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EPICU03 - Validation of the order POST_K_BETA in the case of a semi-elliptic defect.

Summary:

The order **POST_K_BETA** calculate the elastic factor of intensity of the constraints and the elastoplastic factor of intensity of the constraints (known as also “corrected plastically”) to the two points of the semi-elliptic defect under coating, to the assistance respectively of the examination of the constraints to the nodes resulting from the mechanical resolution via the method of the coefficients of influence and the method known as of the “correction$\mathrm{B}$ ” both described in the RSE-M.

This test initially validates the determination of the factors of intensity of the constraints of a semi-elliptic defect under coating of longitudinal orientation and circumferential orientation in the second time on the level of the point of the defect located side base metal.

The thermomechanical transient considered being supposed spatially uniform at every moment and the thermal and mechanical properties of the coating as base metal being also spatially invariant, the absence of effective defect in the grid of the zone of heart of the tank, which is inherent in the present simplified method of analysis of harmfulness of defect, then makes it possible to carry out this test while resting on an axisymmetric modeling of the zone of heart of the tank.

2 Problem of reference

2.1 Geometry

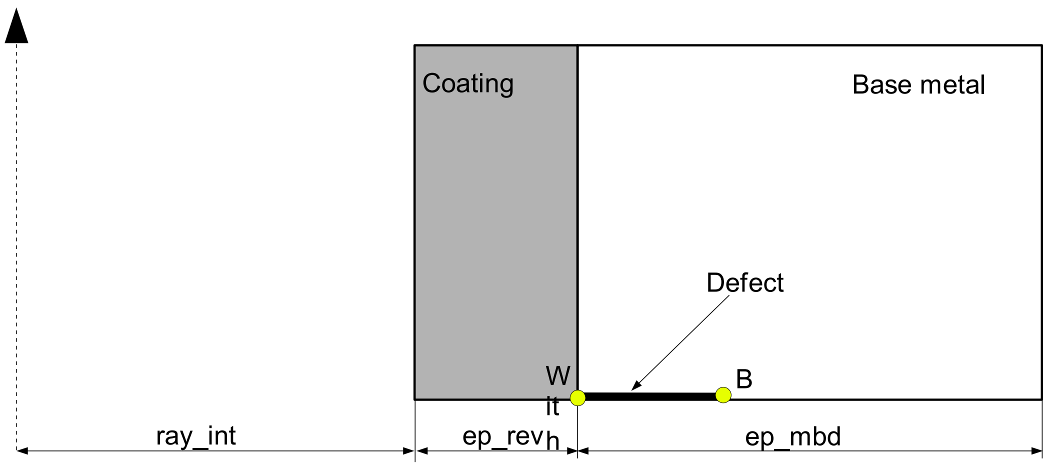
The studied geometry is that of the zone of heart of a generic tank of the stage 1300 MWe.

2.2 Defect considered

Within the framework of the simplified methodology of analysis of harmfulness of defect, the method of calculating of the elastic factor of intensity of the constraints via the method of the coefficients of influence intrinsically supposes the absence of effective modeling of the defect in the grid. Indeed, the grid makes it possible to initially calculate the constraints with the nodes and a postprocessing is then applied to calculate the elastic factor of intensity of the constraints by the method of the coefficients of influence to be precisely left these constraints to the nodes (the method is detailed in [R7.02.10]).

For this test, the defect under-coating considered is semi-elliptic and of longitudinal orientation initially and circumferential orientation in the second time. Its point side coating rests rigorously on the interface between the coating and the base metal. Its dimensions are the following ones (see figure which follows):

- depth: $prof_{def} = 5mm$
- width: $2b = 25mm$



2.3 General description of the thermomechanical chaining

The study consists of a thermomechanical chaining. Thermal calculation as well as mechanical calculation are carried out on the same grid. The grid used for these two calculations is only made up of elements of the 2ème order (grid known as “quadratic”). Taking into account invariances of the problem, selected modeling is axisymmetric and only a mesh is used in the direction height of tank.

2.4 Material properties

For calculation in thermics:

Two properties are indicated, it acts of:

- LAMBDA : thermal conductivity isotropic function of the temperature, expressed in $W.m^{-1}.K^{-1}$,
- BETA : voluminal enthalpy according to the temperature, expressed in $J.m^{-3}$.

