

## RCCM13 – Analysis of piping with POST\_RCCM in ZE200

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### Summary:

This test is an elementary test of validation of the order `POST_RCCM` with `TYPE_RESU_MECA=' ZE200a'` and `'ZE200b'`.

The analytical solution is simple, and makes it possible to test postprocessing within the meaning of the RCCM. The constraints are not calculated but are not extracted from tables.

More precisely, modeling A makes it possible to test Lbe option `SN` and `TIREDDNESS` for results of the type `ZE200a` with and without earthquake.

More precisely, modeling B allows to test L ' option `SN` for results of the type `ZE200b` with and without earthquake.

## 1 Problem of reference

### 1.1 Material properties

The properties material and characteristics suitable for calculation RCC-M are the following ones:

- 1) module of Young:  $E = 2.E + 05 MPa$  ;
- 2) constant material for the calculation of  $Ke$  :  $n = 0.2$  ,  $m = 2$  ;
- 3) Young modulus of reference:  $E_{REFE} = 2.E + 05 MPa$  ;
- 4) working stress:  $Sm = 2000 MPa$  .

The curve of Wöhler is analytically defined:  $N_{adm} = \frac{5.10^5}{S_{alt}}$

### 1.2 Evolution of the constraints

The constraints on the segment of analysis are not calculated but are not read directly in a table. The only nonworthless component of the tensor of the constraints is  $\sigma_{yy}$  . Two situationS are consideredEs. These situationS do not aim representing a specific real transient, but at covering the whole of the possible constraints (constant, linear or non-linear evolution of the constraint in the thickness).

Mome nt	Constraints thermic			Constraints had with the pressure			Constraints thermiques+pression		
	X-coordinate			X-coordinate			X-coordinate		
	0	1	2	0	1	2	0	1	2
1,5	90	100	110	90	100	110	180	200	220
2,5	0	100	0	0	100	0	0	200	0
3,5	100	-50	-100	100	-50	-100	200	-100	-200
4,5	0	0	0	0	0	0	0	0	0

**Table 1.2-1** : Definition of the constraints  $\sigma_{yy}$  (in  $MPa$  ) for the moments of situation 1 according to the curvilinear X-coordinate

Mome nt	Constraints thermic			Constraints had with the pressure			Constraints thermiques+pression		
	X-coordinate			X-coordinate			X-coordinate		
	0	1	2	0	1	2	0	1	2
1	90	100	90	0	0	0	90	100	90
2	0	100	0	0	0	0	0	100	0
3	100	-50	-100	0	0	0	100	-50	-100
4	0	0	0	0	0	0	0	0	0

**Table 1.2-2** : Definition of the constraints  $\sigma_{yy}$  (in  $MPa$  ) for the moments of the situation 2 according to the curvilinear X-coordinate

In ZE200, the moments are defined according to two torques (in ze200a, pressure also)

	$P_A$	$P_B$	$M_{xA}$	$M_{yA}$	$M_{zA}$	$M_{xB}$	$M_{yB}$	$M_{zB}$
Situation 1	201	1	21	0	0	1	0	0
Situation 2	0	0	1	0	0	61	0	0

**Table 1.2-3** : Definition of torques at the time (in N.mm) and pressure (in MPa) pour situationS 1 and 2

In ZE200, L be characteristic of piping (thickness, ray, moment of inertia) are necessary to the calculation of the sizes, just as the indices of constraints. In this example, one chooses **arbitrarily**

$$e = 1 \text{ mm}$$

$$R = 0,5 \text{ mm}$$

$$I = 1 \text{ m}^4$$

$$K_1 = 1 \quad \text{and} \quad C_1 = 1$$

$$K_2 = 1 \quad \text{and} \quad C_2 = 2$$

$$K_3 = 1 \quad \text{and} \quad C_3 = 1$$

$M_{xS}$	$M_{yS}$	$M_{zS}$
21	0	0

**Table 1.2-4** : Definition of torques at the time (in N.mm) p our earthquake

## 2 Reference solution

### 2.1 Results of reference

#### 2.1.1 zE200a

##### 2.1.1.1 Sn calculation

The parameter  $S_n$  represent the amplitude of variation of Contrainte linear (average constraint  $\pm$  bending stress) between two moments of the transient considered.

