Postprocessing according to the RCC-M

Summary:

The operator POST_RCCM [U4.83.11] allows to check the criteria of level 0 and certain criteria of level A of the B3200 chapter of the RCC - M, for modelings of continuous mediums 2D or 3D. The criteria of level 0 aim at securing the material against the damage of excessive deformation, of plastic instability, elastic and elastoplastic. The criteria of level A aim as for them at securing the material against the damage of progressive deformation and tiredness.
It also allows the calculation of the criteria of level A of the B3600 chapters and ZE200 in postprocessing of calculations of pipings.
Lastly, it makes it possible to evaluate the environmental resistance to fatigue for chapters B3200 and ZE200.
In addition, the operator POST_RCCM allows to calculate the factor of starting on the level of a singular zone, within the meaning of appendix ZD of the RCC-M.

Contents

1 Introduction

The RCC-M [1] described the general rules of analysis of the behavior of the materials of Centrales Nucléaires. These rules aim at ensuring the components of the power plants REFERENCE MARK of the sufficient safety margins with respect to the various types of damage to which they could be exposed because of the loadings which are applied to them: excessive deformation and plastic instability, elastic or elastoplastic instability, progressive deformation under the effect of repeated requests, tiredness (progressive cracking), brutal rupture…

In C*ode_hasster*, it is possible to carry out four types of calculation:

- calculation of the criteria of level 0 and A of chapitrE B3200 in postprocessing of calculations on structures 2D or 3D;
- calculation of the criteria of tiredness of chapter B3600 in postprocessing of calculations of pipings;
- calculation of the criteria of tiredness DE the appendix ZE200 in postprocessing of calculations of pipings. Method according to L'appendix ZE200 is a mixed method which mixes simplified equations of B3600 and analyzes detailed of B3200.
- environmental fatigue analysis compatible with the B3200 chapters and the appendix ZE200 of the RCC-M. The environmental resistance to fatigue was integrated into the RCC-M edition 2016 in the form of a Rule in Probatory Phase (RP).

Chapter 2 recalls general information on chapter B3200 and the appendix ZE200 of the RCC-M.

The criteria of B3200 correspond in the operator `POST_RCCM` with methods (`TYPE_RESU_MECA`) `'B3200'` and `'EVOLUTION'`. Their calculation is detailed inS chapterS 3 and 6. `'EVOLUTION'` allows to do calculation of factor of starting for the geometrical singularities and is well adapted to the cases where there are few situations. A contrario, `'B3200'`is well adapted to calculations for many situations, which can be distributed on several groups of operation. The earthquake, the situations of passage and environmental tiredness can be taken into account with it `TYPE_RESU_MECA`.

The criteria of the ZE200 correspond in the operator `POST_RCCM` with methods `'ZE200a'` and `'ZE200b'`. Their calculation is detailed in the chapitrE 4.

The calculation of the environmental resistance to fatigue is described in the chapter 5.

The criterion of tiredness of B3600 corresponds in the operator `POST_RCCM` with the method `'B3600'`. Their calculation is detailed in the chapter 7.

2 General information

This chapter aims at pointing out some basic definitions associated with the B3200 chapter and with the appendix ZE200 of the RCC-M. **It does not relate to the B3600 chapter.**

This chapter also allows to describe the adaptations necessary realized in C*ode_hasster*, which is justified in [2] and [8]. The criteria of the B3200 chapter correspond in the operator `POST_RCCM` with methods `TYPE_RESU_MECA='EVOLUTION'` and `TYPE_RESU_MECA='B3200'`. The criteria DE the appendix ZE200 correspond in the operator `POST_RCCM` with methods `TYPE_RESU_MECA='ZE200a'` and `TYPE_RESU_MECA='ZE200b'`.

2.1 Geometrical data

The user of the RCC-M must distinguish in his structure the zones of major discontinuity, the zones of minor discontinuity and the zones comprising of the geometrical singularities. These last require a specific treatment (described in the part 6.5).

Current zone (except geometrical singularity):
The RCC-M defines "segments of support" which are used to linearize the constraints. These segments are, out of zones of discontinuity, of the generally normal segments on the median surface of the wall, and in the zones of discontinuity, the shortest segments making it possible to join the 2 faces of the wall.
The user of C*ode_hasster* must thus define the whole of the sections of the structure where the calculations of postprocessing will be done (it is him who knows if these sections pass by current zones, or zones of geometrical discontinuity). In practice, one works:

- maybe on an existing segment in the grid;
- maybe on a segment defined in `MACR_LIGN_COUPE`.

One systematically calculates all the criteria at the two ends of the segment (calculation of Pm, the factor of use…).

Geometrical singularity:
Zones of local discontinuities whose geometrical contour present of the abrupt variations are the seat of stress concentrations acute. In this case, the classical methods associated with the current zones are unsuited and one introduces the concept of factor of starting. This parameter must be calculated on a circle (of imposed ray, depend on material) around the singularity. The factor of starting can be calculated only with the type '`EVOLUTION'`.
The user must thus define this line of cut. In practice, one works:

- maybe on a circular line of cut existing in the grid;
- maybe on a line of circular cut defined in `MACR_LIGN_COUPE`.

2.2 Data material

The data material necessary to calculation are the following ones:

- Sm : acceptable value (tabulée in Additional RCC-M ZI).
- Sy : conventional limit of elasticity (tabulée in Additional RCC-M ZI 2.1).
- m, n : constant material for the calculation of Ke (defined in the RCC-M B3234.6)
- E_c , E : moduli of elasticity (for the correction of the curve of tiredness, additional ZI).
- Curves of tiredness of material: according to additional RCC-M ZI.
- Distance *D* with the geometrical singularity and law of starting of material (as defined and tabulées in appendix ZD2200 of the RCC-M) for the calculation of the factor of starting.

2.3 Simplifying assumptions

In the RCC-M, the user must be able to say, after analysis of the results of calculation, if them principal directions in a given point are fixed or if they turn in the course of time. Dyears the order POST_RCCM, one can not make an assumption. One will consider only the case where the principal directions are unspecified.

Moreover, the user must be able to classify the constraints in the following categories:

- General primary education of membrane: Pm
- Primary education of local membrane: Pl
- Primary education of inflection: Pb
- Thermal expansion: Pe
- Secondary: Q
- Of point: F

This choice cannot be made by POST_RCCM. Only the user can qualify a stress field (“ primaire “, “secondary”, or summon it of both). The criteria which are to be checked are calculated starting from (constant or function stress fields of time) provided by the user. It is him who ensures coherence between the calculation of these fields and the criteria applied.

However, to fix the ideas, classification is simpler in the following cases:

- a constant or variable loading with force or imposed pressure is primary, except for certain very particular structures,
- a constant or variable loading with imposed displacement is in theory, secondary (except in the case of “the effect spring”),
- a permanent or transitory thermal loading is in theory secondary.

On the other hand, the combination of these types of loadings leads to a result which cannot be qualified any more of primary education or secondary. According to the criteria, the user will be able to thus have to break up his loadings.

2.4 Calculations carried out by POST_RCCM

One describes in the continuation the operation of the order POST_RCCM allowing to carry out the calculation of certain criteria of levels 0 and A of the RCC-M B3200 and the criteria of level A DE the appendix ZE200. The realization described here does not take into account all the criteria of B3200 and could be supplemented.

The principal data is the segment (of support) where calculations will be carried out. It is the user who chooses the segment and which is in charge of finding that for which the quantities intervening in the criteria are maximales. The automatic search for this segment is a difficult problem, and is not programmed.

After having calculated one or more results by MECA_STATIQUE or STAT_NON_LINE, the user must extract the constraints on the segment from analysis by POST_RELEVE_T or MACR_LIGN_COUPE. To finish, the user asks for the calculation of the criteria by the operator POST_RCCM.

Four types of criteria are accessible each one by keyword factor 'OPTION' :

- criteria of level 0 by the keyword PM_PB,
- criteria of level A (except tiredness) by the keyword SN,
- criteria of tiredness of level A by the keywords TIREDNESS (for types 'B3200', 'ZE200a' and 'ZE200b') or FATIGUE_ZH210 (for the type 'EVOLUTION'),
- a criterion of environmental tiredness by the keyword EFAT. This criterion is compatible with the options 'B3200', 'ZE200a' and 'ZE200b'.

In addition, with the method 'EVOLUTION' only, it is possible to check the criterion of starting (criterion of level A) in a singular zone (keyword STARTING).

2.5 Criteria of level 0 specified by the RCC-M (keyword PM_PB)

The criteria of level 0 aim at securing the material against the damage of excessive deformation, plastic instability and elastic and elastoplastic instability. They must be checked by the situation of reference (see B3121 and B3151). These criteria require the calculation of the equivalent constraints P_m , P_l , P_b who are below defined and are available for the types 'B3200' and 'EVOLUTION'.

2.5.1 General primary equivalent constraint of membrane

Being data the primary constraint of the situation of reference (1era category) and a segment located out of a zone of major discontinuity. In each point end of this segment length *L*, one calculates P_m and LE criterion is written (B3233.1):

$$P_m \leq S_m$$

S_m is the acceptable equivalent constraint, tabulée in appendix ZI RCC-M. S_m is defined in calculation by the operand SM keyword factor RCCM (or RCCM_FO) of DEFI_MATERIAU. It can be a function of the temperature.

2.5.2 Primary equivalent constraint of local membrane

Being data the primary constraint of the situation of reference (1E category) and a segment **located in a zone of major discontinuity**, the definition of P_l is identical to that of P_m on this segment.

The criterion is written (B3233.2):

$$P_l \leq 1.5\ S_m$$

2.5.3 Primary equivalent constraint of membrane+flexion

Being given the primary constraint of the situation of reference (1era category) and a segment (directed). In each point end of this segment length l , (ends corresponding the skins external and to intern), one calculates P_{mb} and P_{lb} and Lbe criteria are written (B3233.3):

$$P_{mb} \leq 1.5\ S_m$$
$$P_{lb} \leq 1.5\ S_m$$

2.6 Criteria of level With specified by the RCC-M (keywordS SN and FATIGUE/FATIGUE_ZH210)

The criteria of level A aim at securing the material against the damage of progressive deformation and progressive cracking. With methods 'EVOLUTION', 'B3200', 'ZE200a' and 'ZE200b', four types of criteria can be checked:

- Amplitude of variation of the linearized constraints S_n (option 'SN');
- Amplitude of variation of S_n^* (option 'SN');
- Calculation of the thermal ratchet (option 'SN');
- Calculation of the factor of use in fatigue (optionS 'TIREDNESS'/'FATIGUE_ZH210')

1.

These various parameters and the associated criteria are described below such as defined in the RCC-M. In Lhas bytie 2.3, one introduces a simplifying assumption before detailing their calculation in C*ode_hasster* in chapters 3.4 and 6.

2.6.1 Sn calculation and Sn*

One takes into account the more secondary primary constraints and the constraints resulting from opposed thermal dilations: $P_l+P_b+P_E+Q$ who thus represents the constraints linearized associated with all the loading (mechanical and thermal).

The points of calculation are the two ends of the segment. In each point end of this segment length l , one calculates S_n according to the B3232.6 paragraph and LE criterion of total adaptation is written (B3234.2):

$$S_n \leq 3\ S_m$$

S_m being the working stress function of material and temperature, given by the operand `SM` keyword factor `RCCM` (or `RCCM_FO`) of `DEFI_MATERIAU`.

If this criterion is not checked, one can practise the simplified elastoplastic analysis of B3234.3. The three following operations should be carried out:

• ON calculate S_n^* the amplitude S_n calculated without taking into account stresses bending of origin thermal and one must to check the criterion:

$$S_n^* \leq 3\ S_m$$

• to make an elastoplastic correction ($Ke>1$) in the analysis with tiredness,
• to check the criterion of the thermal ratchet (B3234.8) in the current parts of the cylindrical hulls (and pipes) subjected to a pressure and a gradient of cyclic temperature.

2.6.2 Calculation of the thermal ratchet

The wall of a device subjected simultaneously to a constant pressure and cyclic variations of temperature can undergo great deformations under thermal ratchet. It is about a particular mechanism of progressive deformation in which the deformation roughly increases same quantity with each cycle.

The condition to respect is written below and relates to the acceptable maximum value of the amplitude of variation of the constraint of thermal origin, cf B3234.8. It refers to the case of a hull with symmetry of revolution charged by a pressure interns constant. One notes:

σ_θ , acceptable maximum value of the amplitude of variation of the thermal constraint of origin,

σ_m , maximum of the average (or) membrane stress general due to the pressure,

S_y , conventional limit of elasticity read on tables Z I 2.1, for the maximum temperature reached during the cycle.

The criterion is form: $\sigma_\theta = f(\ \sigma_m, S_y)$. While posing $y' = \frac{\sigma_\theta}{S_y}$ and $x = \frac{\sigma_m}{S_y}$, one has

- if the temperature variation is linear through the wall:
  $y' = 1/x$ for $0 < x \leq 0.5$
  $y' = 4(1-x)$ for $0.5 < x < 1$
- if the temperature variation is parabolic in the wall:
  $y' = 5{,}2(1-x)$ for $0.615 \leq x < 1$
  and for $x < 0{,}615$: linear interpolation enters the points: $x = 0{,}3\ ; 0{,}4\ ; 0{,}5$ and $y' = 4{,}65\ ; 3{,}55\ ; 2{,}7$.

In short, Lhas membrane stress σ_m thus is calculated by linearization of the constraint of pressure, then one from of deduced two sizes $\sigma_{\theta_{LINE}}$ and $\sigma_{\theta_{PARA}}$ thanks to the equations above. These two sizes are the respective acceptable maximum values of Sn_{ther} and Sp_{ther} .

2.6.3 Calculation of the factor of use in fatigue

The principle general of calculation to tiredness consists in combining each situation two with two and to make sure that the factor of definite total use in this paragraph is lower than 1.

$$FU_{TOTAL}<1$$

2.6.3.1. Calculation algorithm of the factor of total use

In a schematic way, the calculation algorithm of FU_{TOTAL} defined in chapter B3200 of the RCC-M is the following:

1) One CalculE it elementary factor of use of each combination of situations. The combination of the situations p and Q rests on the definition of two fictitious transients 1 and 2. The elementary factor of use is the sum of the factors of use due to each one of these transients. At the end of this stage, one has a symmetrical matrix (nxn) of elementary factors of use (N being the number of situations),

$$FU_{ELEM}(p,q)=FU_{transitoire1}+FU_{transitoire2}$$

2) One initializes the factor of total use to 0,

$$FU_{TOTAL}=0$$

3) One identifies the combination of situations K and L more penalizing (factor of maximum elementary use) and one multiplies it by the minimum of the numbers of occurrences of these two situations,

$$FU_{TOTAL}=FU_{TOTAL}+FU_{ELEM}(k,l)*min(n_k,n_l)$$

4) One RéactualisE number occurrences situations K and L,

$$n_k=n_k-min(n_k,n_l) \qquad n_l=n_l-min(n_k,n_l)$$

5) Return at stage 3 until exhaustion of all the occurrences.

The definition of the two fictitious transients constitutes a delicate stage of this algorithm. The rule is different according to whether the principal directions are fixed or variable.

$FU_{ELEM}(p,q)$ LE factor of use elementary for a combination of situations p and Q is calculated by introducing into the curve of tiredness of the material (curve of Wöhler) Lbe amplitudeS of variation of the alternate constraints of the two fictitious transients $S^1_{ALT}(p,q)$ and $S^2_{ALT}(p,q)$.

2.6.3.2. Calculation of Salt

$S^1_{ALT}(p,q)$ and $S^2_{ALT}(p,q)$ SoneT definiteS starting from the amplitude of variation of the linearized constraints $S_n(p,q)$ and the amplitude of variation of the constraints total of the two fictitious transients $S^1_p(p,q)$ and $S^2_p(p,q)$.