For the coating:

Temperature ($°C$)	LAMBDA
0	14.7
20	14.7
50	15.2
100	15.8
150	16.7
200	17.2
250	18
300	18.6
350	19.3

Temperature ($°C$)	BETA
0	0.000000.E+00
50	1.102100.E+08
100	3.013300.E+08
150	5.014300.E+08
200	7.081300.E+08
250	9.188800.E+08
300	1.132910.E+09
350	1.348980.E+09

For the base metal:

Temperature ($°C$)	LAMBDA
20	37.7
50	38.6
100	39.9
150	40.5
200	40.5
250	40.2
300	39.5
350	38.7

Temperature ($°C$)	BETA
0	0.000000.E+00
50	1.061900.E+08
100	2.903300.E+08
150	4.829100.E+08
200	6.832800.E+08
250	8.921600.E+08
300	1.109440.E+09
350	1.335060.E+09

For calculation in mechanics:

Five parameters are indicated, it acts of:

- E : Young modulus, expressed in Pa ,
- nu coefficient of PoissoN(N=0.3),
- `ALPHA:` isotropic thermal dilation coefficient, expressed in $°C$,
- `TEMP_DEF_ALPHA = 20:` value of the temperature to which values of the thermal dilation coefficient `ALPHA` were determined, expressed in $°C$.
- `VALE_REF = 280` Temperature of reference $T_{Réf}$ for which there is no déformatione of thermal origin, expressed in $°C$.

For the coating:

Temperature ($°C$)	E
0	1.985E+11
20	1.97E+11
50	1.95E+11
100	1.915E+11
150	1.875E+11
200	1.84E+11
250	1.8E+11
300	1.765E+11
350	1.72E+11

Temperature ($°C$)	ALPHA
0	1.756E-05
20	1.764E-05
50	1.7787E-05
100	1.8019E-05
150	1.8225E-05
200	1.8575E-05
250	1.8568E-05
300	1.8768E-05

For the base metal:

Temperature ($°C$)	E
0	2.05E+11
20	2.04E+11
50	2.03E+11
100	2E+11
150	1.97E+11
200	1.93E+11
250	1.89E+11
300	1.85E+11
350	1.8E+11

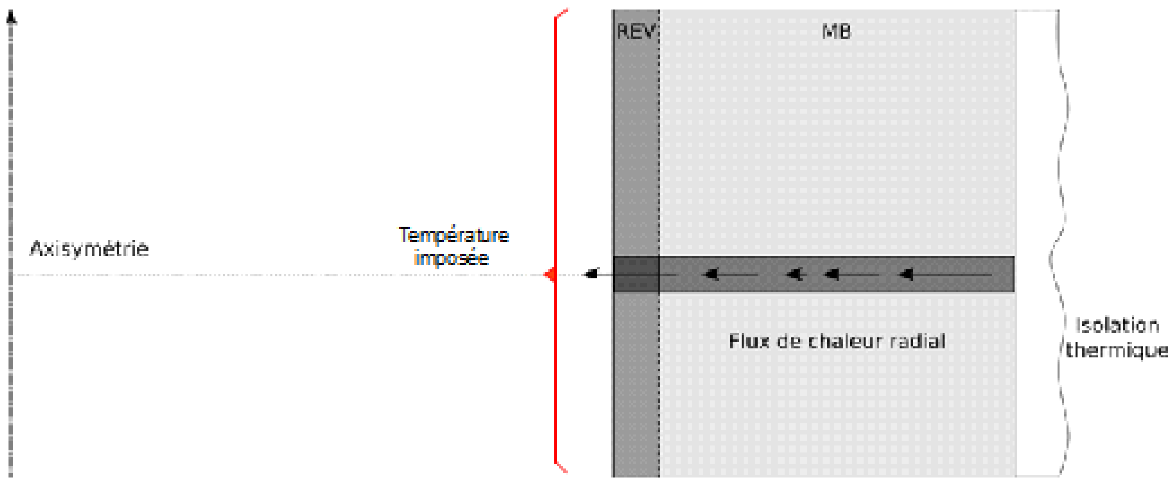
Temperature ($°C$)	ALPHA
0	1.122E-05
20	1.122E-05
50	1.145E-05
100	1.179E-05
150	1.247E-05
200	1.278E-05
250	1.308E-05
300	1.34E-05

2.5 Boundary conditions and loadings

2.5.1 Stage 1 : non-linear thermal calculation

The limiting conditions applied to thermal calculation are summarized on the Figure below and break up as follows:

- temperature imposed in internal wall,
- thermal isolation in external wall.



