RCCM15 - Validation of POST_RCCM in B3600

Summary:

This test makes it possible to validate the option of calculation to tiredness according to code RCC-M (B3600). The constraints are not calculated but are not extracted from tables.

This test comprises two modelings, which differ by the taking into account from the thermal transients:

- the first carries out the calculation of the two thermal transients out of two axisymmetric sections same diameter and thickness that the right pipes and the elbow,
- the second directly reads the values resulting from a statement of the temperatures on the thermal calculation of the elbow, modelled before in $3D$ by department MMC.

The reference solution is digital (code SYSPIPE and note EDF/MMC).

1 Problem of reference

1.1 Geometry

This test is extracted from a study, carried out by the Department MMC, which related to the modeling of a piping industrialistE. She caused a fatigue analysis according to the RCC-M B3600.

The line comprises 10 elbows. It is directed since the node NR1 until the node N2.

Characteristics of the sections:

- Right parts:
  - $R=406.4 mm$, $EP=32. mm$
  - Pipe 1, $R=410. mm$, $EP=38. mm$;
  - Pipe 2 , $R=444.4 mm$, $EP=70. mm$;
- Elbows:
  - Group of meshs $POUCT$: $R=406.4 mm$; $EP=34. mm$;
  - Coefficient of flexibility for all the elbows, $cflex=6.032$;
  - Rays of bending of the elbows: $1220 mm$

Moreover for seismic calculation, 6 discrete elements (DIS_T) are added in 3 points of the line (1vertical and horizontal by point of anchoring).

For the transitory thermal calculation (which makes it possible to estimate the variations in temperature through the wall), one does not carry out a calculation on an elbow $3D$, but only on two representative sections:

- section of the right tubes (thickness $32 mm$),
- section of the elbows (thickness $34 mm$).

These calculations are axisymmetric. The solution being independent of the axis, one finely models the portion of piping by a rectangle, with a grid according to the ray, and comprising only one element along the axis.

Two transients are modelled.

1.2 Properties of materials

The lignE is out of steel standard. Calculations of the efforts are carried out with various values of temperature. One thus considers the properties of materials according to the temperature:

Temperature ($°C$)	Young modulus (GPa)	Average dilation coefficient (from $20°C$)
0.0	205	1.092e-05
20.0	204	1.092e-05
50.0	203	1.114e-05
100.0	200	1.15e-05
150.0	197	1.187e-05
200.0	193	1.224e-05
250.0	189	1.257e-05
300.0	185	1.289e-05
350.0	180	1.324e-05

Poisson's ratio: 0.3

The curve of WOHLER is defined by:

Salt (MPa)	Many cycles
0.01	1.E15
86	1000000
93	500000
114	200000
138	100000
160	50000
215	20000
260	10000
330	5000
440	2000
570	1000
725	500
1070	200
1410	100
1900	50
2830	20
4000	10

The interpolation is logarithmic curve, and the prolongation on the left is linear. With cause low values of amplitudes of constraints for this line, one adds the first point artificially:

0.01 1.E15

The characteristics used for the analysis with tiredness according to the RCC-M are:

- $m=3$
- $n=0.2$
- $Sm=133.6\,MPa$

The densities integrate heat insulation.

The thermal characteristics are provided to the average temperature of the calculated transient:

Transient 2: average temperature = $273.5\,°C$,
Transient 6: average temperature = $281\,°C$,

Temperature ($°C$)	273.5	281
Thermal conductivity ($W/m.°C$)	46,595	46.37
Heat-storage capacity ($J/m^3.°C$)	4.25 10^6	4.27 10^6

The discrete elements used for seismic calculation have as a stiffness:

$$K1=0.5\,10^8\,N/m$$
$$K2=1.0\,10^8\,N/m$$

1.3 Boundary conditions and loadings

The various elementary mechanical loadings considered constitute the stabilized states corresponding to the situations of design of the line:

Loadings of thermal dilation:

One carries out a calculation by loading, which combines the efforts of thermal dilation opposed in the line at the prescribed temperature, those caused by displacement of component (the temperature of reference is equal to $20\,°C$ in all the cases):

Number of loading	Temperature ($°C$)	U_x (mm)	U_y (mm)	U_z (mm)
1	10	0	0	0
2	287	0.046466	– 0.0304945	0,076
3	274.5	0.046466	– 0.0304945	0,072
4	272.5	0.046466	– 0.0304945	0,072
5	286	0.046466	– 0.0304945	0,076
6	275	0.046466	– 0.0304945	0,072
7	290	0.046466	– 0.0304945	0,077
8	284	0.046466	– 0.0304945	0,077
10	256	0.0360129	– 0.0245167	0,067
12	257	0.0360129	– 0.0245167	0,067
14 (hydraulic test)	20	0	0	0

Boundary conditions: for all the preceding loadings the node NR2 is embedded.

Note:

Displacements of component according to X and there used do not correspond to those provided in the list of the situations of the note [2], because it are expressed in another reference mark (reference mark related to the line, such as the axis x room forms an angle of 25° with the axis X total). One uses here the displacements expressed in total reference mark (that which is used to define the geometry of the line).

