \leq 0$$

where $K^* = R/\sqrt{2}$ where R radius of the smallest sphere circumscribed with the way of loading within the space of stress deviators $\tilde{s}$.

$$R = \underset{0\leq t\leq T}{Max}\sqrt{(\tilde{s}(t)-C^*):(\tilde{s}(t)-C^*)} \text{ where } C^* \text{ is the center of the hypersphère}$$

$$C^* = \underset{C\in K}{Min}\;\underset{0\leq t\leq T}{Max}\sqrt{(\tilde{s}(t)-C):(\tilde{s}(t)-C)}$$

$$P_{max} = \underset{0\leq t\leq T}{Max}\left(\frac{1}{3}trace(\sigma)\right) = \text{ maximum hydrostatic pressure}$$

$$a = \left(\tau_0 - \frac{d_0}{\sqrt{3}}\right) / \left(\frac{d_0}{3}\right) \text{ and } b = \tau_0$$

with τ_0 = limit of endurance in alternate pure shears
d_0 = limit of endurance in alternate pure traction and compression

the criterion is: $R_{crit} = K^* + a\,P_{max} - b$

If $Rcrit$ is negative or null, there is no damage. If $Rcrit$ is positive, there is likely to be damage.

1.1.1 Material properties

τ_0 = limit of endurance in alternate pure shears = $352.\ MPa$
d_0 = limit of endurance in alternate pure traction and compression = $540.97\ MPa$

1.1.2 History of loading

t	1.	2.	3.
$\sigma_{xx}(t)$	411.	0.	– 411.
$\sigma_{xy}(t)$	205.	0.	– 205.
$\sigma_{yy}(t)=\sigma_{zz}(t)=\sigma_{xz}(t)=\sigma_{yz}(t)$	0.	0.	0.

The loading is considered periodic.

1.2 Modelization B

the material properties and the load history identical and are obtained starting from benchmarks SSLV135A.

1.3 Modelization C

the material properties and the load history identical and are obtained starting from benchmarks SSLV135E .

1.4 Modelization D

the material properties and the load history identical and are obtained starting from benchmark SSLV135F .

1.5 Modelization E

the material properties and the load history identical and are obtained starting from benchmarks SSLV135 B .

1.6 Modelization F

the material properties and the load history are identical and obtained starting from benchmarks SSLV135 G

2 Reference solution

2.1 Modelization A

2.1.1 Méthode de calcul used for the reference solution

the results of reference result from the thesis of I. PAPADOPOULOS [bib1]. For the criterion of CROSSLAND, one can also obtain them manually.

The loading being radial the two criteria must provide the same results.

2.1.2 Results of Reference

For **the criterion of CROSSLAND**, the value of the amplitude of scission, the value of the maximum hydrostatic pressure and the value of the criterion are tested:

$$\tau_a = 313.579\,Mpa \quad P_{max} = 137.\,Mpa \quad Rcrit = -8.281$$

For **the criterion of DANG VAN-PAPADOPOULOS**, one tests the value of the radius of the smallest sphere circumscribed with the loading, the value of the maximum hydrostatic pressure and the value of the criterion:

$$K^* = 313.579\,Mpa \quad P_{max} = 137.\,Mpa \quad Rcrit = -8.281$$

2.2 Modelizations B, C, D, E and F

One bases oneself on the modelizations calculated by `CALC_FATIGUE` in benchmark SSLV135. See [V3.04.135] for the reference solutions.

2.3 Uncertainty on the solution

Solutions analytical or obtained from `CALC_FATIGUE`.

2.4 Bibliographical references

1.Thesis of I. PAPADOPOULOS “Tires polycyclic metals: a new approach” (1987) ENPC.

3 Modelization A

3.1 Characteristic of the modelization

One tests criteria CROSSLAND , DANG VAN-PAPADOPOULOS and in formula.

3.2 Characteristics of the mesh

The mesh is not necessary.