$$S_n = C_1 \frac{R}{e} |P_A - P_B| + C_2 \frac{R}{I} \sqrt{((M_{xA} - M_{xB})^2 + (M_{yA} - M_{yB})^2 + (M_{zA} - M_{zB})^2)} + \|\sigma_{tran}^{lin}(t_1) - \sigma_{tran}^{lin}(t_2)\|$$

Without thermal stresses, for situation 1  $S_n = 120$  and for situation 2  $S_n = 60$  (at the origin and the end).

With thermal stresses, one calculates the maximum amplitudes of thermal stresses linearized at the origin then at the end.

#### Situation 1

Moment	Constraints Thermic			$\sigma_{moyen}$	$\sigma_{flexion}$	$\sigma_0^{lin}$	$\sigma_L^{lin}$
	X-coordinate						
	0	1	2				
1,5	90	100	110	100	10	90	110
2,5	0	100	-90	27.5	-45	72.5	-17.5
3,5	100	-50	-100	-25	-100	75	-125
4,5	0	0	0	0	0	0	0

Moment 1	Moment 2	$S_{n_0}$	$S_{n_L}$
1,5	2,5	17.5	127.5
1,5	3,5	15	<b>235</b>
1,5	4,5	<b>90</b>	110
2,5	3,5	2.5	107.5
2,5	4,5	72.5	17.5
3,5	4,5	75	125

For situation 1 with thermal stresses,  $S_{n_0} = 120 + 90 = 210$  and  $S_{n_L} = 120 + 235 = 355$ .

## Situation 2

Moment	Constraints Thermic			$\sigma^{moyen}$	$\sigma^{flexion}$	$\sigma_0^{lin}$	$\sigma_L^{lin}$
	X-coordinate						
	0	1	2				
1	90	100	90	95	0	95	95
2	0	100	-90	27.5	-45	72.5	-17.5
3	100	-50	-100	-25	-100	75	-125
4	0	0	0	0	0	0	0

Moment 1	Moment 2	$Sn_0$	$Sn_L$
1	2	22, 5	112, 5
1	3	20	<b>220</b>
1	4	<b>95</b>	95
2	3	2.5	107.5
2	4	72, 5	17.5
3	4	75	125

For the situation 2 with thermal stresses,  $Sn_0 = 60 + 95 = 155$  and  $Sn_L = 60 + 220 = 280$ .

### 2.1.1.2 Sn calculation with earthquake

One comes to add the contribution of the earthquake to the size Sn such as

$$S_{nS} = C_1 \frac{R}{e} |P_A - P_B| + C_2 \frac{R}{I} \sqrt{((M_{xA} - M_{xB} \pm 2 M_{xS})^2 + (M_{yA} - M_{yB} \pm 2 M_{yS})^2 + (M_{zA} - M_{zB} \pm 2 M_{zS})^2)} + \|\sigma_{tran}^{lin}(t_1) - \sigma_{tran}^{lin}(t_2)\|$$

For situation 1 without constraints in the form of transient,

$$S_{nS} = C_1 \frac{R}{e} |P_A - P_B| + C_2 \frac{R}{I} \sqrt{((M_{xA} - M_{xB} \pm 2 M_{xS})^2)}$$

$$S_{nS} = 1 * \frac{0,5}{1} |201 - 1| + 2 * \frac{0,5}{1} \sqrt{((21 - 1 \pm 2 * 21)^2)} = 100 + 62 = 162 \text{ with the origin and at the end.}$$

For the situation 2 without constraints in the form of transient,

$$S_{nS} = 1 * \frac{0,5}{1} |0 - 0| + 2 * \frac{0,5}{1} \sqrt{((1 - 61 \pm 2 * 21)^2)} = 102 \text{ at the origin and the end.}$$

### 2.1.1.3 Calculation of tiredness for situations 1 and 2 in the same group

Calculation is detailed for combination of situationS 1 and 2 only and at the origin.