Two formulas are proposed (cf §B3234.6):

- KE_MECA :

$$S^1_{ALT}(p,q)=\frac{1}{2}.\frac{E_c}{E}.K_e(S_n).S^1_p$$

$$S^2_{ALT}(p,q)=\frac{1}{2}.\frac{E_c}{E}.K_e(S_n).S^2_p$$

The Young modulus of reference (E_c) is provided by the user in DEFI_MATERIAU, under the keyword E_REFE, keyword factor TIREDNESS. K_e is the elastoplastic concentration factor function of $S_n(p,q)$:

$$K_e(S_n)=\begin{cases} 1 & \text{si } S_n \le 3.S_m \\ 1+\dfrac{1-n}{n.(m-1)}.\left(\dfrac{S_n}{3.S_m}-1\right) & \text{si } 3.S_m < S_n < 3.m.S_m \\ \dfrac{1}{n} & \text{si } S_n \ge 3.m.S_m \end{cases}$$

Parameters m and n are provided in DEFI_MATERIAU, under the keywords M_KE and N_KE, keyword factor RCCM. If keywords TEMP_REF_A and TEMP_REF_B are present, S_n is interpolated for this temperature (which must correspond to the average temperature of the transient). If not, S_n is taken with room temperature.

KE_MIXTE : since the modifying 1997 of the RCC-M [1], one can choose another formula, based on a decomposition of S_{ALT} :

$$S^1_{ALT}(p,q)=\frac{1}{2}.\frac{E_c}{E}.\left(K_e^{meca}(S_n).S_p^{meca,1}+K_e^{ther}(S_n).S_p^{ther,1}\right)$$

$$S^2_{ALT}(p,q)=\frac{1}{2}.\frac{E_c}{E}.\left(K_e^{meca}(S_n).S_p^{meca,2}+K_e^{ther}(S_n).S_p^{ther,2}\right)$$

with:

- $K_e^{meca}(S_n)$ is equal to K_e defined above,

- $K_e^{ther}(S_n)=\max\begin{cases} 1,86\left(1-\dfrac{1}{1,66+\dfrac{S_n}{S_m}}\right) \\ 1 \end{cases}$,

- $S_p^{meca,1}$ and $S_p^{meca,2}$ representNT amplitudeS of variation on mechanical behalf of the constraints total fictitious transients 1 and 2

- $S_p^{ther,1}$ and $S_p^{ther,2}$ SoneT calculatedS starting from the total constraints S_p^1 and S_p^2 to which one cuts off respectively constraints of mechanical origin $S_p^{meca,1}$ and $S_p^{meca,2}$.

One calculates finally $FU_{ELEM}(p,q)$ the factor of use elementary associated with the combination of the situations *p* and *Q*, definite starting from the curve of tiredness of material $N_{adm}=f(S_{alt})$:

$$FU_{ELEM}(p,q)=FU_{transitoire1}+FU_{transitoire2}=f(S^{1}_{ALT})+f(S^{2}_{ALT}) .$$

Note:

1) To even calculate the elementary factor of use of a situation p combined with it, in `KE_MECA`*,*
$S^{1}_{ALT}(p,q)=\frac{1}{2}.\frac{E_c}{E}.K_e(S_n(p,p)).S_p(p,p)$ *and* $S^{2}_{ALT}(p,q)=0$ *.*
E N `KE_MIXTE`*,*
$S^{1}_{ALT}(p,q)=\frac{1}{2}.\frac{E_c}{E}.\left(K^{meca}_{e}(S_n(p,p)).S^{meca}_{p}(p,p)+K^{ther}_{e}(S_n(p,p)).S^{ther}_{p}(p,p)\right)$ *and*
$S^{2}_{ALT}(p,q)=0$

2) In the RCC-M, the contribution of the under-cycles is also taken into account in the elementary factor of use. In code_aster, this size is not taken into account.

3 Type `'B3200'`

3.1 Data of chargemenT

LE standard `'B3200'` is well adapted to calculations on a component subjected to many situations. Several groups of operation can also be defined, with possibly situations of passage between these groups. Groups of division and an earthquake can be taken into account also.

A situation is defined by its thermal loading, of pressure and mechanics (efforts and moments). In code_aster the loadings can étre sunken in various forms.

- thermics can be returned only in the form of transient σ_{ther} (`RESU_THER`)
- loadings of pressure can to be returned in two manners:
  - in the form of transient σ_{pres} (`RESU_PRES`)
  - in the form of unit loading σ^P with two pressures P_A and P_B for the stabilized states (`RESU_MECA_UNIT, PRES_A` and `PRES_B`),
- Lbe forced related to the loadings mechanics (efforts and moments) :
  - in form D 'one transient σ_{meca} (`RESU_MECA`)
  - with unit loadings (efforts and unit total moments applied to the limits of the model) with two torques for the stabilized states (`CHAR_ETAT_With` and `CHAR_ETAT_B`). These efforts can be is calculated with C*ode_hasster* , that is to say resulting from database OAR.
  - with unit loadings to which one applies one torque, this torque is calculated by Interpol ation enters two torques (`CHAR_ETAT_ With` and `CHAR_ETAT_ B`) who correspond to the temperatures `TEMP_A` , and `TEMP_B` and thanks to the temperature during the situation `TABL_TEMP`.

<u>All the types of situations can be combined in code_aster</u>. For example, the user can return a first situation of which all the loadings are in the form of transient then one second situation whose it thermal and the pressure are in the form of transient and mechanics with unit loadings.

By preoccupation with a clearness, only the equations if all the situations are described by transitory loadings are presented in this chapter.

Appendix 1 gives the equations if all the situations are described in unit form. Appendix 2 gives the equations if all the situations are described in unit form with interpolation on the temperature.

In this chapter, all them situationS of operation littleVennT being broken upS in transients, i.e. evolutions of constraints due to the various loadings according to time:
- a transient summons transients due to the efforts and the times (definite under `'RESU_MECA'`),
- a transient due to pressure (definite under `'RESU_NEAR'`),
- a thermal transient (definite under `'RESU_THER'`).

Note:
- *For prickings, the user must then return under `RESU_MECA` a transitory mechanical tensor which is the sum of the two tensors of efforts associated with the body and the pipe. The Appendix 3 summarize the equations in this case.*
- *The thermal transient, the transient of pressure and the mechanical transient corresponding to a situation must be defined at the same moments*

3.2 Calculations carried out with the option `'PM_PB'`

For the moment, this option is available if all mechanical loadings and of pressure of the situations are

in unit form.
Being data the primary constraint of the situation of reference (1era category) and a segment located out of a zone of major discontinuity. In each point end of this segment length *L*, one calculates for a situation :

With $\sigma_{ij}=\sigma_{ij,pres}+\sigma_{ij,meca}$

$$P_m=\max_t \|\sigma_{ij}^{moy}\|_{TRESCA} \quad \text{avec} \quad \sigma_{ij}^{moy}=\frac{1}{l}\int_0^l \sigma_{ij}\,ds \quad \text{et} \quad \|\tau_{ij}\|_{TRESCA}=\max_{I,J}|\tau_I-\tau_J|$$
$$\left(\tau_{I\ \ I=1,3}\ \text{étant les contraintes principales}\right)$$

$$P_b=\max_t \|\sigma_{ij}^{fle}\|_{TRESCA} \quad \text{avec} \quad \sigma_{ij}^{fle}=\frac{6}{l^2}\int_0^l \left(s-\frac{l}{2}\right)\sigma_{ij}\,ds$$

$$P_{mb}=\max_t \|\sigma_{ij}^{lin}\|_{TRESCA} \quad \text{avec} \quad \sigma_{ij}^{lin}(s=0)=\sigma_{ij}^{moy}-\sigma_{ij}^{fle}$$
$$\sigma_{ij}^{lin}(s=l)=\sigma_{ij}^{moy}+\sigma_{ij}^{fle}$$

3.3 Calculations carried out with the option `'SN'`

The points of calculation are the two ends of the segment. For a given situation, EN each point end of this segment length l , one calculates S_n according to the B3232.6 paragraph:

$$S_n=\max_{t_1,t_2}\|\sigma_{ij}^{lin}(t_1)-\sigma_{ij}^{lin}(t_2)\|_{TRESCA} \ \text{Où} \ \sigma^{lin}(s=0)=\sigma^{moy}-\sigma^{fle} \ \text{and} \ \sigma^{lin}(s=l)=\sigma^{moy}+\sigma^{fle}$$

If the situation is described in an instantaneous way (cf left 3.1), this definition is applicable directly.
In Code_ hasster, when the situation is defined in a unit way with two stabilized states and a thermal transient, the formula was adapted by introducing a method of selection of the moments. This method is described in the part 3.3.1 .

3.3.1 Method of selection of the moments

In Lhas method `'B3200'` developed in C*ode_hasster*, a method of selection of the moments was implemented (`'TRESCA'` under the keyword `'METHOD'`)

One will thus suppose that the moments which correspond to the extrema of the amplitude of variation of the constraints (linearized or total) combination of two situations are also the moments corresponding to the extrema of the constraints of each situation catches only.

Four moments $t^{\max Sn}$, $t^{\min Sn}$, $t^{\max Sp}$ and $t^{\min Sp}$ are thus identified beforehand for each situation. One notes σ_{tran} the tensor of the constraints summons tensors in the form of transient.

$t^{\max Sn}$ and $t^{\min Sn}$ correspond to the extrema of the constraint transient linearized situation, within the meaning of an equivalent constraint of Tresca signed by the trace of the constraints:

$$t^{\min Sn}=Arg\,\min\left(\|\sigma_{tran}^{lin}(t)\|.\,\mathrm{sgn}\left(Tr\left(\sigma_{tran}^{lin}(t)\right)\right)\right)$$
$$t^{\max Sn}=Arg\,\max\left(\|\sigma_{tran}^{lin}(t)\|.\,\mathrm{sgn}\left(Tr\left(\sigma_{tran}^{lin}(t)\right)\right)\right)$$

$t^{\max Sp}$ and $t^{\min Sp}$ correspond to the extrema of the constraint transient total situation, within the meaning of an equivalent constraint of Tresca signed by the trace of the constraints:

$$t^{\text{minSp}} = Arg \min\left(\|\sigma_{tran}(t)\|.\text{sgn}\left(Tr\left(\sigma_{tran}(t)\right)\right)\right)$$

$$t^{\text{maxSp}} = Arg \max\left(\|\sigma_{tran}(t)\|.\text{sgn}\left(Tr\left(\sigma_{tran}(t)\right)\right)\right)$$

Note:

There is actually 2x4 urgent which is identified as a preliminary for each situation : at the origin and the end of the segment of analysis.

This method of selection of the moments allows a considerable time-saver. It is available by choosing the value `'TRESCA'` under the keyword `'METHOD'`.The method of selection of the moments by the signed tresca is taken by default if the user does not specify anything. But it can miss robustness in the case in particular where the reference mark of the principal constraints turn.
It is then possible to test every moment Dbe transientS, by choosing the value `'TOUT_INST'` under the keyword `'METHOD'`. One cannot differentiate the method of selection from the moments for Sn and Sp.

3.3.2 Sn calculation

One notes $\sigma_{tran}(t)$ the tensor transient associated with the situation; and t^{maxSn} and t^{minSn} extreme moments such as definite with 3.3.1.

With `'METHOD' = 'TRESCA'`, LE parameter S_n for the situation is defined by :

$$S_n = \|\sigma_{tran}^{lin}(t^{\text{maxSn}}) - \sigma_{tran}^{lin}(t^{\text{minSn}})\| \quad .$$

With `'METHOD' = 'TOUT_INST'`, LE parameter S_n for the situation is defined by :

$$S_n = \max_{t_1, t_2} \|\sigma_{tran}^{lin}(t_1) - \sigma_{tran}^{lin}(t_2)\| \quad .$$

Note:

In this case, $\sigma_{tran}(t) = \sigma_{ther}(t) + \sigma_{pres}(t) + \sigma_{meca}(t)$ *.*

3.3.3 Calculation of Sn*

One notes S_n^* the amplitude S_n calculated without taking into account stresses bending of origin thermal. One translates this definition by:

- At the origin of the segment:

$$S_n* = \max_{t_1, t_2} \|\sigma_{tran}^{lin}(t_1) + \sigma_{ther}^{fle}(t_1) - (\sigma_{tran}^{lin}(t_2) + \sigma_{ther}^{fle}(t_2))\|$$

- At the end of the segment:

$$S_n* = \max_{t_1, t_2} \|\sigma_{tran}^{lin}(t_1) - \sigma_{ther}^{fle}(t_1) - (\sigma_{tran}^{lin}(t_2) - \sigma_{ther}^{fle}(t_2))\|$$

with $\sigma_{ther}^{fle} = \frac{6}{l^2} \int_0^l \left(s - \frac{l}{2}\right) \sigma^{th} ds$.

3.3.4 Calculation of the thermal ratchet

It is necessary beforehand to have defined the conventional limit of elasticity for the maximum temperature reached during the cycle is by the operand `SY_MAX` of `POST_RCCM`; maybe by the operand `SY_02` keyword `RCCM` in `DEFI_MATERIAU` [U4.43.01]. If no elastic limit is defined, the calculation of the thermal ratchet is impossible.

In the table generated by the order appear, for each end of each segment of analysis, for the situations and the combinations of situations:

- the maximum of general membrane stress due to the pressure σ_m (`'SIG_PRES_MOY'`)
- the amplitude linearized of variation of the thermal constraint of origin Sn_{ther} and its acceptable maximum value $\sigma_{\theta_{LINE}}$ (`'SN_THER'` and `'CRIT_LINE'`)
- the amplitude of variation of the thermal constraint of origin Sp_{ther} and its acceptable maximum value $\sigma_{\theta_{PARA}}$ (`'SP_THER'` and `'CRIT_ PARAB '`)

3.4 Calculations carried out with the option `'TIREDNESS'`

It is pointed out that LE calculation of the factor of use elementary require as a preliminary the calculation of the amplitude of variation of the constraints linearized S_n and total S_p for each combination of situations (part 2.6.3). This calculation is carried out successively for the situations inside each group with or without earthquake, then for the combinations of situations of passage between groups of situations.
One uses then a method of office plurality of the elementary factors of use, based on the assumption of the linear office plurality of the damage, to obtain the factor of total use.

3.4.1 Combination of the situations inside each group of situations

3.4.1.1. Calculation of SN

It is necessary not to forget the case where combination more penalizing constraints linearized to both extrema of the same situation corresponds. For the combination of the situations p and Q :

$$S_n = \max\left(S_n(p,p)\ ,\ S_n(q,q)\ ,\ S_n(p,q)\right)$$

Sizes $S_n(p,p)$ and $S_n(q,q)$ are calculated according to the part 3.3 and the calculation of the size $S_n(p,q)$ is described in the continuation of this part.

3.4.1.2. Calculation of SN (p, Q)

One notes $\sigma_{tran,p}(t)$ tensor transient associated with situation p and $\sigma_{tran,q}(t)$ the transitory tensor associated with the situation Q. t_p^{maxSn} and t_p^{minSn} extreme moments DU transient situation p and t_q^{maxSn} and t_q^{minSn} extreme moments DU transient situation Q such as definite with 3.3.1.

With `'METHOD'` = `'TRESCA'`, LE parameter S_n for combination of situationS p and Q is defined by :

$$S_n(p,q) = max\left(\|\sigma_{tran,p}^{lin}(t_p^{maxSn}) - \sigma_{tran,q}^{lin}(t_q^{minSn})\|, \|\sigma_{tran,q}^{lin}(t_q^{maxSn}) - \sigma_{tran,p}^{lin}(t_p^{minSn})\|\right) \ .$$

With `'METHOD'` = `'TOUT_INST'`, LE parameter S_n for Lhas combination of situationS p and Q is defined by :

$$S_n(p,q) = \max_{t_p,t_q} \|\sigma_{tran,p}^{lin}(t_p) - \sigma_{tran,q}^{lin}(t_q)\| \quad .$$

Note:

In this case, $\sigma_{tran}(t) = \sigma_{ther}(t) + \sigma_{pres}(t) + \sigma_{meca}(t)$.