Hydraulic test: it is defined (apart from the proving pressure defined in the list of the situations) by the loading 14: ends N1 and N2 blocked and efforts due unlike weight enters the full line and the blank line. Moreover of the supports – weights are added for this loading: they are modelled by a condition $DZ=0$, applied in 7 nodes distributed to the line.

Earthquake: the spectra of floor corresponding to SNA (earthquake considered for the analysis with tiredness) are:

Frequency (Hz)	**Acceleration (g) Spectrum of horizontal floor (SNA)**
1.0	0.18
2.2	1.56
3.0	1.56
10.0	0,513
20.0	0,281
25.0	0,245
50.0	0,245

Frequency (Hz)	Acceleration (g) Spectrum of vertical floor
1.0	0.11
2.0	0.21
3.0	0,265
4.0	0.31
6.4	0.31
9.0	0.21
10.0	0.17
25.0	0.1
50.0	0.1

Associated displacements of anchoring are:

- Node N2: $Dx=4\,mm$, $Dy=7\,mm$, $Dz=5\,mm$
- Node N1: $Dx=11.96\,mm$, $Dy=4.35\,mm$, $Dz=1\,mm$

Definition of the situations:

Situation	Many occurrences	Pressure (bar)	Number of loading	Thermal transient
1	190	1 71.5	1 2	-
2	1300000	58.9 57.6	3 4	2
3	4000	70 59	5 6	6
4	100000	73.4 68.1	7 8	2
5	16080	71.5 44	9 10	6
6	790	74.5 44	11 12	6
7	10 390 under-cycles	-	Earthquake	-
11	13	112 1	14	-

Thermal transients: two transients are calculated. They correspond to a condition of exchange in internal skin of axisymmetric calculation defined by a coefficient of exchange $H=30000\,W/m^{2.}\,°C$ and two stories of temperatures fluid:

- transient 2:

Time (s)	Fluid temperature ($°C$)
0.0	274.5
10.0	274.5
310.0	272.5
610.0	274.5
910.0	272.5

- transient 6:

Time (s)	Fluid temperature ($°C$)
0.0	272.0
11.0	272.0
20.0	290.0
40.0	290.0

The analysis in fatigue is carried out on the first node located immediately after the exit of component ($N80$ belonging to the mesh $M1$).

2 Reference solution

2.1 Method of calculating used for the reference solution

This test is extracted from a study, carried out by the Department MMC, which related to the modeling of an industrial piping. She caused comparisons enters *Code_hasster* and SYSPIPE of FRAMATOME codes it. The reference solution is digital (comparison between the results of design and the results of *Code_hasster* for the mechanical loadings) and the results of tiredness got by an EXCEL procedure.

2.2 Results of reference

The final result of the fatigue analysis, on the node at the entrance of first elbow after the exit of component, provides a factor of total use: $u=0.00648$.

This result is based on the results of mechanical and thermal calculations carried out on the line. In order to validate the whole of the computation channel, one makes sure that the results of mechanical calculations are identical to those of reference. Those are summarized here:

Eigen frequencies of the blank line (embedded at the two ends) with springs and at the temperature of $20°C$:

NUMBER	**FREQUENCY (Hz)** **Circus calculation/Aster**
1	5,059
2	6,023
3	6,866
4	8,204
5	9,733
6	9,987
7	16,535
8	17,329
9	18,282
10	19,004
11	20,271

Inflection and torques for each mechanical loading:

Loading case	Mx ($N.m$)	My ($N.m$)	Mz ($N.m$)	$\|Mx^2+My^2\|$
1	5947	4412.5	– 5526	
2	– 41084	– 25691	91767.3	
3	– 34253	– 20695.4	83346.2	
5	– 32752	– 19577	81995.4	
5	– 40330	– 25129	91089.6	
6	– 34565	– 20927.8	83624.6	
7	– 42718	– 26884	93803.2	
8	– 38457	– 23711	89984.4	
10	– 43556	– 28408.2	86848.7	
12	– 44175	– 28868.5	87403.1	
14	1381	5671	5671	
earthquake	240269	– 107195	16785	108501

Thermal calculations:

The results available in the note were carried out on a modeling `3D` elbow located after the exit component The results are provided for segments of analysis located in the right part and the elbow:

$T_{moy}(i,j) = \frac{1}{e}\int_{e/2}^{e/2} T(i,j)(y).dy = \frac{1}{e}\int_{e/2}^{e/2} T(i)(y).dy - \frac{1}{e}\int_{e/2}^{e/2} T(j)(y).dy = T_{moy}(i) - T_{moy}(j)$: median value of $T(i)-T(j)$ on the ligament

$\Delta T_1(i,j) = \frac{12}{e^2}\int_{e/2}^{e/2} y.T(i,j)(y).dy = \frac{12}{e^2}\int_{e/2}^{e/2} y.T(i)(y).dy - \frac{12}{e^2}\int_{e/2}^{e/2} y.T(j)(y).dy = \Delta T_1(i) - \Delta T_1(j)$: variation of a linear distribution of T (I, J).