One seeks to fill out the table of the elementary factors of use.

One calculates initially the sizes by situations then combination.

### Situation 1

For situation 1, qu is pointed out 'with the thermal stresses  $Sn_0=210$  (part 2.1.1 ). One calculates the Sp size at the origin .

$$S_p = K_1 C_1 \frac{R}{e} |P_A - P_B| + K_2 C_2 \frac{R}{I} \sqrt{((M_{xA} - M_{xB})^2 + (M_{yA} - M_{yB})^2 + (M_{zA} - M_{zB})^2)} + \|\sigma_{tran}(t_1) - \sigma_{tran}(t_2)\|$$

Without thermal stresses, for situation 1  $S_p^0 = 120$  .

With thermal stresses, one calculates the maximum amplitudes of thermal stresses linearized in the beginning:

Moment 1	Moment 2	$S_{p_0}$
1,5	2,5	90
1,5	3,5	10
1,5	4,5	90
2,5	3,5	<b>100</b>
2,5	4,5	0
3,5	4,5	<b>100</b>

For situation 1, one thus has  $S_{p_0} = 120 + 100 = 220$  .

For  $Sm = 2000 MPa$  , one thus has  $Ke = 1$  and  $Salt_0 = \frac{1}{2} \frac{E_c}{E} Ke S_{p_0} = 110 MPa$  .

According to the curve of Wöhler one thus has  $Nadm_0 = \frac{500000}{Salt_0} = 4545$  that is to say

$$FU_0 = 2,2 \cdot 10^{-4} .$$

### Situation 2

In a similar way for situation 2, one has  $Sn_0 = 155$  ,  $S_{p_0} = 60 + 100 = 160$  , that is to say  $Ke = 1$  and  $Salt_0 = 80 MPa$  that is to say  $FU_0 = 1,6 \cdot 10^{-4}$  .

### Combination of situations 1 and 2

For the combination of situations 1 and 2 one has without thermics

$$S_n^0 = C_1 \frac{R}{e} |201 - 0| + C_2 \frac{R}{I} \sqrt{((21 - 61)^2)} = 100,5 + 40 = 140,5$$

With thermics one has  $Sn_0 = 95 + 140,5 = 235,5$  for moments 4,5 and 1. Thus  $Ke = 1$  .

Without thermics  $Sp_0^1 = 140,5$  then for example by combining moments 2,5 and 3  $Sp_0^1 = 240,5$  that is to say  $FU_0^1 = 2,405 \cdot 10^{-4}$ .

One calculates the second fictitious transient, without thermics the times and the pressure one takes the complementary states is  $Sp_0^2 = C_1 \frac{R}{e} |1-0| + C_2 \frac{R}{I} \sqrt{((1-1)^2)} = 0,5$ . Puis by combining moments 3.5 and 2  $Sp_0^2 = 100 + 0,5 = 100,5$  that is to say  $FU_0^2 = 1,005 \cdot 10^{-4}$ .

The factor of use of the combination of situations 1 and 2 is thus  $FU = FU_0^1 + FU_0^2 = 2,405 \cdot 10^{-4} + 1,005 \cdot 10^{-4} = 3,41 \cdot 10^{-4}$

The table of the elementary factors of use at the origin is thus

	Situation 1	Situation 2
Situation 1	$2,2 \cdot 10^{-4}$	$3,41 \cdot 10^{-4}$
Situation 2		$1,6 \cdot 10^{-4}$

As one has  $Nocc_1 = 1$  and  $Nocc_2 = 1$  one has  $FU_{TOTAL}^{ORI} = 3,41 \cdot 10^{-4}$ .

## 2.1.2 ZE200B

### 2.1.2.1 Sn calculation

The parameter  $S_n$  represent the amplitude of variation of Contrainte linear (average constraint  $\pm$  bending stress) between two moments of the transient considered.

$$S_n = C_2 \frac{R}{I} \sqrt{((M_{xA} - M_{xB})^2 + (M_{yA} - M_{yB})^2 + (M_{zA} - M_{zB})^2) + \|\sigma_{tran}^{lin}(t_1) - \sigma_{tran}^{lin}(t_2)\|}$$

Without thermal stresses nor of pressure, for situation 1  $S_n = 20$  (at the origin and the end).