3.4.1.3. Calculation of S_p

One calculates in fact the amplitude of variation of the constraints total of the two fictitious transients $S_p^1(p,q)$ and $S_p^2(p,q)$. It is necessary not to forget the case where combination more penalizing constraints Totales to both extrema of the same situation corresponds. One thus modifies the definition of S_p^1 and of S_p^2 as follows:

$$S_p^1=max(S_p(p,p),S_p(q,q),S_p^1(p,q))$$

If $S_p^1=S_p^1(p,q)$, then $S_p^2=S_p^2(p,q)$;
If $S_p^1=S_p(p,p)$, then $S_p^2=S_p(q,q)$;
If $S_p^1=S_p(q,q)$, then $S_p^2=S_p(p,p)$.

Sizes $S_p(p,p)$ and $S_p(q,q)$ are calculated according to Appendix 4 and the calculation of the sizes $S_p^1(p,q)$ and $S_p^2(p,q)$ is described in the continuation of this part.

3.4.1.4. Calculation of S_p^1(p, Q) and S_p^2(p, Q)

One notes $\sigma_{tran,p}(t)$ tensor transient associated with situation p and $\sigma_{tran,q}(t)$ the transitory tensor associated with the situation q. t_p^{maxSp} and t_p^{minSp} extreme moments DU transient situation p and t_q^{maxSp} and t_q^{minSp} extreme moments DU transient situation q such as definite with 3.3.1.

With `'METHOD'` = `'TRESCA'`, LES parameterS S_p^1 and S_p^2 for combination of situationS p and Q SoneT defined by :

$$S_p^1(p,q)=max(\|\sigma_{tran,p}(t_p^{maxSp})-\sigma_{tran,q}(t_q^{minSp})\|,\|\sigma_{tran,q}(t_q^{maxSp})-\sigma_{tran,p}(t_p^{minSp})\|)$$
$$S_p^2(p,q)=min(\|\sigma_{tran,p}(t_p^{maxSp})-\sigma_{tran,q}(t_q^{minSp})\|,\|\sigma_{tran,q}(t_q^{maxSp})-\sigma_{tran,p}(t_p^{minSp})\|)\ .$$

With `'METHOD'` = `'TOUT_INST'`, LE parameter S_p^1 for combination of situationS p and Q is defined by :

$$S_p^1(p,q)=\max_{t_1,t_2}\|\sigma_{tran,p}(t_1)-\sigma_{tran,q}(t_2)\|\ .$$

If t_1^p and t_1^q are the moments of the fictitious transient 1, then one determines the moments of the fictitious transient 2 t_2^p and t_2^q according to the method described inWithnnexe 5 and size $S_p^2(p,q)$ is worth:

$$S_p^2(p,q)=\|\sigma_{tran,p}(t_2^p)-\sigma_{tran,q}(t_2^q)\|$$

Note:

- *The user has the possibility of returning of the indices of constraints under the keyword `INDI_SIGM` in order to compare the results got with the method `'ZE200a'` or `'ZE200b'`. Equations corresponding are described in the Appendix 6.*
- *In ittte part ,* $\sigma_{tran}(t)=\sigma_{ther}(t)+\sigma_{pres}(t)+\sigma_{meca}(t)$.

3.4.1.5. Calculation of $S_p^{méca}$ and S_p^{ther}

If the method is used KE_MIXTE, it is necessary to break up the amplitude of variation of the constraints into a mechanical part and a thermal part. For the definition of $S_p^{méca}$, LE RCC-M (§B3234.6) leaves freedom between (cf §2.6.3.1):

- to take the mechanical share of the amplitude of the maximum constraints between the two transients;
- to take the maximum value of the amplitude of the mechanical constraints during these transients.

It is this last method, more conservative but simpler to implement, which was retained.

It is necessary not to forget the case where combination more penalizing constraints total to both extrema of the same situation corresponds. One thus modifies the definition of $S_p^{meca,1}$ and of $S_p^{meca,2}$ as follows:

If $S_p^1=S_p^1(p,q)$, then $S_p^{meca,1}=S_p^{meca,1}(p,q)$ and $S_p^{meca,2}=S_p^{meca,2}(p,q)$.
If $S_p^1=S_p(p,p)$, then $S_p^{meca,1}=S_p^{meca}(p,p)$ and $S_p^{meca,2}=S_p^{meca}(q,q)$.
If $S_p^1=S_p(q,q)$, then $S_p^{meca,1}=S_p^{meca}(q,q)$ and $S_p^{meca,2}=S_p^{meca}(p,p)$.

Sizes $S_p^{meca}(p,p)$ and $S_p^{meca}(q,q)$ are calculated according to Appendix 4 and the calculation of the sizes $S_p^{meca,1}(p,q)$ and $S_p^{meca,2}(p,q)$ is described in the continuation of this part. Lbe amplitudeS of thermal stress are worth $S_p^{ther,1}=max(0,S_p^1-S_p^{meca,1})$ and $S_p^{ther,2}=max(0,S_p^2-S_p^{meca,2})$.

One notes t_p^{maxSp} and t_p^{minSp} extreme moments DU transient situation p and t_q^{maxSp} and t_q^{minSp} extreme moments DU transient situation Q such as definite with 3.3.1.

With 'METHOD' = 'TRESCA', LES parameterS S_p^1 and S_p^2 for combination of situationS p and Q SoneT defined by :

If $S_p^1(p,q)=\|\sigma_{tran,p}(t_p^{maxSp})-\sigma_{tran,q}(t_q^{minSp})\|$, then

$$S_p^{meca,1}(p,q)=\|\sigma_{meca+pression,p}(t_p^{maxSp})-\sigma_{meca+pression,q}(t_q^{minSp})\|$$

and $$S_p^{meca,2}(p,q)=\|\sigma_{meca+pression,q}(t_q^{maxSp})-\sigma_{meca+pression,p}(t_p^{minSp})\|.$$

If $S_p^1(p,q)=\|\sigma_{tran,q}(t_q^{maxSp})-\sigma_{tran,p}(t_p^{minSp})\|$, then

$$S_p^{meca,1}(p,q)=\|\sigma_{meca+pression,q}(t_q^{maxSp})-\sigma_{meca+pression,p}(t_p^{minSp})\|$$

and $$S_p^{meca,2}(p,q)=\|\sigma_{meca+pression,p}(t_p^{maxSp})-\sigma_{meca+pression,q}(t_q^{minSp})\|.$$

With 'METHOD' = 'TOUT_INST', moments t_1^p, t_1^q, t_2^p, t_2^q, defining the fictitious transients 1 and 2 (cf left 3.4.1.3) also intervene in LES parameterS $S_p^{meca,1}$ and $S_p^{meca,2}$

$$S_p^{meca,1}(p,q)=\|\sigma_{meca+pression,p}(t_1^p)-\sigma_{meca+pression,q}(t_1^q)\|$$

$$S_p^{meca,2}(p,q)=\|\sigma_{meca+pression,p}(t_2^p)-\sigma_{meca+pression,q}(t_2^q)\|.$$

3.4.1.6. Calculation of S ALT and FUELEM

amplitudeS of constraint S_n , S_p^1 and S_p^2 ($S_p^{meca\,1}$, $S_p^{meca\,2}$, $S_p^{ther\,1}$ and $S_p^{ther\,2}$ if KE_MIXTE) allow to lead to the amplitudes of constraint S_{ALT}^1 and S_{ALT}^2 according to the equations of the part 2.6.3.2.

One from of deducted via the curve from Wöhler F the numbers of cycles acceptable N_{adm}^1 and N_{adm}^2 such as $N_{adm}^1 = f\left(S_{ALT}^1\right)$ and $N_{adm}^2 = f\left(S_{ALT}^2\right)$.

The elementary factor of use of the combination of situation is then equal to

$$FU_{ELEM} = FU_1 + FU_2 = \frac{1}{N_{adm}^1} + \frac{1}{N_{adm}^2}$$

3.4.2 Situations of passage

Dthem situations p and Q are combinable only if they belong to the same group or if there exists a situation of passage between the groups to which they belong. In this last case, one will associate with the combination situations p and Q the number of occurrences of the situation of passage. Once this number of occurrences N_{pass} is then exhausted these situations are not combinable. An example is given in the part 3.4.5.
A situation of passage can connect to the maximum 20 groups of operation. The situation of passage must belong to all the groups which it connects.
Several situations of passage can be declared at the same time. If several situations of passage connect the same groups, one will take the number of occurrence of that which gives the elementary factor of use less in addition penalizing.

3.4.3 Group of Partold

Situations being part of the same group of division share their number of occurrences. This group of division is numbered under the keyword 'NUMÉRIQUE_PARTAGE' and have nothing to dohas nothing to do with the group of operation under 'NUMÉRIQUE_GROUPE'. A given situation can belong only to one group of division.

3.4.4 Management of the under-cycles

Method of calculating of the amplitude of constraint with the fictitious transients selects a couple of moments. It is also necessary to take into account the under-cycles which comprised each situation. The user has this possibility while specifying SOUS_CYCL = 'YES' but only when METHODE=' TOUT_INST'

At the stage of calculation of the sizes for the situations alone, once the couple of extreme moments is found, one also extracts the under-cycles from each situations. For example, for a situation p, N are extracted$_p$ Sp under-cycles$_{I,\,p}$ and for a situation Q, N are extracted$_Q$ Sp under-cycles$_{J,\,Q.}$

To the elementary factor of use calculated previously, one adds the contribution of the under-cycles then,
$FU_{ELEM} = FU_1 + FU_2 + FU_{souscycl}$. This contribution is function of the under-cycles extracted previously and That equivalent who was useful for the combination of the situations.

$$FU_{souscycl} = \sum_{i=1}^{n_p} \left(\frac{1}{N_i}\right) + \sum_{j=1}^{n_q} \left(\frac{1}{N_j}\right) \text{ with } N_i = f\left(S_{ALT,i}\right) \text{ and } N_j = f\left(S_{ALT,j}\right) ,$$

$$S_{ALT,i} = \frac{1}{2}\frac{E_c}{E} Ke\left(Sn(p,q)\right) Sp_i \text{ and } S_{ALT,j} = \frac{1}{2}\frac{E_c}{E} Ke\left(Sn(p,q)\right) Sp_j .$$

3.4.5 Storage

To carry out the calculation of the factor of total use, the elementary factors of use calculated previously and the associated numbers of occurrences are stored in a square matrix containing all the elementary factors of use FU except earthquake, for all the possible combinations of situations, i.e. inside each group of situations, and between two groups if there exists a situation of passage. The matrix has as a dimension the sum amongst situations of all the groups and being symmetrical, one fills it only with the top of the diagonal.

Example 1

In the table below, one set the example of a calculation with three groups of operation.

- Group 1 contains the numbered situations 1.2 and 3
- Group 2 contains the numbered situations 4.5 and 6
- Group 3 contains the numbered situations 7.8 and 9

It is calculated FU_{ELEM} possible combinations, if not one puts one zero in the table.

FU_{ELEM}	Group 1			Group 2			Group 3		
	Situ 1	Situ 2	Situ 3	Situ 4	Situ 5	Situ 6	Situ 7	Situ 8	Situ 9
Situ 1	FU (1.1)	FU (1,2)	FU (1,3)	0	0	0	0	0	0
Situ 2		FU (2.2)	FU (2,3)	0	0	0	0	0	0
Situ 3			FU (3.3)	0	0	0	0	0	0
Situ 4				FU (4.4)	FU (4,5)	FU (4,6)	0	0	0
Situ 5					FU (5.5)	FU (5.6)	0	0	0
Situ 6						FU (6.6)	0	0	0
Situ 7							FU (7.7)	FU (7,8)	FU (7,9)
Situ 8								FU (8.8)	FU (8,9)
Situ 9									FU (9.9)

Example 2

In the table below, one set the example of a calculation with three groups of operation, situation 7 is a situation of passage between groups 1 and 3.

- Group 1 contains the numbered situations 1,2,3 and 7
- Group 2 contains the numbered situations 4.5 and 6
- Group 3 contains the numbered situations 7.8 and 9

It is calculated FU_{ELEM} possible combinations, if not one puts one zero in the table. One does not give twice situation 7 in the table even if it belongs to two groups.

FU (1.7), FU (2.7) and FU (3.7) from now on are calculated because situations 1,2,3 and 7 are part of the same group.

The situation of passage number 7 created the passage between groups 1 and 3et one thus calculates them terms ***FU (1.8), FU (1.9), FU (2.8), FU (2.9), FU (3.8) and FU (3.9)***.

	Table of FU_{ELEM}								
	Situ 1	Situ 2	Situ 3	Situ 4	Situ 5	Situ 6	Situ 7	Situ 8	Situ 9
Situ 1	FU (1.1)	FU (1,2)	FU (1,3)	0	0	0	FU (1.7)	***FU (1.8)***	***FU (1.9)***
Situ 2		FU (2.2)	FU (2,3)	0	0	0	FU (2.7)	***FU (2.8)***	***FU (2.9)***
Situ 3			FU (3.3)	0	0	0	FU (3.7)	***FU (3.8)***	***FU (3.9)***

Situ 4				FU (4.4)	FU (4,5)	FU (4,6)	0	0	0
Situ 5					FU (5.5)	FU (5.6)	0	0	0
Situ 6						FU (6.6)	0	0	0
Situ 7							FU (7.7)	FU (7,8)	FU (7,9)
Situ 8								FU (8.8)	FU (8,9)
Situ 9									FU (9.9)

3.4.6 Taking into account of the earthquake

When an earthquake is taken into account, one builds one second matrix of the factors of elementary use with earthquake. This matrix is filled of the same manner as the matrix without earthquake by taking account only possible combinations (groups and situations of passage).

Lastly, the elementary factors of use with earthquake are the sum of the factor of use of the combination of the situation p and Q with earthquake, contribution of the under-cycles of the situations (cf 3.4.4) and of the contribution of under seismic cycles FU_{ss}.

$$FU_{ELEM}(p,q,S)=FU(p,q,S)+FU_{souscycl}+FU_{ss}$$

with $FU_{ss}=(2n_s-1)FU(S)$ where $FU(S)$ is the factor of use due to the earthquake alone and n_s is the number of seismic under-cycles (`NB_CYCL_SEISME`).

If the user chose `'SOUS_CYCL' = 'YES'`, for the calculation of $FU_{souscycl}$, one takes again the method applied in the part 3.4.4 by taking the That depend one on the earthquake only.

To obtain $FU(p,q,S)$, Lsecond phase has consists in calculating the amplitudes of constraints which correspond to the combinations situations of a given group, by taking of account seismic loadings.

According to the definition of the situations, the earthquake can also be defined in two different ways:

- unit: it is described by one mechanical state (S) and the corresponding torque $\{F_X^S, F_Y^S, F_Z^S, M_X^S, M_Y^S, M_Z^S\}$ under `CHAR_ETAT`, the keyword `'RESU_MECA_UNIT'` must be well informed.
- with six tensors corresponding to the efforts and moments $\sigma_{FX,S}$, $\sigma_{FY,S}$, $\sigma_{FZ,S}$, $\sigma_{MX,S}$, $\sigma_{MY,S}$, $\sigma_{MZ,S}$

Note:

> *For prickings, L E torque of effort passes from 6 to 12 components into unit and the number of tensors passes from 6 to 12 into instantaneous*

The seismic loadings are not signed. Each component of the tensor of the constraints can thus take two values (positive and negative). At the time of the superposition of a loading not signed with a signed loading, the RCC-M forces to retain on each component a sign such as constraint calculated (in fact S_{ALT}) that is to say raised.