3.3 Quantities tested and results

For criteria called by the names:

Standard	identification of reference	Value of reference
Criterion of CROSSLAND		
PRES_HYDRO_MAX ($Pmax$)	" SOURCE_EXTERNE "	137.
AMPLI_CISSION (τ_a)	" SOURCE_EXTERNE "	313.579
Criterion ($Rcrit$)	" SOURCE_EXTERNE "	– 8.281
Criterion of DANG VAN-PAPADOPOULOS		
PRES_HYDRO_MAX ($Pmax$)	" SOURCE_EXTERNE "	137.
RAYON_SPHERE ($k*$)	" SOURCE_EXTERNE "	313.579
Criterion ($Rcrit$)	" SOURCE_EXTERNE "	– 8.281

For criteria called by the formula:

Standard	identification of reference	Value of reference
Criterion of CROSSLAND		
PHYDRM ($Pmax$)	" SOURCE_EXTERNE "	137.
AMPCIS (τ_a)	" SOURCE_EXTERNE "	313.579
Criterion ($Rcrit$)	" SOURCE_EXTERNE "	– 8.281
Criterion of DANG VAN-PAPADOPOULOS		
PHYDRM ($Pmax$)	" SOURCE_EXTERNE "	137.
RAYSPH ($k*$)	" SOURCE_EXTERNE "	313.579
Criterion ($Rcrit$)	" SOURCE_EXTERNE "	– 8.281

4 Modelization B

4.1 Characteristic of the modelization

One tests the criteria in formulas (to find the results of benchmark SSLV135D), "MATAKE_MODI_AC" DANG_VAN_MODI_AC (to find the results of benchmarks SSLV135A) ;

4.2 Characteristics of the mesh

The mesh is not necessary.

4.3 Quantities tested and results

For the quantities of SSLV135D:

Standard	identification of reference	Value of reference
"DEPSPE"	"ANALYTIQUE"	7.5E-4
"EPSPR1"	"ANALYTIQUE"	7.625E-4
"SIGNM1"	"ANALYTIQUE"	200
"APHYDR"	"ANALYTIQUE"	66.6666
"DENDIS"	"ANALYTIQUE"	0.45
"DENDIE"	"ANALYTIQUE"	0.173333
"DSIGEQ"	"ANALYTIQUE"	200
"EPSNM1"	"ANALYTIQUE"	1.75E-3
"INVA2S"	"ANALYTIQUE"	1.616666E-3
"DSITRE"	"ANALYTIQUE"	50
"DEPTRE"	"ANALYTIQUE"	6.0625E-4
"DEPTRE"	"ANALYTIQUE"	3.67423E-3

For the criteria "MATAKE_MODI_AC" and the criterion in formula associated (SSLV135A) with the option COURBE_GRD_VIE = "WOHLER" and for the option COURBE_GRD_VIE = "FORM_VIE" and FORMULE_VIE = WHOL:

Standard	identification of reference	Value of reference
$\Delta\tau(n_1)$	"ANALYTIQUE"	1 . 500000E+02
component x of n_1	"ANALYTIQUE"	– 7.071068E-01
component y of n_1	"ANALYTIQUE"	7.071068E-01
component z of n_1	"ANALYTIQUE"	0.0
$N_{max}(n_1)$	"ANALYTIQUE"	5.000000E+01
$N_m(n_1)$	"ANALYTIQUE"	0.0

$\varepsilon_{max}(n_1)$	"ANALYTIQUE"	1.750000E-04
$\varepsilon_m(n_1)$	"ANALYTIQUE"	0.0
$\sigma_{eq}(n_1)$	"ANALYTIQUE"	3.000000E+02
$Nb_{cr}(n_1)$	"ANALYTIQUE"	1.094600E+04
$ENDO(n_1)$	"ANALYTIQUE"	9.135647E-05
$\Delta\tau(n_2)$	"ANALYTIQUE"	1 . 500000E+02
component x of n_2	"ANALYTIQUE"	7.071068E-01
component y of n_2	"ANALYTIQUE"	7.071068E-01
component z of n_2	"ANALYTIQUE"	0.0
$N_{max}(n_2)$	"ANALYTIQUE"	5.000000E+01
$N_m(n_2)$	"ANALYTIQUE"	0.0
$\varepsilon_{max}(n_2)$	"ANALYTIQUE"	1.750000E-04
$\varepsilon_m(n_2)$	"ANALYTIQUE"	0.0
$\sigma_{eq}(n_2)$	"ANALYTIQUE"	3.000000E+02
$Nb_{cr}(n_2)$	"ANALYTIQUE"	1.094600E+04
$ENDO(n_2)$	"ANALYTIQUE"	9.135647E-05