$$\Delta T_2(i,j) = \max \left| \begin{array}{l} \left|T_{\max}(i,j) - T_{moy}(i,j)\right| - \left|\tfrac{1}{2}\Delta T_1(i,j)\right| \\ \left|T_{\min}(i,j) - T_{moy}(i,j)\right| - \left|\tfrac{1}{2}\Delta T_1(i,j)\right| \\ 0 \end{array} \right.$$

These quantities are maximized for the whole of the couples of moments i and j :

Thermal transient	$\Delta T_1(i,j)$ $°C$	$\Delta T_2(i,j)$ $°C$	$T_{moy}(i,j)$ right part	$T_{moy}(i,j)$ elbow
2	0,741	0,125	1,043	1,445
6	15.48	2.84	5.99	5.69

2.3 Uncertainty on the solution

Digital solution, obtained with identical data and comparable elements. One can thus estimate the precision at 1% for the mechanical solution.

3 Modeling A

3.1 Characteristics of modeling

439 POU_D_T

3.2 Characteristics of the grid

Many nodes: 440
Number of meshs and type: 339 SEG2 and 6 SEG2 (DIS_T)

Note:
Care should be taken to correctly order the groups of nodes on which the statements of temperatures and calculations of averages are carried out.

3.3 Sizes tested and results

In order to validate the fatigue analysis correctly, one makes sure that the results of mechanical calculations are sufficiently close to the reference.

Eigen frequencies of the blank line:

Num. mode	Reference	*Aster*	% difference
1	5.059	5.05799	0.02
2	6.023	5.98255	0.67
3	6.866	6.86007	0.09
4	8.204	8.20337	0.01
5	9.733	9.73339	0.00
6	9.987	9.95736	0.30
7	16.535	16.4647	0.43
8	17.329	17.326	0.02
9	18.282	18.2823	0.00
10	19.004	18.996	0.04
11	20.271	20.2708	0.00

Efforts (moments) with the node N1

N1	Reference			*Aster*			% difference		
Loading case	Mx ($N.m$)	My ($N.m$)	Mz ($N.m$)	Mx ($N.m$)	My ($N.m$)	Mz ($N.m$)	Mx	My	Mz
1	5947	4412.5	– 5526	5985.5	4440.76	– 5561.92	– 0.65	– 0.64	– 0.65
2	– 41084	– 25691	91767.3	– 41041.6	– 25659.6	91727.2	0.10	0.12	0.04
3	– 34253	– 20695.4	83346.2	– 34212.8	– 20665.9	83307.7	0.12	0.14	0.05
5	– 32752	– 19577	81995.4	– 32802.8	– 19615.8	82041.5	– 0.16	– 0.20	– 0.06
5	– 40330	– 25129	91089.6	– 40335.5	– 25133.6	91094.1	– 0.01	– 0.02	0.00
6	– 34565	– 20927.8	83624.6	– 34565.3	– 20928.5	83624.3	0.00	0.00	0.00
7	– 42718	– 26884	93803.2	– 42664.3	– 26845.2	93752.5	0.13	0.14	0.05
8	– 38457	– 23711	89984.4	– 38426.1	– 23688.3	89954	0.08	0.10	0.03
10	– 43556	– 28408.2	86848.7	– 43537.4	– 28394.9	86830	0.04	0.05	0.02
12	– 44175	– 28868.5	87403.1	– 44232.3	– 28912.1	87456.1	– 0.13	– 0.15	– 0.06
14	1381	5671	– 3179	1370	5700	– 3320	0.59	– 0.54	– 4.45

Reference		NR1	*Aster*		% difference	
Mx ($N.m$)	$\|Mx^2+My^2\|$	Loading case	Mx ($N.m$)	$\|Mx^2+My^2\|$	Diff Mx	Diff $\|Mx^2+My^2\|$
240269	108501	earthquake	239009	108167	0.52	0.31

Thermal calculations:

	Reference	***Aster***	% **difference**
Thermal transient	$\Delta T_1(i,j)$ $°C$	$\Delta T_1(i,j)$ $°C$ right side	
2	0,741	0,719	3
6	15.48	15.38	3

	Reference	***Aster***	% **difference**
Thermal transient	$T_{moy}(i,j)$ right side	$T_{moy}(i,j)$ right side	
2	1,043	1.8	73
6	5.99	9.34	56

	Reference	***Aster***	% **difference**
Thermal transient	$T_{moy}(i,j)$ side bends	$T_{moy}(i,j)$ side bends	
2	1,445	2.4	65
6	5.69	8.8	54

Note:

The average temperatures are relatively different from the reference. This can be due to modeling (here axisymmetric, and $3D$ *in [bib2]). In practice, only the difference in average temperature between the elbow and the right pipe intervene in calculations of the constraints.*

Finally, the factor of cumulated total use is worth:

	Reference	***Aster***	% **difference**
Node/Mesh	Factor of use	Factor of use	
$N80$, $M1$	0.00648	0.0079	22

4 Summary of the results

The results in term of factor of use can be regarded as rather close to those of référencE.