An analytical thermal transient $T(t, z, \theta)$, with an initial temperature of 280°C, is imposed on the internal wall of the tank. This transient describes the temporal evolution of the temperature T_i in internal wall of the tank according to the azimuth position θ and of the longitudinal position z , thus offering a three-dimensional analytical transient rather near to a real transient.

The analytical expression of the transient is provided in the Equation {1}.

$$T(t,z,\theta)=T_{is}+T_1\times e^{\frac{-t}{[(\sum_{i=0}^{6} a_k\theta^k)(t_{rg}(1-\frac{z}{H_{cuve}})+t_{rgcuve}\times\frac{Z}{H_{cuve}})]}}+T_2\times\sin(f_{2nd}\times t)e^{\frac{-t}{t_{r2nd}}} \quad (1)$$

with the following notation:

- T_{is} : temperature of the injection of security
- T_1 : temperature of the amplitude of the decrease enters the initial temperature and the final temperature (temperature of the injection of security)
- T_2 : temperature of the secondary oscillations around the decrease
- T_{rg} total response time
- T_{rgcuve} total response time of the bottom of the tank
- t_{r2nd} response time of the secondary oscillations
- f_{2nd} frequency of the secondary oscillations
- H_{cuve} height of the tank

$T_{is}(°C)$	$T_1(°C)$	$T_{rg}(S)$	$T_{rgcuve}(S)$	$f_{2nd}(Hz)$	$T_2(°C)$	$t_{r2nd}(S)$	H_{cuve}
10	270	200	700	0.05	20	1000	5000

a_0	a_1	a_2	a_3	a_4	a_5	a_6
2.01373	-1.45143E-2	1.321E-3	-8.07773E-5	1.60275E-6	-1.26618E-8	3.51716E-11

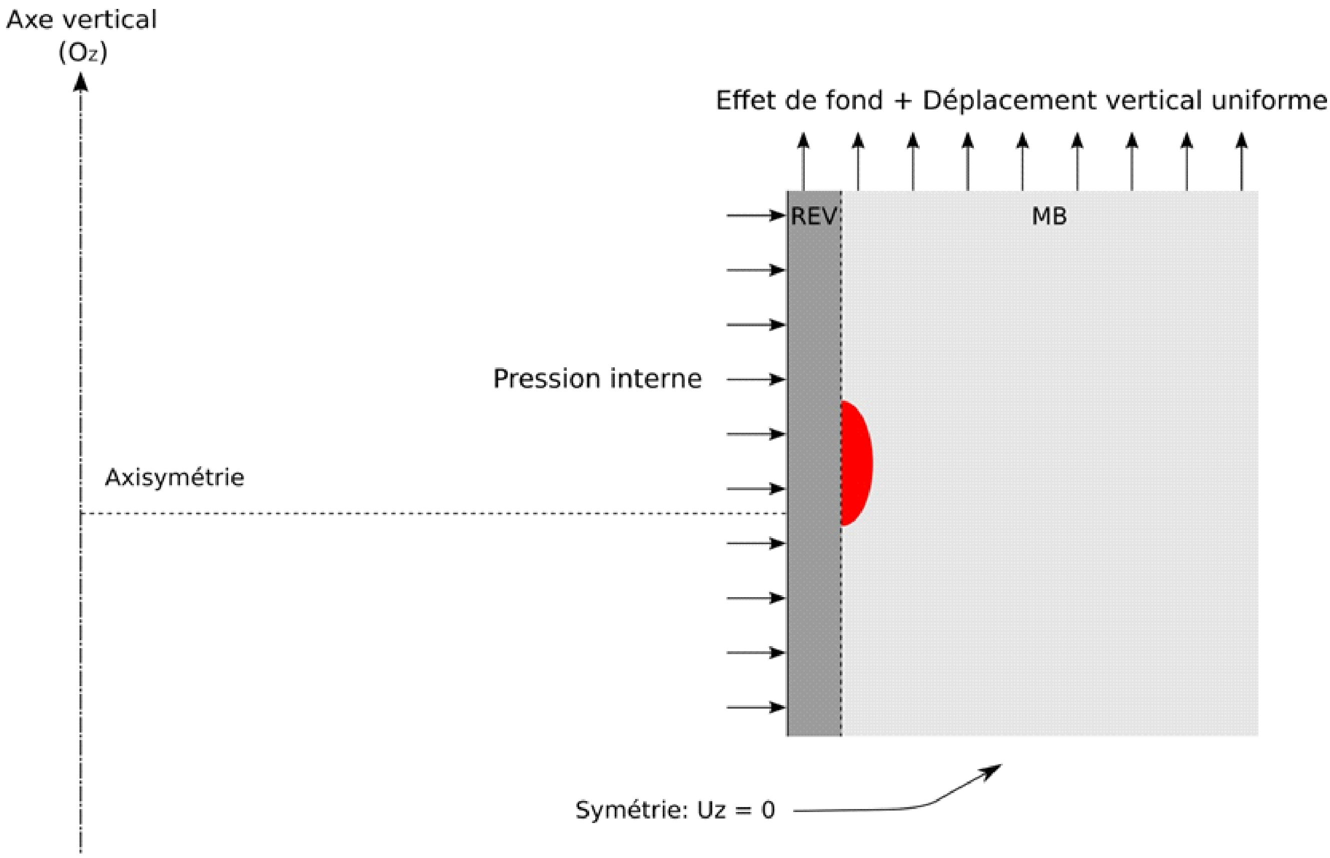
In this CAS-test, one is interested in the position of azimuth $\theta=0$ and of longitude $z=0$.