For the criteria "DANG_VAN_MODI_AC" and the criterion in formula associated (SSLV135A) with the option COURBE_GRD_VIE = "WOHLER" and for the option COURBE_GRD_VIE = "FORM_VIE" and FORMULE_VIE = "WHOL" :

Standard	identification of reference	Value of reference
$\Delta\tau(n_1)$	"ANALYTIQUE"	1 . 500000E+02
component x of n_1	"ANALYTIQUE"	7.071068E-01
component y of n_1	"ANALYTIQUE"	7.071068E-01
component z of n_1	"ANALYTIQUE"	0.0
$N_{max}(n_1)$	"ANALYTIQUE"	5.000000E+01
$N_m(n_1)$	"ANALYTIQUE"	0.0
$\varepsilon_{max}(n_1)$	"ANALYTIQUE"	1.750000E-04

$\varepsilon_m(n_1)$	"ANALYTIQUE"	0.0
$\sigma_{eq}(n_1)$	"ANALYTIQUE"	2.750000E+02
$Nb_{cr}(n_1)$	"ANALYTIQUE"	1.490300E+04
$ENDO(n_1)$	"ANALYTIQUE"	6.709959E-05
$\Delta\tau(n_2)$	"ANALYTIQUE"	1 . 500000E+02
component x of n_2	"ANALYTIQUE"	– 7.071068E-01
component y of n_2	"ANALYTIQUE"	7.071068E-01
component z of n_2	"ANALYTIQUE"	0.0
$N_{\max}(n_2)$	"ANALYTIQUE"	5.000000E+01
$N_m(n_2)$	"ANALYTIQUE"	0.0
$\varepsilon_{\max}(n_2)$	"ANALYTIQUE"	1.750000E-04
$\varepsilon_m(n_2)$	"ANALYTIQUE"	0.0
$\sigma_{eq}(n_2)$	"ANALYTIQUE"	2.750000E+02
$Nb_{cr}(n_2)$	"ANALYTIQUE"	1.490300E+04
$ENDO(n_2)$	"ANALYTIQUE"	6.709959E-05

5 Modelization C

5.1 Characteristic of the modelization

One The mesh tests the criteria in formulas (to find the results of benchmark SSLV135E

5.2) Characteristic of

the mesh is not necessary.

5.3 Quantities tested and results

the value of reference corresponds to damage (ENDO1) and the results were obtained via **the formula of Basquin** :

Standard	identification of reference	Value of reference
Criteria		
$\frac{\lvert SIPR1-SIPR2\rvert}{2}$	"ANALYTIQUE"	1.0707149E-03
$\frac{\lvert SITN1-SITN2\rvert}{2}$	"ANALYTIQUE"	1.0707149E-03
$\frac{SIPN1-SIPN2}{2}$	"ANALYTIQUE"	1.0707149E-03
$\frac{SIGEQ1-SIGEQ2}{2}$	"ANALYTIQUE"	4.287285E-03

the value of reference always corresponds to damage (ENDO1) and the results were obtained with **an interpolation** of the curve of Wöhler :

Standard	identification of reference	Value of reference
Criteria		
$\frac{\lvert SIPR1-SIPR2\rvert}{2}$	"ANALYTIQUE"	1.9212572E-03
$\frac{\lvert SITN1-SITN2\rvert}{2}$	"ANALYTIQUE"	1.9212572E-03
$\frac{SIPN1-SIPN2}{2}$	"ANALYTIQUE"	1.9212572E-03
$\frac{SIGEQ1-SIGEQ2}{2}$	"ANALYTIQUE"	5.8175699E-03

6 Modelization D

6.1 Characteristic of the modelization

One The mesh tests the criteria in formulas (to find the results of sslv135F benchmark

6.2) Characteristic of

the mesh is not necessary.