Parameters $S_p^1(p,q,S)$, $S_p^2(p,q,S)$, $S_n(p,q,S)$ and $S_{alt}(p,q,S)$ with earthquake are calculated same manner as without earthquake, but by maximizing the amplitude of the constraints by report with all the possibilities of sign. In order to better understand, an example is given in the continuation of this paragraph, more equations with the earthquake are summarized in Appendix 7.

For example, for the method of selection of moments `'TOUT_INST'` ,

$$S_p^1(p,q,S)=\max_{t_1,t_2}\|\sigma_{tran,p}(t_1)-\sigma_{tran,q}(t_2)\pm\sigma_{FX,S}\pm\sigma_{FY,S}\pm\sigma_{FZ,S}\pm\sigma_{MX,S}\pm\sigma_{MY,S}\pm\sigma_{MZ,S}\| .$$

3.4.7 Calculation of the factor of total use

If there is NR situations, with the exit of the preceding stages, one thus has:

- one matrix $[N,N]$ factors of use elementary $FU_{ELEM}(p,q,S)$ with earthquake
- one matrix $[N,N]$ factors of use elementary $FU_{ELEM}(p,q)$ without earthquake.

One notes:

- n_p the number D'occurrences associated with the situation p
- n_q the number D'occurrences associated with the situation q
- N_s the number of occurrences of the earthquake
- n_{pass} many cycles associated with a possible situation with passage between p and Q if these situations do not belong to the same group

- 1) O N initializes the factor of total use $FU_{TOTAL}=0$
- 2)
  - If $N_s/2>0$, one seek in the table $FU_{ELEM}(p,q,S)$ the greatest factor of elementary use with earthquake
  - If $N_s/2=0$, one goes at the stage 8
- 3) O N multiplies it elementary factor of use $FU_{ELEM}(p,q,S)$ by its number of occurrenc E
  - $n_{occ}=min\{n_p,n_q,N_s/2\}$ in general
  - $n_{occ}=min\{n_p,n_q,N_s/2,n_{pass}\}$ if the situations p and Q are connected only by one situation of passage
- 4) O N obtains the factor of partial use due to this combination $FU_{partiel}=n_{occ}*FU_{ELEM}(p,q,S)$.
- 5) O N increments the factor of total use with the factor of partial use found at the preceding stage $FU_{TOTAL}=FU_{TOTAL}+FU_{partiel}$
-
- 6) O N updates the numbers of occurrences
  - In general, $n_p=n_p-n_{occ}$, $n_q=n_q-n_{occ}$ and $N_s/2=N_s/2-n_{occ}$.
  - If a situation made the passage, one puts also up to date $n_{pass}=n_{pass}-n_{occ}$
- 7) S I the situation p or the situation Q belongs to a group of division, one updates the numbers of occurrences of the situations D E it even group of division. Then one takes again the loop at stage 2.
- 8) O N seek in the table $FU_{ELEM}(p,q)$ the greatest factor of elementary use
- 9) O N multiplies this factor of elementary use $FU_{ELEM}(p,q)$ by its number of occurrence
  - $n_{occ}=min\{n_p,n_q\}$ in general
  - $n_{occ}=min\{n_p,n_q,n_{pass}\}$ if the situations p and Q are connected only by one situation of passage
- 10) O N obtains the factor of partial use due to this combination $FU_{partiel}=n_{occ}*FU(p,q)$
- 11) O N increments the factor of total use with the factor of partial use found at the preceding stage $FU_{TOTAL}=FU_{TOTAL}+FU_{partiel}$
-
- 12) O N updates the numbers of occurrences

- In general, $n_p = n_p - n_{occ}$, $n_q = n_q - n_{occ}$.
- If a situation made the passage, one puts also up to date $n_{pass} = n_{pass} - n_{occ}$

- 13) S I the situation p or the situation Q belongs to a group of division, one updates the numbers of occurrences of the situations D E it even group of division. Then one takes again the loop at the stage 8 until exhaustion of all numbers of occurrences of all the situations.

Note:

Appendix ZI of code RCC-M defines the curve of Wöhler until an amplitude of constraint minimum corresponding to one lifetime of 10^6 cycles. If the value S'_{alt} calculated for a combination (i, j) of stabilized state is lower than this amplitude minimum, the factor of use is equal to 0 for the combination (i, j) considered.

4 Types 'ZE200a' and 'ZE200b'

4.1 Data of loading

Lbe standard 'ZE200a' and 'ZE200b' SoneT adapted wellS with calculations on a piping or a pricking subjected to many situations. Several groups of operation can also be defined, with possibly situations of passage between these groups. Groups of division and an earthquake can be taken into account also.

Each situation is described by two stabilized states and a thermal transient. The stabilized states describe the loadings had with moments via a torque $\{M_X, M_Y, M_Z\}$.
Lpressure has can be described in two different ways:

- 'ZE200a' : it is associated with the stabilized states which are then defined by a pressure P
- 'ZE200b' : it is in the form of transient under the keyword 'RESU_PRES'.

The use of itS optionS require the preliminary calculation of the stress fields for each thermal transient; these fields are to be provided on the segment of analysis to the moments of discretization of calculation via tables.

Additional data are necessary for calculation following L'Appendix ZE200 of the RCC-M. These data intervene in the simplified equations resulting from the B3600 chapter. They are the following ones:

- Geometrical characteristics of piping: thickness EP, ray R and moment of inertia I under the keyword PIPE.
- Indices constraints of the B3680 paragraph of the RCC-M : C1, C2, C3, K1, K2, K3 under the keyword INDI_SIGM

Note:

- *For prickings, it is also possible to use Lbe typES ZE200a and* ZE200b *by defining two torques moments associated respectively with the body and the pipe. It is also necessary to define the rays of the body and the pipe under 'TUYAU' like their indices of constraints under 'INDI_SIGM'. The Appendix 3 summarize the equations in this case.*
- *efforts are not taken into account in ZE200*
- *EN 'ZE200b' , the user must also provide the stress fields for each transient of pressure and they must be defined at the same moments as the thermal transients*
- *Lbe two methods of selection of moments 'TRESCA' and 'TOUT_INST' are available (cf left 3.3.1)*

4.2 Calculations carried out with the option 'SN'

4.2.1 Type ' ZE200a '

One notes σ_{ther} the tensor constraints DU transient thermics associated with the situation and t^{maxSn} and t^{minSn} extreme moments of this transient such as definite with 3.3.1. One index A and B sizes of the stabilized states of the situation (pressure and torque at the time). R, E, and I am the geometrical characteristics of piping, C_1 and C_2 are indication of constraints of the RCC-M.

With 'METHOD' = 'TRESCA', LE parameter S_n for the situation is defined by:

$$S_n = C_1 \frac{R}{e} |P_A - P_B| + C_2 \frac{R}{I} \sqrt{(M_{XA} - M_{XB})^2 + (M_{YA} - M_{YB})^2 + (M_{ZA} - M_{ZB})^2} + \| \sigma_{ther}^{lin}(t^{maxSn}) - \sigma_{ther}^{lin}(t^{minSn}) \|$$

With `'METHOD' = 'TOUT_INST'`, LE parameter S_n for the situation is defined by :

$$S_n = C_1 \frac{R}{e}|P_A - P_B| + C_2 \frac{R}{I}\sqrt{(M_{XA}-M_{XB})^2+(M_{YA}-M_{YB})^2+(M_{ZA}-M_{ZB})^2} + \max_{t_1,t_2} \|\sigma_{ther}^{lin}(t_1) - \sigma_{ther}^{lin}(t_2)\|$$

4.2.2 Type `' ZE200b '`

One notes σ_{tran} the tensor summons transients associated with the situation and t^{maxSn} and t^{minSn} extreme moments of this transient such as definite with 3.3.1. One index A and B sizes of the stabilized states of the situation (torque at the time). R, E, and I am the geometrical characteristics of piping, C_2 ESt L'index of constraints of the RCC-M.

With `'METHOD' = 'TRESCA'`, LE parameter S_n for the situation is defined by:

$$S_n = C_2 \frac{R}{I}\sqrt{(M_{XA}-M_{XB})^2+(M_{YA}-M_{YB})^2+(M_{ZA}-M_{ZB})^2} + \|\sigma_{tran}^{lin}(t^{maxSn}) - \sigma_{tran}^{lin}(t^{minSn})\|$$

With `'METHOD' = 'TOUT_INST'`, LE parameter S_n for the situation is defined by :

$$S_n = C_2 \frac{R}{I}\sqrt{(M_{XA}-M_{XB})^2+(M_{YA}-M_{YB})^2+(M_{ZA}-M_{ZB})^2} + \max_{t_1,t_2} \|\sigma_{tran}^{lin}(t_1) - \sigma_{tran}^{lin}(t_2)\|$$

Note:

In it paragraph , $\sigma_{tran}(t) = \sigma_{ther}(t) + \sigma_{pres}(t)$.

4.3 Calculations carried out with the option `'TIREDNESS'`

It is pointed out that LE calculation of the factor of use elementary require as a preliminary the calculation of the amplitude of variation of the constraints linearized S_n and total S_p for each combination of situations (part 2.6.3).

4.3.1 Combination of the situations inside each group of situations

4.3.1.1. Calculation of S_N

It is necessary not to forget the case where combination more penalizing constraints linearized to both extrema of the same situation corresponds. For the combination of the situations p and Q :

$$S_n = \max\left(S_n(p,p),\ S_n(q,q),\ S_n(p,q)\right)$$

Sizes $S_n(p,p)$ and $S_n(q,q)$ are calculated according to the part 4.2 and the calculation of the size $S_n(p,q)$ is described in the continuation of this paragraph.

One notes $\sigma_{tran,p}$ the tensor summons transients associated with the situation p and $\sigma_{tran,q}$ the tensor summons transients associated with the situation Q. t_p^{maxSn}, t_p^{minSn}, t_q^{maxSn}, t_q^{minSn}, extreme moments of itS transientS such as definite with 3.3.1. One index p and Q sizes of the states stabilized ofS two situationS (pressureS and torqueS at the time). R, E, and I am the geometrical characteristics of piping, C_1 and C_2 are indication of constraints of the RCC-M.

For the two types `'ZE200a'` and `'ZE200b'`, ON maximizes initially the size S_n'' on the four possibilities of combination of stabilized states.

For `'ZE200a'`

$$\sigma_{tran}(t) = \sigma_{ther}(t)$$

$$S_n''=\max_{p,q}\left(C_1\frac{R}{e}|P_p-P_q|+C_2\frac{R}{I}\sqrt{(M_{Xp}-M_{Xq})^2+(M_{Yp}-M_{Yq})^2+(M_{Zp}-M_{Zq})^2}\right)$$

For 'ZE200b'

$$\sigma_{tran}(t)=\sigma_{ther}(t)+\sigma_{pres}(t)$$

$$S_n''=\max_{p,q}\left(C_2\frac{R}{I}\sqrt{(M_{Xp}-M_{Xq})^2+(M_{Yp}-M_{Yq})^2+(M_{Zp}-M_{Zq})^2}\right)$$

Puis, pour both typbe, the continuation of calculation is identical.

With 'METHOD' = 'TRESCA', LE parameter S_n for the situation is defined by:

$$S_n(p,q)=S_n'+S_n'' \text{ with } S_n'=\max(S_{nA},S_{nB})$$

$$S_{nA}=\|\sigma^{lin}_{tran,p}(t_p^{maxSn})-\sigma^{lin}_{tran,q}(t_q^{minSn})\| \text{ and } S_{nB}=\|\sigma^{lin}_{tran,q}(t_q^{maxSn})-\sigma^{lin}_{tran,p}(t_p^{minSn})\| .$$

If $S_n'=S_{nA}$, then $S_{n,ther}'=\|\sigma^{lin}_{ther,p}(t_p^{maxSn})-\sigma^{lin}_{ther,q}(t_q^{minSn})\|$ and if 'ZE200b', $S_{n,pres}'=\|\sigma^{lin}_{pres,p}(t_p^{maxSn})-\sigma^{lin}_{pres,q}(t_q^{minSn})\|$.

If $S_n'=S_{nB}$, then $S_{n,ther}'=\|\sigma^{lin}_{ther,q}(t_q^{maxSn})-\sigma^{lin}_{ther,p}(t_p^{minSn})\|$ and if 'ZE200b', $S_{n,pres}'=\|\sigma^{lin}_{pres,q}(t_q^{maxSn})-\sigma^{lin}_{pres,p}(t_p^{minSn})\|$.

Or, with 'METHOD' = 'TOUT_INST', LE parameter S_n for the situation is defined by:

$$S_n(p,q)=S_n'+S_n'' \text{ with } Sn'=\max_{t_1,t_2}\|\sigma^{lin}_{tran,p}(t_1)-\sigma^{lin}_{tran,q}(t_2)\| .$$

If $Sn'=\|\sigma^{lin}_{tran,p}(t_p)-\sigma^{lin}_{tran,q}(t_q)\|$, then $S_{n,ther}'=\|\sigma^{lin}_{ther,p}(t_p)-\sigma^{lin}_{ther,q}(t_q)\|$ and if 'ZE200b', $S_{n,pres}'=\|\sigma^{lin}_{pres,p}(t_p)-\sigma^{lin}_{pres,q}(t_q)\|$.

4.3.1.2. Calculation of S_p

It is necessary not to forget the case where combination more penalizing constraints Totales to both extrema of the same situation corresponds. One thus modifies the definition of S_p^1 and of S_p^2 as follows:

$$S_p^1=\max(S_p(p,p),S_p(q,q),S_p^1(p,q))$$

If $S_p^1=S_p^1(p,q)$, then $S_p^2=S_p^2(p,q)$;
If $S_p^1=S_p(p,p)$, then $S_p^2=S_p(q,q)$;
If $S_p^1=S_p(q,q)$, then $S_p^2=S_p(p,p)$.

Sizes $S_p(p,p)$ and $S_p(q,q)$ are calculated according to Appendix 4 and the calculation of the sizes $S_p^1(p,q)$ and $S_p^2(p,q)$ is described in the continuation of this paragraph.

One notes $\sigma_{tran,p}$ the tensor summons transients associated with the situation p and $\sigma_{tran,q}$ the tensor summons transients associated with the situation Q. t_p^{maxSp}, t_p^{minSp}, t_q^{maxSp}, t_q^{minSp}, extreme moments of itS transientS such as definite with 3.3.1. One index p and Q sizes of the states stabilized ofS two situationS (pressureS and torqueS at the time). R, E, and I am the geometrical characteristics of piping, K_1, K_2, K_3, C_1, C_2 and C_3 are indication of constraints of the RCC-M.

For the two types `ZE200a'` and `ZE200b'`, ON maximizes initially the size S_p'' on the four possibilities of combination of stabilized states, $S_{n,ther}'$ and $S_{n,pres}'$ having been given in the part 4.3.1.1.

For `ZE200a'`_

$$\sigma_{tran}(t)=\sigma_{ther}(t)$$

$$S_p^1''=\max_{p,q}[K_1C_1\frac{R}{e}|P_p-P_q|+K_2C_2\frac{R}{I}\sqrt{(M_{Xp}-M_{Xq})^2+(M_{Yp}-M_{Yq})^2+(M_{Zp}-M_{Zq})^2}]$$

S_p^2'' is the complementary one to S_p^1'' on the stabilized states.

For example, by indiçant A and B stabilized states of the situations p and Q, if $S_p^1''=K_1C_1\frac{R}{e}|P_{pA}-P_{qB}|+K_2C_2\frac{R}{I}\sqrt{(M_{XpA}-M_{XqB})^2+(M_{YpA}-M_{YqB})^2+(M_{ZpA}-M_{ZqB})^2}$ then

$$S_p^2''=K_1C_1\frac{R}{e}|P_{pB}-P_{qA}|+K_2C_2\frac{R}{I}\sqrt{(M_{XpB}-M_{XqA})^2+(M_{YpB}-M_{YqA})^2+(M_{ZpB}-M_{ZqA})^2}.$$

$$S_p'''=(K_3C_3-1)S_{n,ther}'$$

For `ZE200 B `

$$\sigma_{tran}(t)=\sigma_{ther}(t)+\sigma_{pres}(t)$$

$$S_p^1''=\max_{p,q}[K_2C_2\frac{R}{I}\sqrt{(M_{Xp}-M_{Xq})^2+(M_{Yp}-M_{Yq})^2+(M_{Zp}-M_{Zq})^2}]$$

S_p^2'' is the complementary one to S_p^1'' on the stabilized states.