2.5.2 Stage 2 : mechanical calculation in linear elasticity

Taking into account the constituting number of important points LE transitory in pressure, this one is not presented.

The limiting conditions of the mechanical problem are summarized on the Figure hereafter and break up as follows:

- fluid pressure in internal wall,
- symmetry according to the axis Oz on the lower segment,
- basic effect like uniform displacement according to the axis Oz on the higher segment.



3 Reference solution

3.1 Results of reference

The results of reference are those resulting from a similar calculation carried out to leave tool for analysis of harmfulness of defects CUVE1D.

3.2 Uncertainty on the solution

Uncertainties on the reference solution are estimated at 2% .

4 Modeling A

4.1 Characteristics of modeling

Modeling 2D , axisymetic (SEG3, QUAD8)

4.2 Characteristics of the grid

Many nodes: 1443
Many elements: 578 SEG3, 288 QUAD8.

4.3 Sizes tested and results

Below the comparison of the results *Aster* compared to the results of reference.

4.3.1 Semi-elliptic defect of longitudinal orientation

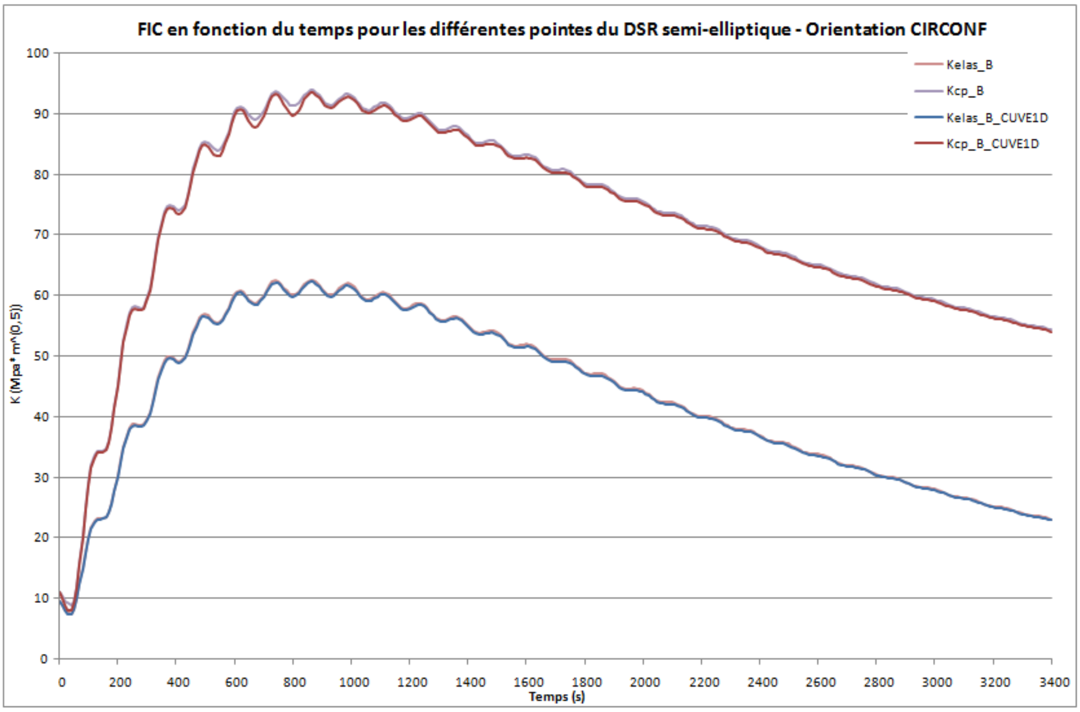
Type of value	Moment	Type of Reference	Value of reference (Mpa)	Tolerance %
K1_MDB	0.0	'AUTRE_ASTER'	21.12	0.75
KCP_MDB	0.0	'AUTRE_ASTER'	30.44	0.5
K1_MDB	640.	'AUTRE_ASTER'	63.96	0.75
KCP_MDB	640.	'AUTRE_ASTER'	95.19	1.5
K1_MDB	3400.	'AUTRE_ASTER'	23.01	0.75
KCP_MDB	3400.	'AUTRE_ASTER'	55.12	0.75

