# RCCM13 – Analysis of piping with POST_RCCM in ZE200

**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 RCC-M. The constraints are not calculated but are not extracted from tables.

More precisely, modeling A makes it possible to test Lbe optionS SN and TIREDNESS 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).

| Moment | **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

| Moment | **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**

$$e=1\,mm$$
$$R=0{,}5\,mm$$
$$I=1\,m^4$$

$$K_1=1 \quad \text{and} \quad C_1=1$$
$$K_2=1 \quad \text{and} \quad C_2=2$$
$$K_3=1 \quad \text{and} \quad C_3=1$$

| $M_{xS}$ | $M_{yS}$ | $M_{zS}$ |
|---|---|---|
| 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 $Sn$ represent the amplitude of variation of Contrainte linear (average constraint $\pm$ bending stress) between two moments of the transient considered.

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

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 | 1 0 | 90 | 11 0 |
| 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 | $Sn_0$ | $Sn_L$ |
|---|---|---|---|
| 1,5 | 2,5 | 17.5 | 127.5 |
| 1,5 | 3,5 | 15 | **235** |
| 1,5 | 4,5 | **90** | 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, $Sn_0 = 120 + 90 = 210$ and $Sn_L = 120 + 235 = 355$ .

**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 | **220** |
| 1 | 4 | **95** | 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

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

<u>For situation 1 without constraints in the form of transient,</u>

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

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

<u>For the situation 2</u> <u>without constraints in the form of transient,</u>

$Sn_S=1*\frac{0,5}{1}|0-0|+2*\frac{0,5}{1}\sqrt{\left((1-61\pm 2*21)^2\right)}=102$ 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 | $Sp_0$ |
|---|---|---|
| 1,5 | 2,5 | 90 |
| 1,5 | 3,5 | 10 |
| 1,5 | 4,5 | 90 |
| 2,5 | 3,5 | **100** |
| 2,5 | 4,5 | 0 |
| 3,5 | 4,5 | **100** |

For situation 1, one thus has $Sp_0=120+100=220$ .

For $Sm=2000\,MPa$ , one thus has $Ke=1$ and $Salt_0=\frac{1}{2}\frac{E_c}{E}Ke\,Sp_0=110\,MPa$ .

According to the curve of Wöhler one thus has $Nadm_0=\frac{500000}{Salt_0}=4545$ that is to say $FU_0=2{,}2\,10^{-4}$ .

**Situation 2**

In a similar way for situation 2, one has $Sn_0=155$ , $Sp_0=60+100=160$ , that is to say $Ke=1$ and $Salt_0=80\,MPa$ that is to say $FU_0=1{,}6.10^{-4}$ .

**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 $FU_0^1=2{,}405.10^{-4}$ .

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 $FU_0^2=1{,}005.10^{-4}$ .

The factor of use of the combination of situations 1 and 2 is thus $FU=FU_0^1+FU_0^2=2{,}405.10^{-4}+1{,}005.10^{-4}=3{,}41.10^{-4}$

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

| | Situation 1 | Situation 2 |
|---|---|---|
| Situation 1 | $2{,}2\,10^{-4}$ | $3{,}41.10^{-4}$ |
| Situation 2 | | $1{,}6.10^{-4}$ |

As one has $Nocc_1=1$ and $Nocc_2=1$ one has $FU_{TOTAL}^{ORI}=3{,}41.10^{-4}$ .

### 2.1.2 ZE200B

#### 2.1.2.1 Sn calculation

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

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

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

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

**<u>Situation 1</u>**

| 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 | 2 0 | 180 | 22 0 |
| 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 | **470** |
| 1,5 | 4,5 | **180** | 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 $S_n=60$ (at the origin and the end).

Lsituation has 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` (part2.1.1.1).

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

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

For situation 1 without constraints in the form of transient,

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

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

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

## 2.2 Uncertainty on the solution

Analytical solution.

# 3 Modeling A

## 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 TIREDNESS.

## 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

## 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

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`.