With constraints in the form of transient, one calculates the maximum amplitudes of thermal stresses+pression linearized at the origin then at the end.

#### Situation 1

Moment	Constraints Thermiques+pression			$\sigma^{moyen}$	$\sigma^{flexion}$	$\sigma_0^{lin}$	$\sigma_L^{lin}$
	X-coordinate						
	0	1	2				
1,5	180	200	220	200	20	180	220
2,5	0	200	-180	55	-90	145	-35
3,5	200	-100	-200	-50	-200	150	-250
4,5	0	0	0	0	0	0	0

Moment 1	Moment 2	$Sn_0$	$Sn_L$
1,5	2,5	35	255
1,5	3,5	30	<b>470</b>
1,5	4,5	<b>180</b>	220
2,5	3,5	5	215
2,5	4,5	145	35
3,5	4,5	150	250

For situation 1 with constraints in the form of transient,  $Sn_0 = 20 + 180 = 200$  and  $Sn_L = 20 + 470 = 490$ .

## Situation 2

Without thermal stresses nor of pressure, for the situation 2  $Sn = 60$  (at the origin and the end).

Situation 2 thus does not have constraints of pressure the calculation of the part in the form of transient is the same one as in ZE200a (part 2.1.1.1).

For the situation 2 with thermal stresses,  $Sn_0 = 60 + 95 = 155$  and  $Sn_L = 60 + 220 = 280$ .

### 2.1.2.2 Sn calculation with earthquake

One comes to add the contribution of the earthquake to the size Sn such as

$$S_{nS} = C_2 \frac{R}{I} \sqrt{((M_{xA} - M_{xB} \pm 2 M_{xS})^2 + (M_{yA} - M_{yB} \pm 2 M_{yS})^2 + (M_{zA} - M_{zB} \pm 2 M_{zS})^2)} + \|\sigma_{tran}^{lin}(t_1) - \sigma_{tran}^{lin}(t_2)\|$$

For situation 1 without constraints in the form of transient.

$$S_{nS} = C_2 \frac{R}{I} \sqrt{((M_{xA} - M_{xB} \pm 2 M_{xS})^2)} = 2 * \frac{0,5}{1} \sqrt{((21 - 1 \pm 2 * 21)^2)} = 62 \text{ with the origin and at the end.}$$

For the situation 2 without constraints in the form of transient.

$$S_{nS} = C_2 \frac{R}{I} \sqrt{((M_{xA} - M_{xB} \pm 2 M_{xS})^2)} = 2 * \frac{0,5}{1} \sqrt{((1 - 61 \pm 2 * 21)^2)} = 102 \text{ at the origin and the end.}$$

## 2.2 Uncertainty on the solution

Analytical solution.



## 3 Modeling A

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### 3.1 Characteristics of modeling

No thermal or mechanical calculation is carried out in this test: the tables of statements of constraints are directly provided to the operator `POST_RCCM`. Results of type `ZE200has` are analyzed for the options `SN` and `TIREDNES`.

### 3.2 Sizes tested and results

On this case simple test, the whole of the results tested is in agreement with the reference solution with a precision of  $10^{-4}$  %.

- for the calculation of `Sn`, of `Sp`, `Salt` and the factor of use,
- for a junction of piping,
- with and without earthquake.

## 4 Modeling B

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### 4.1 Characteristics of modeling

No thermal or mechanical calculation is carried out in this test: the tables of statements of constraints are directly provided to the operator `POST_RCCM`. Results of type `ZE200B` are analyzed for the option `SN`.

### 4.2 Sizes tested and results

On this case simple test, the whole of the results tested is in agreement with the reference solution:

- for the calculation of `Sn`,
- for a junction of piping,
- with and without earthquake.

## 5 Summary of the results

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The results are exact and show that the operator `POST_RCCM` select the quantities correctly to be treated and correctly calculates the integrals (average on the segments) as well for the results of the type `ZE200a` that of type `ZE200B`.