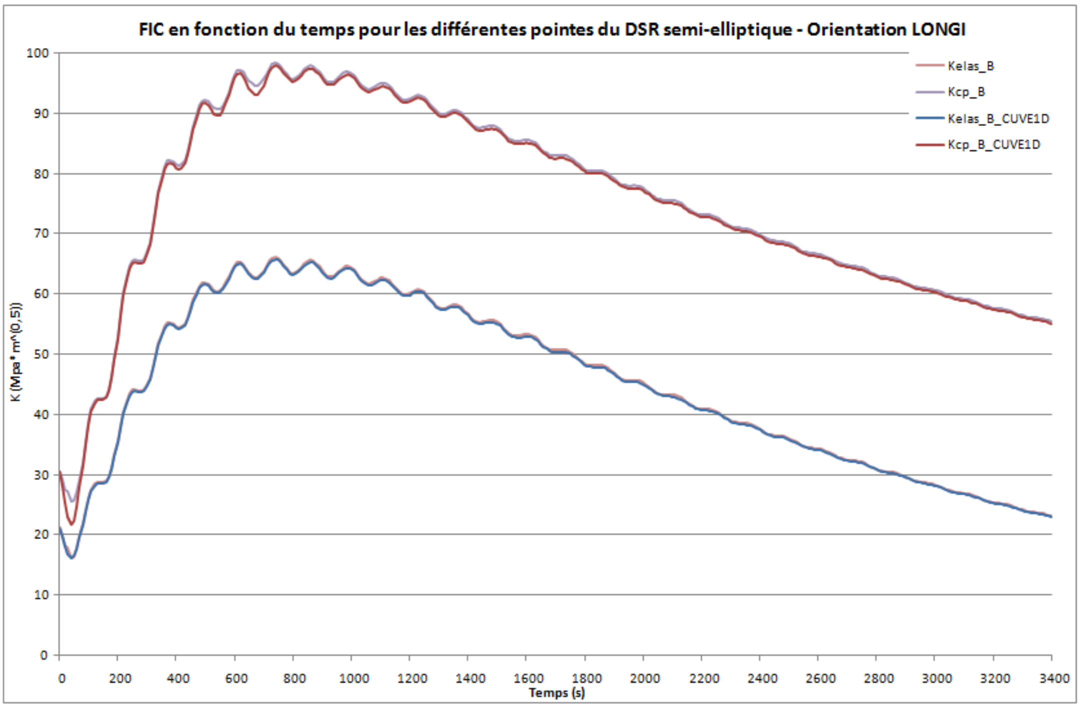
4.3.2 Semi-elliptic defect of circumferential orientation

Type of value	Moment	Type of Reference	Value of reference (Mpa)	Tolerance %
K1_MDB	0.0	'AUTRE_ASTER'	9.57	0.75
KCP_MDB	0.0	'AUTRE_ASTER'	11.00	0.5
K1_MDB	640.	'AUTRE_ASTER'	59.74	0.75
KCP_MDB	640.	'AUTRE_ASTER'	89.61	1.2
K1_MDB	3400.	'AUTRE_ASTER'	22.91	0.75
KCP_MDB	3400.	'AUTRE_ASTER'	54.05	0.75

4.4 Remarks

On the following figures are represented the temporal evolution of the elastic factor of intensity of the constraints as well as the temporal evolution of the elastoplastic factor of intensity of the constraints (known as “corrected plastically”) on the level of the point B of the defect such as they are obtained with Code_Aster. These evolutions are also compared with their equivalents provided in the reference solution, the got results are very satisfactory.





5 Summary of the results

This case test validates the application of the order POST_K_BETA on the level of the point B located side base metal, in the case of a defect under semi-elliptic coating of longitudinal orientation and circumferential orientation.