6.3 Quantities tested and results

Result obtained with first loading (**SOL_NL** of SSLV135 F):
The value of reference corresponds to damage (ENDO1) and the results were obtained via **the formula of Basquin** :

Standard	identification of reference	Value of reference
Criteria		
$\dfrac{\lvert EPSN1-EPSN2\rvert}{2}$	"ANALYTIQUE"	1.08363973E-05
$\dfrac{\lvert ETPR1-ETPR2\rvert}{2}$	"ANALYTIQUE"	1.0 8363973 E-0 5
$\dfrac{\lvert ETEQ1-ETEQ2\rvert}{2}$	"ANALYTIQUE"	1.06338423E-05

the value of reference always corresponds to damage (ENDO1) and the results were obtained with **an interpolation** of the curve of Wöhler :

Standard	identification of reference	Value of reference
Criteria		
$\dfrac{\lvert EPSN1-EPSN2\rvert}{2}$	"ANALYTIQUE"	3.26558686E-05
$\dfrac{\lvert ETPR1-ETPR2\rvert}{2}$	"ANALYTIQUE"	3.26558686E-05
$\dfrac{\lvert ETEQ1-ETEQ2\rvert}{2}$	"ANALYTIQUE"	3.21404432E-05

Result obtained with second loading (**SOL_NL2** of SSLV135 F):
The value of reference corresponds to damage (ENDO1) and the results were obtained via **the formula of Basquin** :

Standard	identification of reference	Value of reference
Criteria		

$\frac{\lvert EPSN1-EPSN2\rvert}{2}$	"ANALYTIQUE"	1.449229E-04
$\frac{\lvert ETPR1-ETPR2\rvert}{2}$	"ANALYTIQUE"	1. 449229 E-0 4
$\frac{\lvert ETEQ1-ETEQ2\rvert}{2}$	"ANALYTIQUE"	6.5320499E-05

the value of reference always corresponds to damage (ENDO1) and the results were obtained with **an interpolation** of the curve of Wöhler :

Standard	**identification of reference**	**Value of reference**
Criteria		
$\frac{\lvert EPSN1-EPSN2\rvert}{2}$	"ANALYTIQUE"	2.408735E-04
$\frac{\lvert ETPR1-ETPR2\rvert}{2}$	"ANALYTIQUE"	2.408735 E-0 4

Result obtained with third loading (**SOL_NL3** of SSLV135 F):
The value of reference corresponds to damage (ENDO1) and the results were obtained via **the formula of Basquin** :

Standard	**identification of reference**	**Value of reference**
Criteria		
$\frac{\lvert EPPR1-EPPR2\rvert}{2}$	"ANALYTIQUE"	1.377855E-02

the value of reference always corresponds to damage (ENDO1) and the results were obtained with **an interpolation** of the curve of Wöhler :

Standard	**identification of reference**	**Value of reference**
Criteria		
$\frac{\lvert EPPR1-EPPR2\rvert}{2}$	"ANALYTIQUE"	2.1858445E-03

7 Modelization E

7.1 Characteristic of the modelization

One tests the criteria in formulas, "MATAKE_MODI_AV", "DANG_VAN_MODI_AV", "FATESOCI_MODI_AV" (to find the results of benchmarks SSLV135 B)

7.2 Characteristic of the mesh

The mesh is not necessary.

7.3 Quantities tested and results

For the criteria "MATAKE_MODI_A V " and the criterion in formula associated (SSLV135 B)

For the results with option COURBE_GRD_VIE=' WOHLER' and for the option COURBE_GRD_VIE = "FORM_VIE" and FORMULE_VIE = "WHOL" :

Standard	identification of reference	component Value of reference
x of n_1 and n_2	"AUTRE_ASTER "	-0.38268343236509 0.38268343236509
component y of n_1 and n_2	"AUTRE_ASTER "	0.92718385456679 0.92387953251129
component z of n_1 and n_2	"AUTRE_ASTER "	0.0000000000000E+00
$ENDO(n_1)$	"AUTRE_ASTER "	7.0532362250863E-04

In the table above, the components x and y of n_1 and n_2 has two values because there exist two vectors which correspond to the same value of damage $ENDO(n_1)$ =formule $ENDO(n_2)$.