For example, by indiçant A and B stabilized states of the situations p and Q, if $S_p^1''=K_2C_2\frac{R}{I}\sqrt{(M_{XpA}-M_{XqB})^2+(M_{YpA}-M_{YqB})^2+(M_{ZpA}-M_{ZqB})^2}$ then

$$S_p^2''=K_2C_2\frac{R}{I}\sqrt{(M_{XpB}-M_{XqA})^2+(M_{YpB}-M_{YqA})^2+(M_{ZpB}-M_{ZqA})^2}.$$

$$S_p'''=(K_3C_3-1)S_{n,ther}'+(K_1C_1-1)S_{n,pres}'$$

For two types, the continuation of calculation is identical.

$$S_p^1(p,q)=S_p^1'+S_p^1''+S_p'''$$

$$S_p^2(p,q)=S_p^2'+S_p^2''+S_p'''$$

With 'METHOD' = 'TRESCA', LES parameterS $S_p^1{}'$ and $S_p^2{}'$ for combination of situationS p and Q SoneT defined by :

$$S_p^1{}'=max(\|\sigma_{tran,p}(t_p^{maxSp})-\sigma_{tran,q}(t_q^{minSp})\|,\|\sigma_{tran,q}(t_q^{maxSp})-\sigma_{tran,p}(t_p^{minSp})\|)$$
$$S_p^2{}'=min(\|\sigma_{tran,p}(t_p^{maxSp})-\sigma_{tran,q}(t_q^{minSp})\|,\|\sigma_{tran,q}(t_q^{maxSp})-\sigma_{tran,p}(t_p^{minSp})\|)$$

With 'METHOD' = 'TOUT_INST', LE parameter $S_{p1}{}'$ for combination of situationS p and Q is defined by :

$$S_p^1{}'=\max_{t_1,t_2}\|\sigma_{tran,p}(t_1)-\sigma_{tran,q}(t_2)\| \ .$$

If t_1^p and t_1^q are the moments of the fictitious transient 1 $S_p^1{}'$, then one determines the moments of the fictitious transient 2 t_2^p and t_2^q according to the method described inWithnnexe 5 and size $S_p^2{}'$ is worth:

$$S_p^2{}'=\|\sigma_{tran,p}(t_2^p)-\sigma_{tran,q}(t_2^q)\|$$

4.3.1.3. Calculation of $S_p^{méca}$ and S_p^{ther}

If the method is used KE_MIXTE, it is necessary to break up the amplitude of variation of the constraints into a mechanical part and a thermal part. For the definition of $S_p^{méca}$, LE RCC-M (§B3234.6) leaves freedom between (cf §2.6.3.1):

- to take the mechanical share of the amplitude of the maximum constraints between the two transients;
- to take the maximum value of the amplitude of the mechanical constraints during these transients.

It is this last method, more conservative but simpler to implement, which was retained.

IL is necessary not to forget the case where combination more penalizing constraints total to both extrema of the same situation corresponds. One thus modifies the definition of $S_p^{meca,1}$ and of $S_p^{meca,2}$ as follows:

If $S_p^1=S_p^1(p,q)$, then $S_p^{meca,1}=S_p^{meca,1}(p,q)$ and $S_p^{meca,2}=S_p^{meca,2}(p,q)$.
If $S_p^1=S_p(p,p)$, then $S_p^{meca,1}=S_p^{meca}(p,p)$ and $S_p^{meca,2}=S_p^{meca}(q,q)$.
If $S_p^1=S_p(q,q)$, then $S_p^{meca,1}=S_p^{meca}(q,q)$ and $S_p^{meca,2}=S_p^{meca}(p,p)$.

Sizes $S_p^{meca}(p,p)$ and $S_p^{meca}(q,q)$ are calculated according to Appendix 4 and the calculation of the sizes $S_p^{meca,1}(p,q)$ and $S_p^{meca,2}(p,q)$ is described in the continuation of this paragraph.

The amplitude of thermal stress $S_p^{ther,1}$ (resp. $S_p^{ther,2}$) is defined by taking the amplitude of total constraint S_p^1 (resp. S_p^2) to which one cuts off $s_p^{meca,1}$ (resp. $S_p^{meca,2}$).

One notes $\sigma_{pres,p}$ the tensor had with the pressure associated with the situation p and $\sigma_{pres,q}$ the tensor due to the pressure associated with the situation Q. t_p^{maxSp}, t_p^{minSp}, t_q^{maxSp}, t_q^{minSp}, extreme moments of itS transientS such as definite with 3.3.1. One index p and Q sizes of the states stabilized ofS two situationS (pressureS and torqueS at the time). R, E, and I am the geometrical characteristics of piping, K_1, K_2, K_3, C_1, C_2 and C_3 are indication of constraints of the RCC-M.

For the two types 'ZE200a' and 'ZE200b', ON maximizes initially the size $S_p{}''$ on the four possibilities of combination of stabilized states, $S_{n,pres}{}'$ having been given in the part 4.3.1.1.

For 'ZE200a'_

The states p and Q are the states which maximized the size S_p^1 (part 4.3.1.2).

$$S_p^{meca,1}=K_1 C_1 \frac{R}{e}|P_p-P_q|+K_2 C_2 \frac{R}{I}\sqrt{(M_{Xp}-M_{Xq})^2+(M_{Yp}-M_{Yq})^2+(M_{Zp}-M_{Zq})^2}$$

$S_p^{meca,2}$ is the complementary one to $S_p^{meca,1}$ on the stabilized states.

For `'ZE200 B '`

$$S_p^{meca,1}(p,q)=S_p^{meca,1}{'}+S_p^1{''}+S_p{'''}$$
$$S_p^{meca,2}(p,q)=S_p^{meca,2}{'}+S_p^2{''}+S_p{'''}$$

The states p and Q are the states which maximized the size S_p^1 (part 4.3.1.2).

$S_p^1{''}=K_2 C_2 \frac{R}{I}\sqrt{(M_{Xp}-M_{Xq})^2+(M_{Yp}-M_{Yq})^2+(M_{Zp}-M_{Zq})^2}$, $S_p^2{''}$ is the complementary one to $S_p^1{''}$ on the stabilized states and $S_p{'''}=(K_1 C_1-1)S_{n,pres}{'}$.

With `'METHOD' = 'TRESCA'`, LES parameterS $S_p^{meca,1}{'}$ and $S_p^{meca,2}{'}$ for combination of situationS p and Q SoneT defined starting from the sizes $S_p^1{'}$ and $S_p^2{'}$ part 4.3.1.2 :

If $S_p^1{'}=\|\sigma_{tran,p}(t_p^{maxSp})-\sigma_{tran,q}(t_q^{minSp})\|$, then $S_p^{meca,1}{'}(p,q)=\|\sigma_{pression,p}(t_p^{maxSp})-\sigma_{pression,q}(t_q^{minSp})\|$
and $S_p^{meca,2}{'}(p,q)=\|\sigma_{pression,q}(t_q^{maxSp})-\sigma_{pression,p}(t_p^{minSp})\|$.

If $S_p^1{'}=\|\sigma_{tran,q}(t_q^{maxSp})-\sigma_{tran,p}(t_p^{minSp})\|$, then $S_p^{meca,1}{'}(p,q)=\|\sigma_{pression,q}(t_q^{maxSp})-\sigma_{pression,p}(t_p^{minSp})\|$
and $S_p^{meca,2}{'}(p,q)=\|\sigma_{pression,p}(t_p^{maxSp})-\sigma_{pression,q}(t_q^{minSp})\|$.

With `'METHOD' = 'TOUT_INST'` , one does not carry out a new search for moments per report with the method `KE_MECA` (part 4.3.1.2). Are t_1^p and t_1^q are the moments of the fictitious transient 1 $S_p^1{'}$, and t_2^p and t_2^q moments of the fictitious transient 2 $S_p^2{'}$. Then, parameters $S_p^{meca,1}{'}$ and $S_p^{meca,2}{'}$ for the combination of the situations p and Q are defined by:

$$S_p^{meca,1}=\|\sigma_{pres,p}(t_1^p)-\sigma_{pres,q}(t_1^q)\| \ ,$$
$$S_p^{meca,2}=\|\sigma_{pres,p}(t_2^p)-\sigma_{pres,q}(t_2^q)\| \ .$$

4.3.2 Calculation of the Factor of total use

The taking into account of the earthquake, groups of division, under-cycles, L management of the situations of passage has, the storage of the elementary factors of use and the calculation of the factor of total use are the same ones as for the method `'B3200'` (see parts 3.4.2 with 3.4.7).

5 Environmental tiredness

The taking into account of the effects of environment on the resistance to fatigue in Code_hasster is available for types `B3200`, `ZE200a` and `ZE200b`. This taking into account is carried out after the combination of the situations and the calculation of the factor of usual use described in Lpart has 3.4.7.

5.1 Calculation of the FEN

The environmental factor for combination of situationS p and q express yourself according to $\Delta\epsilon$ increment of deformation, of F partial environmental factor and of the moments t_k and t_l. The index k sweep the moments of the transient of p and the index l sweep the moments of the transient of q .

$$FEN_{comb}(p,q)=\frac{\sum_k F(t_k)\Delta\epsilon(t_k)+\sum_l F(t_l)\Delta\epsilon(t_l)}{\sum_k \Delta\epsilon(t_k)+\sum_l \Delta\epsilon(t_l)} .$$

Whatever the studied material, the general form of the factor of environmental partial F is the following one:

$$F(t_k)=\exp[(A+B\dot{\epsilon}^*(t_k))S^*O^*T^*+C] .$$

- With, B and C are of the constants which depend on the nature of material: ferritic, austenitic, base-nickel (keywords `A_ENV`, `B_ENV` and `C_ENV`),
- S^* is content of suffer analyzed metal, thus commune with all the situations (keyword `S_ETOILE)`,
- O^* is the degree of oxygen dissolved in water in contact with the analyzed section. This size can be different for each situation (keyword `O_ETOILE`),
- T^* is a function which depends on the average temperature T. <u>The user must thus provide a table which contains the change of the temperature during the transient</u> (keyword `TABL_TEMP`).

$$T=\frac{T(t_k)+T(t_{k-1})}{2} .$$

The function T^* is described below and depends on the thresholds $T_{\mathrm{seuil,sup}}$ et $T_{\mathrm{seuil,inf}}$ (keywords `SEUIL_T_SUP` and `SEUIL_T_INF`) and of the values thresholds $T_{\mathrm{sup}}, T_{\mathrm{inf}}, T_{\mathrm{moy,num}}$ et $T_{\mathrm{moy,den}}$ (keywords `VALE_T_SUP`, `VALE_T_INF`, `VALE_T_MOY_NUM` and `VALE_T_MOY_DEN`):

$$T^*=\begin{vmatrix} T_{\mathrm{inf}} & \text{si } T>T_{\mathrm{seuil,sup}} \\ \dfrac{T-T_{\mathrm{moy,num}}}{T_{\mathrm{moy,den}}} & \text{si } T_{\mathrm{seuil,inf}}\le T\le T_{\mathrm{seuil,sup}} \\ T_{\mathrm{sup}} & \text{si } T<T_{\mathrm{seuil,inf}} \end{vmatrix} .$$

- $\dot{\epsilon}^*$ ESt a function which depends on the speed of deformation $\dot{\epsilon}$. This function is described Ci below and depends on the thresholds $\epsilon_{\text{seuil,sup}}$ et $\epsilon_{\text{seuil,inf}}$ (keywords SEUIL_EPSI_SUP and SEUIL_EPSI_INF)

$$\dot{\epsilon}^{*}=\begin{vmatrix} 0 & \text{si } \dot{\epsilon}>\epsilon_{\text{seuil,sup}} \\ \ln\left(\frac{\dot{\epsilon}}{\epsilon_{\text{seuil,sup}}}\right) & \text{si } \epsilon_{\text{seuil,inf}}\leq\dot{\epsilon}\leq\epsilon_{\text{seuil,sup}} \\ \ln\left(\frac{\epsilon_{\text{seuil,inf}}}{\epsilon_{\text{seuil,sup}}}\right) & \text{si } \dot{\epsilon}<\epsilon_{\text{seuil,inf}} \end{vmatrix} .$$

The speed of deformation $\dot{\epsilon}$ is equal to:

$$\dot{\epsilon}(t_k)=\frac{\Delta\epsilon(t_k)}{t_k-t_{k-1}} .$$

The increment of deformation $\Delta\epsilon$ intervenes at the same time in the expression of the environmental factor of the situation FEN and in the partial environmental factor $F(t_k)$ via $\dot{\epsilon}$. $\Delta\epsilon$ is calculated starting from the tensor of the constraints in the forms of transient σ_{tran} in the following way: the tensor is calculated $\Delta\sigma$ such as

$$\Delta\sigma(t_k)=\sigma_{tran}(t_k)-\sigma_{tran}(t_{k-1}) .$$

After diagonalisation,

$$\Delta\sigma(t_k)=\begin{bmatrix} \sigma_1(t_k) & 0 & 0 \\ 0 & \sigma_2(t_k) & 0 \\ 0 & 0 & \sigma_3(t_k) \end{bmatrix} \text{ with } \sigma_1>\sigma_2>\sigma_3 .$$

One can then calculate $\Delta\epsilon$ who is function of the principal constraints, of Ke combination of situation and modulus Young E taken with the average temperature step of time T. Ke was stored during the calculation of the factor of usual use (left 2.6.3.2) and E is calculated by linear interpolation on the curve $E(T)$ data under the keyword TABL_YOUNG.

$$\Delta\epsilon(t_k)=\begin{vmatrix} 0 & \text{si}\,\sigma_1\leq 0 \\ Ke.\frac{\sigma_1(t_k)-\sigma_3(t_k)}{E(T)} & \text{si}\,\sigma_1>0 \end{vmatrix} .$$

Note:

The table of temperature entry under the keyword TABL_TEMP must be defined at the same moments as the tables which contain the constraints in the form of transient (thermal, pressure, mechanics according to the method of calculating)

5.2 Calculation of the factor of use with effect of environment

For the calculation of the factor of use with effect of environment, two sizes still intervene at this stage: a criterion on the deformation (keyword CRIT_EPSI) and the FEN integrated (keyword FEN_INTEGRE). These two sizes do not depend on the combination of situations, one thus returns only one value for all combinations of situations.

5.2.1 Criterion on the minimal deformation

During the calculation of $FEN_{comb}(p,q)$, if the sum of the increments of deformations due to the situations p and Q is lower than CRIT_EPSI then the effect of environment is not taken into account for this combination.

More precisely,

$$\text{si } \sum_k \Delta\epsilon_p(t_k)+\sum_k \Delta\epsilon_q(t_k)\leq\epsilon_{limite} \text{ alors } FEN_{comb}(p,q)=1 .$$

Lastly, to obtain the elementary factor of use with effect of environment, the elementary factor of use is multiplied $U^{elem}(p,q)$ (part 2.6.3) by the FEN of the combination of the situations p and Q:

$$U_{env}^{elem}(p,q)=U^{elem}(p,q).FEN_{comb}(p,q) .$$

The factor of total use with effect of environment U_{env}^{TOT} is calculated while taking into account $U_{env}^{elem}(p,q)$ instead of $U^{elem}(p,q)$ but without passing by again by the algorithm of the part 2.6.3.1.