For the results with option COURBE_GRD_VIE= "FORM_VIE" and FORMULE_VIE = WHOL_F:

Standard	identification of reference	component Value of reference
x of n_1 and n_2	"AUTRE_ASTER "	-0.38268343236509 0.38268343236509
component y of n_1 and n_2	"AUTRE_ASTER "	0.92718385456679 0.92387953251129
component z of n_1 and n_2	"AUTRE_ASTER "	0.0000000000000E+00
$ENDO(n_1)$	"AUTRE_ASTER "	3.3180845213285E-04

In the table above, the components x and y of n_1 and n_2 has two values because there exist two vectors which correspond to the same value of damage $ENDO(n_1)$ =formule $ENDO(n_2)$.

For the criteria " DANG_VAN_MODI_AV " and the criterion in formula associated (SSLV135B)
For the results with option COURBE_GRD_VIE=' WOHLER' and for the option COURBE_GRD_VIE=' FORMES_VIE' and FORMULE_VIE = WHOL:

Standard	identification of reference	component Value of reference
x of n_1 and n_2	"AUTRE_ASTER"	-7.0710678118655E-01 7.0710678118655E-01
component y of n_1 and n_2	"AUTRE_ASTER"	7.0710678118655E-01
component z of n_1 and n_2	"AUTRE_ASTER"	0.0000000000000E+00
$ENDO(n_1)$	"AUTRE_ASTER"	1.3419917535855E-04

In the table above, the components x and y of n_1 and n_2 has two values because there exist two vectors which correspond to the same value of damage $ENDO(n_1)$ =formule $ENDO(n_2)$.

For the results with option COURBE_GRD_VIE= "FORM_VIE" and FORMULE_VIE = WHOL_F:

Standard	identification of reference	component Value of reference
x of n_1 and n_2	"AUTRE_ASTER"	-7.0710678118655E-01 7.0710678118655E-01
component y of n_1 and n_2	"AUTRE_ASTER"	7.0710678118655E-01
component z of n_1 and n_2	"AUTRE_ASTER"	0
$ENDO(n_1)$	"AUTRE_ASTER"	8.7633062468223E-05

In the table above, the components x and y of n_1 and n_2 has two values because there exist two vectors which correspond to the same value of damage $ENDO(n_1)$ =formule $ENDO(n_2)$.

For the criteria " FATESOCI_MODI_AV " and the criterion in formula associated (SSLV135B)

For the results with option COURBE_GRD_VIE=' WOHLER', COURBE_GRD_VIE=' FORMES_VIE' and FORMULE_VIE = MANCO1:

Standard	identification of reference	component Value of reference
x of n_1 and n_2	"AUTRE_ASTER"	-4.3837114678908E-01 4.3837114678908E-01
component y of n_1 and n_2	"AUTRE_ASTER"	8.9879404629917E-01
component z of n_1 and n_2	"AUTRE_ASTER"	0
$ENDO(n_1)$	"AUTRE_ASTER"	1.6823455707218E-01

In the table above, the component x of n_1 and n_2 has two values because there exist two vectors which correspond to the same value of damage $ENDO(n_1)$ =formule $ENDO(n_2)$.

For the results with option COURBE_GRD_VIE= "FORM_VIE" and FORMULE_VIE = MANCO2:

Standard	identification of reference	component Value of reference
x of n_1 and n_2	"AUTRE_ASTER"	-0.43051109680829 0.43051109680830
component y of n_1 and n_2	"AUTRE_ASTER"	0.90258528434986
component z of n_1 and n_2	"AUTRE_ASTER"	6.1232339957368E-17
$ENDO(n_1)$	"AUTRE_ASTER"	0.61539334669938

In the table above, the component x of n_1 and n_2 has two values because there exist two vectors which correspond to the same value of damage $ENDO(n_1)$ $ENDO(n_2)$

8 Modelization F

8.1 Characteristic of the modelization

One tests criteria MATAKE_MODI_AC, DANG_VAN_MODI_AC, MATAKE_MODI_AV, DANG_VAN_MODI_AV, FATESOCI_MODI_AV. One tests the change of the direction of the critical plane on which the damage or the shears is maximum (to find the results of benchmarks SSLV135G)

8.2 Characteristic of the mesh

The mesh is not necessary.