5.2.2 Total FEN and Integrated FEN

A last checking is then made: one defines the total FEN such as:

$$FEN_{global}=\frac{U_{env}^{TOT}}{U^{TOT}}$$

If $FEN_{global}>FEN_{integre}$ then the factor of total use with effect of environment U_{env}^{TOT} is updated by dividing them by FEN_INTEGRE.

6 Type 'EVOLUTION'

6.1 Data of loading

'EVOLUTION' is well adapted to calculations on a component subjected to few situations of loading and not of earthquake. The user of the RCC-M must give the number of occurrences of each situation of operation (for example: heating of the boiler, hot stop, etc.). A situation of operation can be broken up into transients, i.e. evolutions of the total parameters of operation (pressure, temperature) according to time.
In C*ode_hasster*, one treats mechanical results (produced by MECA_STATIQUE or STAT_NON_LINE), therefore transients. For each transient, the stress fields are to be provided on the segment of analysis to the moments of discretization of calculation via tables created by call to POST_RELEVE_T or MACR_LIGN_COUPE.
Several types of results can be necessary for each transient: constraints for the thermomechanical loadings (TABL_RESU_MECA), forced for the thermal loading only (TABL_SIGM_THER), forced for the direct loading of compression (TABL_RESU_PRES) and forced for the singular zones (TABL_SIGM_THETA).

CE TYPE_RESU_MECA is concealmentui who leads to the most precise results. IL indeed requires to introduce any simplifying assumption neither on the definition of the loadings, nor on the calculation of the various criteria of level 0 or level A.
In addition, it allows to calculate the factor of starting on the level of a singular zone, within the meaning of appendix ZD of the RCC-M.

6.2 Calculations carried out with the option 'PM_PB'

The table of the constraints comprises either only one step of time, or a complete transient (*nb_inst* pas de time). In this last case, one will seek the maximum, compared to the list of the sequence numbers, different the terms intervening in the criteria.
It is to the user to know if one calculates Pm (general constraint of membrane: out of zones of geometrical singularity) or Pl (local constraint of membrane: in the singularities). From the statements of constraints provided, one thus calculates a membrane stress.
The algorithm is the following. Sur the whole of the sequence numbers $n=1,\mathrm{nb\_inst}$:

- extraction of the constraints at the moment t
- Sur each end of the segment:
    - calculation of $P_m(t)$, $P_b(t)$, $P_{mb}(t,s=0)$ and $P_{mb}(t,s=l)$ by integration on the segment

$$\sigma_{ij}^{moy}(t)=\frac{1}{l}\int_0^l \sigma_{ij}(t)ds \ , \quad P_m(t)=\|\sigma_{ij}^{moy}(t)\|$$

    - $$\sigma_{ij}^{fle}(t)=\frac{6}{l^2}\int_0^l \left(s-\frac{l}{2}\right)\sigma_{ij}(t)ds \ , \quad P_b(t)=\|\sigma_{ij}^{fle}(t)\|$$

$$P_{mb}(t,s=0)=\max_t \|\sigma_{ij}^{moy}(t)-\sigma_{ij}^{fle}(t)\|$$

    - $$P_{mb}(t,s=l)=\max_t \|\sigma_{ij}^{moy}(t)+\sigma_{ij}^{fle}(t)\|$$

- Research of the maximum of $P_m(t)$, $P_{mb}(t,s=0)$ and $P_{mb}(t,s=l)$
- Exit and storage in the table of the result.

Note:

The thermal stresses are of secondary type and do not have to thus be taken into account in the calculation of the criteria of level 0. In POST_RCCM , if TABL_RESU_MECA and TABL_SIGM_THER are present simultaneously, one supposes that the result TABL_RESU_MECA corresponds to the thermomechanical complete loading, and one thus cuts off the constraints to him of thermal origin.

6.3 Calculations carried out with the option `'SN'`

6.3.1 Sn calculation

One notes $\mathrm{nb\_inst}$ the number of moments selected in the transient considered.
The calculation algorithm of S_n is the following:

- on the whole of the sequence numbers, $n_1=1, \mathrm{nb\_inst}$
  - Extraction of the moment t_1
  - Calculation of $\sigma_{ij}^{lin}(t_1, s=0)$ and $\sigma_{ij}^{lin}(t_1, s=l)$
  - For n_2 varying n_1+1 *with* $\mathrm{nb\_inst}$
    - Extraction of the moment T_2
    - calculation of $\sigma_{ij}^{lin}(t_2, s=0)$ and $\sigma_{ij}^{lin}(t_2, s=l)$ and of
      $\sigma_{ij}^{lin}(t_2, s=0)-\sigma_{ij}^{lin}(t_1, s=0)$ and $\sigma_{ij}^{lin}(t_2, s=l)-\sigma_{ij}^{lin}(t_1, s=l)$
    - calculation of the principal directions and the criterion of Tresca:
      $\left(\sigma_{ij}^{lin}(t_2, s=0)-\sigma_{ij}^{lin}(t_1, s=0)\right)_{Eq.Tresca}$ and $\left(\sigma_{ij}^{lin}(t_2, s=l)-\sigma_{ij}^{lin}(t_1, s=l)\right)_{Eq.Tresca}$
    - research of the maximum thus of S_n at each end

- Exit and storage in the table of the result.

Note:

Quantity S_n calculated here corresponds to an amplitude. It is thus essential that all the states of the system are considered, including the states with worthless constraint (for example cold stop: pressure and moments applied worthless and room temperature).

6.3.2 Calculation of S_N*

This calculation is carried out if the operand `TABL_SIGM_THER` is present. Only the user ensures the coherence of the data, i.e. this result must be produced by a thermomechanical calculation under thermal loading only, knowing that the result given by `TABL_RESU_MECA` can be due to a combination of this thermal loading with other loadings. It is necessary thus in particular that the moments of the tables `TABL_RESU_MECA` and `TABL_SIGM_THER` correspond.

The algorithm is identical to the precedent but relates to two stress fields.

6.3.3 Calculation of the thermal ratchet

Calculation is carried out if the operands `TABL_SIGM_THER` and `TABL_RESU_PRES` are present. It is also necessary beforehand to have defined the conventional limit of elasticity for the maximum temperature reached during the cycle is by the operand `SY_MAX` of `POST_RCCM`; maybe by the operand `SY_02` keyword `RCCM` in `DEFI_MATERIAU` [U4.43.01]. If no elastic limit is defined, the calculation of the thermal ratchet is impossible.

In table result appear, for each end of each segment of analysis, the limit elastic `SY`, the amplitude of variation of the thermal constraint of origin `SP_THER`, the maximum of general membrane stress due to the pressure `SIGM_M_PRES` and two acceptable values maximum of the amplitude of variation of the thermal stress calculated either by supposing a variation of linear temperature in the wall (`VALE_MAXI_LINE`), that is to say by supposing a parabolic temperature variation in the wall (`VALE_MAXI_PARAB`).

6.4 Calculations with tiredness with the option `'FATIGUE_ZH210'`

The requirements relating to the calculation of the factor of use are defined in the §2.6.3.

Method ''EVOLUTION''corresponds to L' additional ZH210 of the RCC-M. It consists in "forgetting" the concept of situation and combining directly *states of loadings*, which is the significant moments of all the transients where the constraints pass by a local extremum. By default, in C*ode_hasster*, every moment of calculation is used. One associates with each one of them the number of occurrences $Nocc$ transient. The definition is thus:

State of loading = {urgent, tensor of constraints, many occurrences}.

Then, one builds the whole of all the states of loading by sweeping all the transients. At the end of the day, the concept of transient is forgotten: one does not work any more but on a set of states of loading. One calculates then the elementary factors of use associated with all the combinations taken two to two. One uses then a method of office plurality of the elementary factors of use, based on the assumption of the linear office plurality of the damage, to obtain the factor of total use.

The main advantage of this method is to consider all the possible under-cycles automatically: it is not necessary to identify the fictitious transients combining the situations between them. Its disadvantage is the number of calculations to be carried out if one does not restrict the whole of the moments used in calculation.

Note:

The algorithm describes here is similar to that of `POST_FATIGUE` . More precisely, the algorithm used in `POST_FATIGUE` is a restriction on the uniaxial case of method ZH210. Indeed, the data of the order `POST-FATIGUE` is a scalar function of time, whereas `POST_RCCM` draft of the tensors of constraints functions of time.

6.4.1 Calculation of the elementary factors of use

At each end of the segment, for any couple of states of loading k and l, the quantities are calculated $S_p(k,l)$ and $S_n(k,l)$ defined by:

$$S_p(k,l)=\left(\left(\sigma_{ij}(k)-\sigma_{ij}(l)\right)_{Eq.Tresca}\right) \qquad S_n(k,l)=\left(\left(\sigma_{ij}^{lin}(k)-\sigma_{ij}^{lin}(l)\right)_{Eq.Tresca}\right)$$

For the calculation of $S_{alt}(k,l)$, two formulas are proposed (cf. part 2.6.3.2) :

- original method (`KE_MECA`) who does not make distinction between the mechanical share and the thermal share :
- .
- method `KE_MIXTE` Introduite in the modifying 1997 of the RCC-M [1] which is based on a decomposition of S_{alt} between the mechanical share and the thermal share.

The curve of tiredness $N_{adm}=f(S_{alt})$ is a function defined by `DEFI_FONCTION`, and introduced into `DEFI_MATERIAU` by the keyword `WOHLER` keyword factor `TIREDNESS`. It makes it possible to calculate the acceptable number of cycles $N_{adm}(k,l)$ associated with $S_{alt}(k,l)$, then the elementary factor of use:

$$u(k,l)=1/N_{adm}(k,l) \; .$$

This calculation is carried out for each combination of two states of loading. One thus obtains (always for each end of the segment) a symmetrical matrix $u(k,l)$, of order the number of states of loading N_{tot} .

6.4.2 Calculation of the factor of total use

The calculation algorithm of the factor of total use, for each end of the line of cut, is the following:

1) $u^{tot}=0$
2) $u^{\max}=0$
3) Buckle $i=1 \ldots N_{tot}$ (research of the maximum in the table)
   If $Nocc(i)>0$:
      Buckle $j=i+1 \ldots N_{tot}$
         If $Nocc(j)>0$ and $u(i,j)>u^{\max}$:
         $u^{\max} = u(i,j)$, $m=i$, $n=j$
4) $Nocc(m,n)=\min(Nocc(m), Nocc(n))$
5) $u^{tot}=u^{tot}+Nocc(m,n)*u(m,n)$
6) Reactualization amongst occurrences:
   $Nocc(m)=Nocc(m)-Nocc(m,n)$
   $Nocc(n)=Nocc(n)-Nocc(m,n)$
7) Return to the beginning of the procedure until elimination of all the occurrences

Note:

• If the number of moments defined for each transient is large, the computing time can be prohibitory. It is thus necessary to be able to restrict it. It is what is made in `POST_FATIGUE` *, by a tri preliminary of the moments. One eliminates the moments such as the scalar function is linear to keep only the ends of the segments of right-hand side. One eliminates also the very small variations. Here, in multiaxial situation, the sorting is more delicate. The concept of constraints proportional could be used, but in practice the user can define itself the list of the moments (keyword* `NUME_ORDRE` *).*

• By this method, one is sure not to forget no under-cycle. On the other hand, it is desirable to eliminate the moments which do not correspond to local extrema, because they could generate factitious under-cycles, increasing the factor of use (these moments are only used for the digital discretization of the mechanical or thermal problem).

•With the option `'FATIGUE_ZH210'` *, the combinations of transients are taken into account in the calculation of* S_n *and of* S_n^* *.*

Example

This paragraph aims at illustrating the calculation algorithm of the factor of use on a simple example, drawn from the case test of elementary validation rccm01a [V1.01.107]. It is supposed that there are three situations of two steps of time each one, the number of occurrences being respectively of 1.5 and 10.
The matrix of the factors of use as calculated by the first part of the algorithm is given below. To reduce the presentation, except the upper part of the symmetrical matrix is written.

	J	*1*	*2*	*3*	*4*	*5*	*6*
I	**Nocc**	**1**	**1**	**5**	**5**	**10**	**10**
1	**1**	0	1.10^{-4}	0	$\mathbf{3.10^{-4}}$	2.10^{-4}	1.10^{-4}
2	**1**		0	1.10^{4}	2.10^{-4}	1.10^{4}	0
3	**5**			0	3.10^{-4}	2.10^{-4}	1.10^{-4}
4	**5**				0	1.10^{-4}	2.10^{-4}
5	**10**					0	1.10^{-4}
6	**10**						0

Table 6.4.2-1 : Initial matrix of the factors of use

The combination more penalizing is $(i=1, j=4)$, of which the number of occurrences is 1:
$FA^{tot}=0+1*3.10^{-4}$

The numbers of occurrences are updated: $Nocc(1)=0$, $Nocc(4)=4$. The matrix of the factors of use is put up to date; if the line i or the column j a number of occurrences no one has, it is put at zero.

	J	*1*	*2*	*3*	*4*	*5*	*6*
I	**Nocc**	**0**	**1**	**5**	**4**	**10**	**10**
1	**0**						
2	**1**		0	1.10^{-4}	2.10^{-4}	1.10^{-4}	0
3	**5**			0	**3.10^{-4}**	2.10^{-4}	1.10^{-4}
4	**4**				0	1.10^{-4}	2.10^{-4}
5	**10**					0	1.10^{-4}
6	**10**						0

Table 6.4.2-2 : Matrix of the factors of use – iteration 1 of calculation

Calculation continues same manner: the combination more penalizing is now $\{i=3, j=4\}$, of which the number of occurrences is 4:

$$FA^{tot}=1*3.10^{-4}+4*3.10^{-4}$$

The penalizing combinations are then successively $\{i=3, j=5\}$ of many occurrences 1; $\{i=5, j=6\}$ of many occurrences 9.

The factor of total use is then:

$$FA^{tot}=1*3.10^{-4}+4*3.10^{-4}+1*2.10^{-4}+9*1.10^{-4} = 2{,}6.10^{-3}$$

6.5 Calculations of the factor of starting with the option `'STARTING'`

6.5.1 Principle of Calcul of the factor of starting

Zones of local discontinuities whose contour present of the abrupt variations are the seat of acute stress concentrations. In this case, definite concept of factor of use previously is not adapted any more and it should be replaced by the concept of factor of starting (B3234.7).
The factor of starting is calculated starting from the amplitude of variation of the constraint in the structure at a distance d singularity, and of a law of starting. The procedure of analysis is defined in appendix ZD2200. The distance d and the laws of starting are characteristics material and are tabulées in table ZD2300.

The law of starting defined in the RCC-M is form:

$$\Delta\sigma_{\theta\theta}(d)=\mathrm{A\_AMORC}.(N_a)^{\mathrm{B\_AMORC}}$$

with N_a the number of acceptable cycles and $\Delta\sigma_{\theta\theta}$ the amplitude of variation of the tangential constraints, in the local reference mark, at the distance d singularity.

The law of starting developed in the operator `POST_RCCM` takes into account the report of load R loading, as recommended in RSE-M (ref. 15):

$$\Delta\sigma_{eff}(d)=\mathrm{A\_AMORC}.(N_a)^{\mathrm{B\_AMORC}}$$

with the following relation between amplitude of real variation of the constraints $\Delta\sigma_{\theta\theta}$ and effective $\Delta\sigma_{eff}$:

$$\Delta\sigma_{eff}=\frac{\Delta\sigma_{\theta\theta}}{1-R/_{\mathrm{R\_AMORC}}}\,.$$

Note:

To use a law of starting such as defined in the RCC-M, that is to say without taking into account of the report of load, it is enough to define a R_AMORC large (1000 for example).

6.5.2 Calculation in Code_hasster

Parameters of the law of starting (A_AMORC, B_AMORC, R_AMORC) and distance it to the singularity D_AMORC are to be defined under the keyword factor RCCM of DEFI_MATERIAU.