8.3 Quantities tested and Criteria

- **results of DANG_VAN_MODI_AC, MATAKE_MODI_AC, DANG_VAN_MODI_AV**

For the results of ϕ_z to the node $N1$ for an elastic material.

Standard value α	formula of reference	Value of reference
−1, -0.5,0..10	"ANALYTIQUE"	45

For the results of ϕ_z to the node $N1$ for an elastoplastic material.

Standard value α	formula of reference	Value of reference
0,1,2,3,4	"ANALYTIQUE"	45

- Criterion of **MATAKE_MODI_AV**

Standard Value α	formula of reference	Value of reference
−1	"ANALYTIQUE"	45
−0.5	"ANALYTIQUE"	45.72
0	"ANALYTIQUE"	46.43
0.5	"ANALYTIQUE"	47.14
1	"ANALYTIQUE"	47.86
1.5	"ANALYTIQUE"	48.56
2	"ANALYTIQUE"	49.27
2.5	"ANALYTIQUE"	49.96
3	"ANALYTIQUE"	50.65
3.5	"ANALYTIQUE"	51.34
4	"ANALYTIQUE"	52.02
4.5	"ANALYTIQUE"	52.69
5	"ANALYTIQUE"	53.35
5.5	"ANALYTIQUE"	54
6	"ANALYTIQUE"	54.65
6.5	"ANALYTIQUE"	55.28

7	"ANALYTIQUE"	55.9
7.5	"ANALYTIQUE"	56.51
8	"ANALYTIQUE"	57.11
8.5	"ANALYTIQUE"	57.7
9	"ANALYTIQUE"	58.28
9.5	"ANALYTIQUE"	58.85
10	"ANALYTIQUE"	59.41

For the results of ϕ_z **to the node** $N1$ for an elastoplastic material.

Standard value α	formula of reference	Value of reference
0	"ANALYTIQUE"	46.43
1	"ANALYTIQUE"	47.86
2	"ANALYTIQUE"	49.27
3	"ANALYTIQUE"	50.65
4	"ANALYTIQUE"	52.02

- **Criterion of FATESOCI_MODI_AV**

For the results of ϕ_z **to the node** $N1$ for an elastic material.

Standard value α	formula of reference	Value of reference
−1	"ANALYTIQUE"	45
−0.5	"ANALYTIQUE"	45.34
0	"ANALYTIQUE"	45.67
0.5	"ANALYTIQUE"	45.99
1	"ANALYTIQUE"	46.31
1.5	"ANALYTIQUE"	46.61
2	"ANALYTIQUE"	46.91
2.5	"ANALYTIQUE"	47.2
3	"ANALYTIQUE"	47.48
3.5	"ANALYTIQUE"	47.75
4	"ANALYTIQUE"	48.01
4.5	"ANALYTIQUE"	48.27
5	"ANALYTIQUE"	48.51
5.5	"ANALYTIQUE"	48.75
6	"ANALYTIQUE"	48.98
6.5	"ANALYTIQUE"	49.2
7	"ANALYTIQUE"	49.42

7.5	"ANALYTIQUE"	49.63
8	"ANALYTIQUE"	49.83
8.5	"ANALYTIQUE"	50.03
9	"ANALYTIQUE"	50.22
9.5	"ANALYTIQUE"	50.4
10	"ANALYTIQUE"	50.58

For the results of ϕ_z **to the node** $N1$ for an elastoplastic material.

Standard value α	**formula of reference**	**Value of reference**
0	"ANALYTIQUE"	45.67
1	"ANALYTIQUE"	46.31
2	"ANALYTIQUE"	46.91
3	"ANALYTIQUE"	47.48
4	"ANALYTIQUE"	48.01

9 Summary of the results

the results provided by *Code_Aster* with `POST_FATIGUE` coincide perfectly with those and values of reference obtained with `CALC_FATIGUE`.