The expected table as starter, under the keyword TABL_SIGM_THETA, corresponds to the statement of the constraints on one **circular line of cut** (of ray D_AMORC) around the singularity. The constraints must be expressed in **local reference mark**.

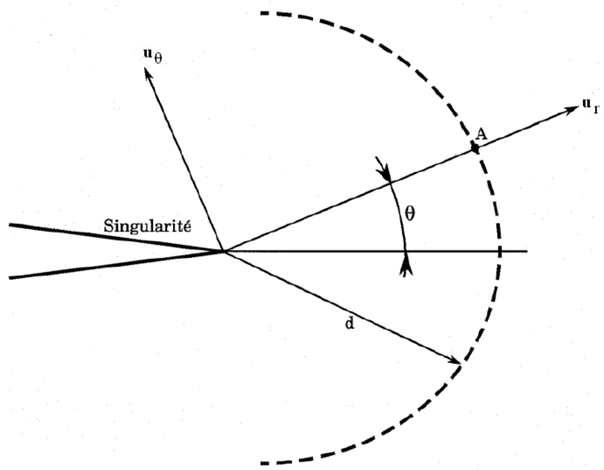

Figure 6.5.2-a : definition of the local reference mark

Such a table can be created using the order MACR_LIGN_COUPE. As in the fatigue analysis (cf §6.4), it is considered that every provided moment corresponds to extrema of the transient. In addition, the concept of transient is forgotten and one does not work any more but on a set of states of loading. One notes $N_{occ}(i)$ the number of occurrences associated with the state with loading i and N_{tot} the full number of states of loading.

The calculation algorithm is then the following:

Buckle on the points of the line of cut

- Checking which the point is at the distance *D* singularity
- Buckle $i=1 \ldots N_{tot}$

  Extraction of $\sigma_{\theta\theta}(i)$

  Buckle $j=i+1 \ldots N_{tot}$

    Extraction of $\sigma_{\theta\theta}(j)$

    Calculation of $\Delta\sigma_{\theta\theta}(i,j)=|\sigma_{\theta\theta}(j)-\sigma_{\theta\theta}(i)|$

    Calculation of $R(i,j)=\min(\sigma_{\theta\theta}(i),\sigma_{\theta\theta}(j)) / \max(\sigma_{\theta\theta}(i),\sigma_{\theta\theta}(j))$

    Calculation of $\Delta\sigma_{eff}(i,j)=\dfrac{\Delta\sigma_{\theta\theta}(i,j)}{1-R(i,j)/\mathrm{R\_AMORC}}$

Calculation amongst acceptable cycles and of the factor of starting elementary

$$N_a(i,j)=\left(\Delta\sigma_{eff}(i,j)\Big/\mathrm{A\_AMORC}\right)^{1/\mathrm{B\_AMORC}}$$

$$FA(i,j)=1\Big/N_a(i,j)$$

At the end of this first part, there is thus a matrix of the factors of starting of the whole of the combinations of states of loading. The size of the matrix is $N_{tot}\times N_{tot}$ but only the part above the diagonal is indicated.

The calculation algorithm of the factor of total starting, for a point given on the line of cut, is then the following:

1. $FA^{max}=0$
2. $FA^{tot}=0$
3. Buckle $i=1\ldots N_{tot}$ (research of the maximum in the table)
   If $Nocc(i)>0$:
   Buckle $j=i+1\ldots N_{tot}$
   If $Nocc(j)>0$ and $FA(i,j)>FA^{max}$:
   $FA^{max}=FA(i,j)\ ,\ m=i\ ,\ n=j$
4. $Nocc(m,n)=\min\left(Nocc(m),Nocc(n)\right)$
5. $FA^{tot}=FA^{tot}+Nocc(m,n)*FA(m,n)$
6. Reactualization amongst occurrences:
   $Nocc(m)=Nocc(m)-Nocc(m,n)$
   $Nocc(n)=Nocc(n)-Nocc(m,n)$
7. Return to the beginning of the procedure until elimination of all the occurrences

At the end of this algorithm, one thus has the factor of starting for each point (i.e for each angle) of the line of cut.

7 Type `'B3600'`

In code_aster, it is possible to evaluate criteria of level A (tiredness) according to the B3600 chapter of the RCC-M. IL is of use in B3600 to define each situation as the passage of a state stabilized A (correspondent with a pressure interns given in the line of piping, a given uniform temperature, and fixed mechanical loadings) in a state stabilized B (with constant loadings different from the precedents). One associates with this situation a thermal transient. Requests of thermal origin can also be taken into account in calculation.

The treatment which is described here is carried out for each node of each mesh of the line of piping considered. The got result will be thus a factor of use (total or partial) for each node of each mesh required by the user.

7.1 Preliminary calculation of all the states of loading

For each node of each mesh, the present stage consists in calculating, for all the situations, the moments relative in each stabilized state (by cumulating the various loadings which intervene).

7.1.1 Calculations of the static states of loading

One treats the results of static calculations (field `EFGE_ELNO` or `SIEF_ELNO`) for the stabilized states of the list of the situations undergone by the line.

A stabilized state can be defined by a list of loading case, each load being signed. In this case, the torques of the stabilized state are obtained by algebraic summation of the torques of each loading case:

$$M_i = M_{i_{CHAR}1} + M_{i_{CHAR}2} \quad +\ldots \quad \mathrm{i} \in \{\mathrm{x; y; z}\}$$

The loadings are for example opposed thermal dilation, the displacement of anchoring.

7.1.2 Calculation of the seismic loadings

The seismic loading breaks up into two parts:
• An inertial part

It is calculated by imposing on the whole of anchorings the same movement characterized by the spectrum envelope of the various spectra of floor, in the horizontal directions X and Y on the one hand, and vertical Z in addition (in the total reference mark). With this intention, the order is used `COMB_SISM_MODAL`, which produces generalized efforts which correspond to each direction of earthquake as well as the quadratic office plurality of these efforts.

The contribution inertial of the earthquake to the component i moment is written:

$$M_{i\_S\_DYN} = \sqrt{\sum_j \left(M_{i\_S\_DYN}\left(spectre_j\right)\right)^2} \qquad (\mathrm{i,j}) \in \{\{x\,;y\,;z\};\{X\,;Y\,;Z\}\}$$

with $M_{i\_S\_DYN}$ (spectrum$_J$) moment in the direction *I* resulting from the dynamic loading in the direction *J*. This office plurality is made directly by `COMB_SISM_MODAL`.

• A quasi-static part

It is estimated by imposing static differential displacements corresponding to maximum of the differences of the seismic movements of the points of anchoring in the course of time. Calculations are thus carried out for each unit loading (a calculation by displacement in a direction given for an end of the line).
One notes N_{ANC} the number of points of anchoring of the structure. The quasi-static contribution of differential displacements of anchoring to the component *I* moment is written:

$$M_{i\_S\_ANC}=\sqrt{\sum_{k=1}^{N\_ANC}(M_{i\_S\_ANC}{}^{k})^2}$$

with $M_{i\_S\_ANC^k}$ $i^{ème}$ component of the moment corresponding to $k^{ème}$ displacement of anchoring.

7.1.2.1. Combination of the inertial components and differentials due to the earthquake

$i^{ème}$ resulting component is obtained by quadratic average of $i^{ème}$ inertial components and differentials:

$$M_{i\_S}=\sqrt{\left(M_{i\_S\_ANC}\right)^2+\left(M_{i\_S\_DYN}\right)^2}\quad i\in\{x\,;y\,;z\}$$

what returns in fact to carry out it average quadratic of every inertial and differential moment,

$$M_{i\_S}=\sqrt{\sum_{k=1,N\_ANC}\left(M^k_{i\_S\_ANC}\right)^2+\left(M_{i\_S\_DYN}\right)^2}\quad i\in\{x\,;y\,;z\}$$

For the user, the situation of earthquake is defined by the list of the results corresponding to the inertial answer and the answers to the displacement of N_{ANC} successive points of anchoring. The recombination by quadratic average is made directly by the operator `POST_RCCM`.

7.1.3 Calculation of the thermal transients

The loadings of type "heat gradient in the thickness" are broken up into three parts, cf. Figure 7.1.3-a :

- a constant value which is the median value of the temperature:

$$T_{moy}=\frac{1}{t}\int_{-t/2}^{t/2}T(y).dy$$, where t corresponds to the nominal thickness of the wall.

- a linear distribution of worthless average (moment of order 1):

$$V=\frac{12}{t^2}\int_{-t/2}^{t/2}y.T(y).dy$$

- a nonlinear distribution of worthless average and null moment compared to average fibre.

For each one of the transients and each section of piping of the line (and each junction), one thus realizes as a preliminary, according to the geometrical complexity of the problem studied a thermal calculation 2D or 3D.

Each calculation is then stripped in order to extract, for each moment of the transient, the temperature on the selected section and the median values (moments of order 0 and 1). This operation can be made for example using two calls to `POST_RELEVE_T` (`OPERATION = 'EXTRACTION'` and `OPERATION = 'AVERAGE'`).

In the case of a discontinuity of material or a junction, one calculates the average temperature (noted T_a and T_b) on the two sides of the junction. In practice, zones a and b will correspond to segments chosen by the user in `POST_RELEVE_T`, and the produced tables will be associated with the two adjacent meshs having jointly the node which corresponds to the junction.

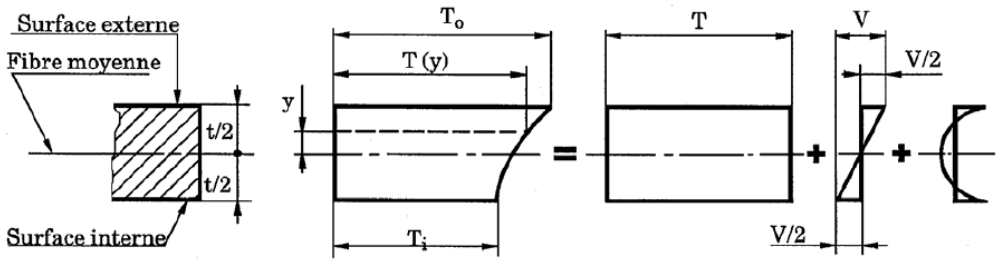

Figure 7.1.3-a : Decomposition of the distribution of temperature in the thickness of the wall (figure extracted the RCC-M, §B3653.4)

7.2 Calculations of the amplitudes of variation of the constraints

7.2.1 Principle of the method

The amplitudes of variation of the constraints are defined in the B3653 paragraph of the RCC-M for combinations between two moments or two states of loadings. While noting t_i and t_j these two moments, one has in a schematic way for the amplitude of variation of a quantity S :

$$S(t_i, t_j)=S^{\text{mécanique}}(t_i)-S^{\text{mécanique}}(t_j)+S^{\text{thermique}}(t_i)-S^{\text{thermique}}(t_j)$$

In the method as developed in C*ode_hasster*, the situations are defined in a way simplified by two stabilized states and a thermal transient: it is then not possible to work directly on each moment of the situations and of the assumptions must be introduced.

The whole of the combinations is thus considered (i, j) with $(i, j)\in(1,2,..,N,1,2,..,N)$, N being the number of states stabilized except earthquake (i.e. 2 times the number of situations of the group). Are two stabilized states, i and j, belonging respectively to the situations p and q. The amplitude of variation S will then be calculated in the following way:

$$S(i, j)=S^{\text{mécanique}}(i)-S^{\text{mécanique}}(j)+\max\left(\Delta S^{\text{thermique}}(p), \Delta S^{\text{thermique}}(q)\right)$$

while noting $\Delta S^{\text{thermique}}(p)$ the amplitude of variation of the thermal stress of the transient p.

Note:

[1] *It is important to note that the amplitude of variation of the constraints is done by maximizing the amplitude of the thermal stresses for each thermal transient independently one of the other. Method of calculating for the case* `'B3600'` *is thus different from that adopted for the case* `'B3200_UNIT'`*.*

[2] *As indicated in the B3653.2 paragraph, all the states of the system must be considered, including the states with worthless constraint (for example cold stop: pressure and moments applied worthless and ambient temperature) .*

7.2.2 Calculation of the combinations of loading inside each group

The objective is to build, for each group of situation, a symmetrical square matrix containing the whole of the amplitudes of variation of the alternate constraint $S'_{alt}(i,j)$, with i and j two stabilized states respectively associated with the situations p and q . This calculation requires the preliminary calculation of the quantities S_p (amplitude of the total constraint) and S_n (amplitude of the linearized constraint).

7.2.2.1. Notations and definitions

One notes:

C_1 , C_2 , C_3 , K_1 , K_2 , K_3	= Indices of constraints provided to the §B3680 of the RCC-M
E	= Modulus of elasticity of piping to room temperature
ν	= Poisson's ratio
α	= Dilation coefficient of piping to room temperature
E_{ab}	= Average modulus of elasticity enters the two zones separated by a discontinuity to the room temperature
D_0	= Diameter external of piping
t	= Nominal thickness of the wall
I	= Moment of inertia of piping: $I=\frac{\pi}{64}\left(D_0^2-\left(D_0^2-2\mathrm{t}\right)^2\right)$
$M_i(i,j)$	= Variation of moment resulting from the various loadings of the situations to which belong the stabilized states i and j : $M_i(i,j)=\sqrt{\left(M_X(i)-M_X(i)\right)^2+\left(M_Y(i)-M_Y(i)\right)^2+\left(M_Z(i)-M_Z(i)\right)^2}$
$P_0(i,j)$	= Difference in pressure between the states i and j
$T_a(t_k,t_l)$, $T_b(t_k,t_l)$	= Amplitude of variation of the average temperatures in the zones a and b between the moments t_k and t_l
$T_o(t_k,t_l)$, $T_i(t_k,t_l)$	= Amplitude of variation of the temperatures on the level of the external wall/intern enters the moments t_k and t_l
$\Delta T_1(t_k,t_l)$	= Amplitude of the variation enters the two moments of the difference in temperature between the walls internal and external, for an equivalent linear distribution of the temperature: $\Delta T_1(t_k,t_l)=\frac{12}{t^2}\int_{-t/2}^{t/2} y.T(t_k,t_l)(y).dy = V(t_k)-V(t_l)$
$\Delta T_2(t_k,t_l)$	= Nonlinear part of the distribution in the thickness of wall of the amplitude of variation in the temperature enters the moments t_k and t_l : $\Delta T_2(t_k,t_l)=\max\begin{vmatrix}\lvert T_o(t_k,t_l)-T_{moy}(t_k,t_l)\rvert-\lvert 1/2\,\Delta T_1(t_k,t_l)\rvert\\ \lvert T_i(t_k,t_l)-T_{moy}(t_k,t_l)\rvert-\lvert 1/2\,\Delta T_1(t_k,t_l)\rvert\\ 0\end{vmatrix}$

7.2.2.2. Calculation of Sp

The amplitude of variation of the total constraints S_p for pipings is defined in equation 11 of the §B3653 of the RCC-M. One calculates:

$$S_p(i,j,t_p)=K_1.C_1.\frac{|P_0(i,j)|.D_0}{2.t}+K_2.C_2.\frac{D_0}{2.I}.M_i(i,j)+\frac{1}{2.(1-\nu)}.K_3.E.\alpha.|\Delta T_1(t_k^p,t_l^p)|$$
$$+K_3.C_3.E_{ab}.|\alpha_a.T_a(t_k^p,t_l^p)-\alpha_b.T_b(t_k^p,t_l^p)|+\frac{1}{1-\nu}.E.\alpha.|\Delta T_2(t_k^p,t_l^p)|$$

(t_k^p,t_l^p) two unspecified moments of the transient associated with the situation indicate p. In the event of discontinuity of matter or a junction, terms ΔT_1 and ΔT_2 to retain are those associated with the section more penalizing.

One calculates in the same way $S_p(i,j,t_q)$ with the thermal transient associated with the situation q. The amplitude S_p for the combination (i,j) is then:

$$S_p(i,j)=\max\left\{\max_{(t_k^q,t_l^q)}\left(S_p(i,j,t_p)\right),\max_{(t_k^q,t_l^q)}\left(S_p(i,j,t_q)\right)\right\}$$

7.2.2.3. Calculation of Sn

The amplitude of variation of the linearized constraints S_n for pipings is defined in equation 10 of the §B3653 of the RCC-M. One calculates:

$$S_n(i,j,t_p)=C_1.\frac{|P_0(i,j)|.D_0}{2.t}+C_2.\frac{D_0}{2.I}.M_i(i,j)+\frac{1}{2.(1-\nu)}.E.\alpha.|\Delta T_1(t_k^p,t_l^p)|$$
$$+C_3.E_{ab}.|\alpha_a.T_a(t_k^p,t_l^p)-\alpha_b.T_b(t_k^p,t_l^p)|$$

$$S_n(i,j,t_q)=C_1.\frac{|P_0(i,j)|.D_0}{2.t}+C_2.\frac{D_0}{2.I}.M_i(i,j)+\frac{1}{2.(1-\nu)}.E.\alpha.|\Delta T_1(t_k^q,t_l^q)|$$
$$+C_3.E_{ab}.|\alpha_a.T_a(t_k^q,t_l^q)-\alpha_b.T_b(t_k^q,t_l^q)|$$

$$S_n(i,j)=\max\left\{\max_{(t_k^q,t_l^q)}\left(S_n(i,j,t_p)\right),\max_{(t_k^q,t_l^q)}\left(S_n(i,j,t_q)\right)\right\}$$

One calculates then $S_n(p,q)=\max_{i,j} S_n(i,j)$, for i and j sweeping the whole of the stabilized states of the two situations p and q (4 possible combinations).

7.2.2.4. Calculation of Salt

Two formulas are proposed to define the amplitude of variation $S'_{alt}(i,j)$ between the states i and j

- KE_MECA : it is the original method, only available in the previous versions to version 7.2:

$$S'_{alt}(i,j)=\frac{1}{2}.\frac{E_c}{E}.K_e\left(S_n(p,q)\right).S_p(i,j)$$

with:

- E_c : Young modulus of reference for the construction of the curve of Wöhler, provided by the user in DEFI_MATERIAU, under the keyword E_REFE, keyword factor TIREDNESS.
- E : Smaller of the Young moduli used for the calculation of the states i and j, i.e. evaluated at the temperatures of these stabilized states.

$$K_e(S_n(p,q)) = \begin{cases} 1 & \text{si } S_n(p,q) \le 3.S_m \\ 1 + \dfrac{1-n}{n.(m-1)}.\left(\dfrac{S_n(p,q)}{3.S_m} - 1\right) & \text{si } 3.S_m < S_n(p,q) < 3.m.S_m \\ \dfrac{1}{n} & \text{si } S_n(p,q) \ge 3.m.S_m \end{cases}$$

with m and n depending on material, and provided by the user in DEFI_MATERIAU, under the keywords M_KE and N_KE, keyword factor RCCM. If keywords TEMP_REF_A and TEMP_REF_B are present, S_n is interpolated for this temperature (which must correspond to the average temperature of the transient). If not, S_n is taken with room temperature.

- KE_MIXTE : since the modifying 1997 of the RCC-M, one can choose another formula, based on a decomposition of S_{alt} :

$$S'_{alt}(i,j) = \frac{1}{2}.\frac{E_c}{E}.\left(K_e^{meca}(S_n(p,q)).S_p^{meca}(i,j) + K_e^{ther}(S_n(p,q)).S_p^{ther}(i,j)\right)$$

with:

- $K_e^{meca}(S_n(p,q))$ is equal to K_e defined above
- $K_e^{ther}(S_n(p,q)) = \max \left| \begin{array}{l} 1,86\left(1 - \dfrac{1}{1,66 + \dfrac{S_n}{S_m}}\right) \\ 1 \end{array} \right.$

- $S_p^{meca}(i,j)$ represent the amplitude of variation on mechanical behalf of the quantity S_p, between the states i and j. It is calculated on the basis of request of mechanical origin: pressure, actual weight, earthquake (inertial and displacements of anchoring), thermal expansion.

- $S_p^{ther}(i,j)$ the amplitude of variation on thermal behalf of the quantity S_p, between the states i and j (terms dependent on T_a, T_b, ΔT_1 and ΔT_2 in the definition of the §7.2.2.2).

Case of the under-cycles

The under-cycles correspond either to the taking into account of the under-cycles related to the earthquake, or with situations for which the keyword COMBINABLE=' NON' was well informed. In both case, one calculates the amplitude of constraints while utilizing only the constraints related to these under-cycles (not of combination of states of loading apart from this situation). For the calculation of S'_{alt}, the factor should be used K_e who corresponds to the principal situation from which the under-cycle is resulting.

7.2.3 Calculation of the combinations of loading for the situations of passage

Two states of loading are combinable only if they belong to the same situation or if there exists a situation of passage between the groups to which they belong. In this last case, one will associate with the combination (i,j) the number of occurrences of the situation of passage. If the situation of passage belongs to the one of the two groups (what is not excluded a priori), it is naturally combined with the other situations of this group, then is used for the combination of the situations of its group with the situations of the group in relation.

For each situation of passage of a group with another, one thus considers the whole of the combinations (i, j) with i belonging to the first group (of dimension N) and j belonging to the second group (of dimension M). For each combination, $S'_{alt}(i, j)$ the same one is obtained way that previously and one associates to him the number of occurrences of the situation of passage. One builds a matrix (rectangular) containing all them $S'_{alt}(i, j)$.

7.3 Calculation of the factor of use

One notes:

- n_k : number of cycles associated with the situation p which belongs the stabilized state k ;
- n_l : number of cycles associated with the situation q which belongs the stabilized state l ;
- N_s : many occurrences of the earthquake;
- n_s : many under-cycles associated with each occurrence with the earthquake;
- n_{pass} : many cycles associated with a possible situation with passage enter p and q if these situations do not belong to the same group, but if there exists a situation of passage between the two.

For the whole of the combinations of states of loading (inside a group of situations or associated with a situation of passage):

If $N_s>0$, they are selected $N_s/2$ combinations of stabilized states k and l more penalizing, i.e. them $N_s/2$ combinations (k, l) leading to the greatest values of $S'_{alt}(k, l)$.

For each one of these $N_s/2$ combinations:

•*A) Superposition of the moments of seismic origin and the combination (k, l) :*

- One superimposes the loadings of earthquake to the variation of moment resulting from the various loadings of the stabilized states k and l :

$$M_i=\sqrt{\left(|M_1(k)-M_1(l)|+\Delta M_{S1}\right)^2+\left(|M_2(k)-M_2(l)|+\Delta M_{S2}\right)^2+\left(|M_3(k)-M_3(l)|+\Delta M_{S3}\right)^2}$$

with:

$M_x(k)$ and $M_x(l)$: components in the direction x ($x\in[1;2;3]$) moments associated with the states k and l ;

ΔM_{Sx} : total amplitude of variation in the direction x moments due to the earthquake ($\Delta M_{Sx}=2\mathrm{M}_{x_s}$ where M_{x_s} is the total resulting moment (inertia and displacements of anchoring) such as defined in the §7.1.2).

- One calculates then S_p and S_n such as previously definite with the new value of M_i (noted respectively S_{p_s} and S_{n_s}) and one calculates:

$$S'_{alt_s}(k, l)=\frac{1}{2}.\frac{E_c}{E}.K_e\left(S_{n_s}(m, n)\right).S_{p_s}(k, l)$$

- One calculates the number of acceptable cycles $N(k, l)$ for the amplitude of constraint $S'_{alt_s}(k, l)$ using the curve of Wöhler associated with material.
- One calculates finally $u_1(k, l)=\dfrac{1}{N(k, l)}$

•*B) Taking into account of* $2n_s-1$ *seismic cycles considered as under-cycles:*

- Amplitude of variation of the seismic constraint only:

$$S'_{alt_{sc}}(k,l)=\frac{E_c}{E}K_e\left(S_{n_s}(k,l)\right).K_2.C_2\frac{D_0}{4.I}\sqrt{\Delta M_{S1}{}^2+\Delta M_{S2}{}^2+\Delta M_{S3}{}^2}$$

- One calculates the number of acceptable cycles $N_{SC}(k,l)$ for the amplitude of constraint $S'_{alt_{sc}}(k,l)$. It should be noted that the value is used $K_e\left(S_{n_s}(k,l)\right)$ previously calculated for the principal cycle.
- One calculates finally $u_2(k,l)=\frac{(2n_s-1)}{N_{SC}(k,l)}$

•*C) Office plurality*

- $u(k,l)=u_1(k,l)+u_2(k,l)$

One starts again this calculation until exhaustion of $N_s/2$ combinations more penalizing.

The calculation of the factor of use is then continued **without taking into account the earthquake**.

If $N_s=0$ **, or after having taken into account the earthquake for** $N_s/2$ **the most unfavourable combinations:**

•The combination is selected (k,l) leading to the maximum value of $S'_{alt}(k,l)$, on the whole of the combinations, such as the number of occurrences n_0 that is to say not no one, with:

$n_0=\min\{n_k,n_l,n_{\text{pass}}\}$ if n_{pass} is nonnull

$n_0=\min\{n_k,n_l\}$ if n_{pass} is null

•One calculates the number of acceptable cycles $N(k,l)$ for the amplitude of constraint $S'_{alt}(k,l)$, using the curve of Wöhler associated with material.

•One calculates then the elementary factor of use: $u(k,l)=\frac{n_0}{N(k,l)}$.

•One replaces finally:
n_k by (n_k-n_0)
n_l by (n_l-n_0)
if it is about a situation of passage, n_{pass} by $(n_{pass}-n_0)$

then:

if $n_k=0$, the column and the line corresponding at the stabilized state k matrix $S'_{alt}(i,j)$ are put at 0.
if $n_l=0$, the column and the line corresponding at the stabilized state l matrix $S'_{alt}(i,j)$ are put at 0.

The loop is repeated until exhaustion amongst cycles.

Note:

Appendix ZI of code RCC-M defines the curves of Wöhler until an amplitude of constraint *minimum corresponding to one lifetime of 10^6 cycles. If the value S'_{alt} calculated for a combination (i, j) of stabilized state is lower than this amplitude minimum, the factor of use is equal to 0 for the combination (I, J) considered. This implicitly amounts considering the existence of a limit of endurance to 10 ^6 cycles.*

8 AnnexE 1: B3200 equations for situations in unit form

Each stabilized mechanical state is described starting from a pressure P and of a torque of effort $\{F_X, F_Y, F_Z, M_X, M_Y, M_Z\}$ defined under the keyword 'CHAR_MECA'. The tensors of the constraints are reconstituted by linear combination starting from the tensors of the constraints associated with each unit loading. For example, ON notes $\underline{\sigma}^{F_X}$ the tensor of the constraints associated with the unit loading in effort according to direction X. The calculation of the tensor of the constraints corresponding to a mechanical loading pertaining in a stabilized state is then obtained in the following way:

$$\underline{\sigma}=F_X.\underline{\sigma}^{F_X}+F_Y.\underline{\sigma}^{F_Y}+F_Z.\underline{\sigma}^{F_Z}+M_X.\underline{\sigma}^{M_X}+M_Y.\underline{\sigma}^{M_Y}+M_Z.\underline{\sigma}^{M_Z}+P.\underline{\sigma}^{P}$$

The use of this option requires the preliminary calculation of the stress fields for the 7 loadings unit and of the stress fields for each thermal transient; Lbe fields unit are to be provided on the segment of analysis via tables under the keyword 'RESU_MECA_UNIT'.

Note:

- *For prickings, it is also possible to define two tensors of efforts respectively associated with the body and the pipe. The torque of effort passes from 6 to 12 components and one passes from 7 to 13 unit loadings. Appendix 5 summarizes the equations in this case.*

8.1 Calculations carried out with the option 'PM_PB'

For the moment, this option is available if the data ofS situations are in unit form only, not in instantaneous form.

Being given the primary constraint of the situation of reference (1era category) and a segment located out of a zone of major discontinuity. In each point end of this segment length *L*, one calculates for a situation :

$$P_m=\max_t \|\sigma_{ij}^{moy}\|_{TRESCA} \quad \text{avec} \quad \sigma_{ij}^{moy}=\frac{1}{l}\int_0^l \sigma_{ij}\,ds \quad \text{et} \quad \|\tau_{ij}\|_{TRESCA}=\max_{I,J} |\tau_I-\tau_J|$$

$$\left(\tau_{I\ \ I=1,3} \text{ étant les contraintes principales}\right)$$

$$P_b=\max_t \|\sigma_{ij}^{fle}\|_{TRESCA} \quad \text{avec} \quad \sigma_{ij}^{fle}=\frac{6}{l^2}\int_0^l \left(s-\frac{l}{2}\right)\sigma_{ij}\,ds$$

$$P_{mb}=\max_t \|\sigma_{ij}^{lin}\|_{TRESCA} \quad \text{avec} \quad \begin{array}{l}\sigma_{ij}^{lin}(s=0)=\sigma_{ij}^{moy}-\sigma_{ij}^{fle}\\ \sigma_{ij}^{lin}(s=l)=\sigma_{ij}^{moy}+\sigma_{ij}^{fle}\end{array}$$

While noting A and B two stabilized mechanical states situation, one a:

$$P_m=\max\left\{\|\sigma_{ij}^{moy}\|^A, \|\sigma_{ij}^{moy}\|^B\right\} \quad \text{and} \quad P_b=\max\left\{\|\sigma_{ij}^{fle}\|^A, \|\sigma_{ij}^{fle}\|^B\right\}$$

$$P_{mb}=\max\left\{\|\sigma_{ij}^{lin}\|^A, \|\sigma_{ij}^{lin}\|^B\right\}.$$

8.2 Calculations carried out with the option `'SN'`

8.2.1 Sn calculation

The points of calculation are the two ends of the segment. For a given situation, EN each point end of this segment length l , one calculates S_n according to the B3232.6 paragraph:

$$S_n = \max_{t_1, t_2} \|\sigma_{ij}^{lin}(t_1) - \sigma_{ij}^{lin}(t_2)\|_{TRESCA} \qquad \text{avec} \qquad \sigma_{ij}^{lin}(s=0) = \sigma_{ij}^{moy} - \sigma_{ij}^{fle}$$

$$\sigma_{ij}^{lin}(s=l) = \sigma_{ij}^{moy} + \sigma_{ij}^{fle}$$

One notes σ_A and σ_B mechanical constraints associated with the two stabilized states of the situation and $\sigma_{ther}(t)$ transient thermics associated with this situation. One has then,

$$\sigma_A^{lin} - \sigma_B^{lin} = (F_{XA} - F_{XB})\sigma^{FX} + (F_{YA} - F_{YB})\sigma^{FY} + ... + (M_{ZA} - M_{ZB})\sigma^{MZ} + (P_A - P_B)\sigma^P$$

According to the method of selected selection of the moments (see 3.3.1), the amplitude Sn is obtained.

With `'METHOD' = 'TRESCA'`, t^{maxSn} and t^{minSn} being extreme moments of this transient such as definite with 3.3.1.IE parameter S_n for the situation is defined by :

$$S_n = \max\left(\|\sigma_A^{lin} - \sigma_B^{lin} + \sigma_{tran}^{lin}(t^{\text{maxSn}}) - \sigma_{tran}^{lin}(t^{\text{minSn}})\|, \|\sigma_B^{lin} - \sigma_A^{lin} + \sigma_{tran}^{lin}(t^{\text{maxSn}}) - \sigma_{tran}^{lin}(t^{\text{minSn}})\|\right) .$$

With `'METHOD' = 'TOUT_INST'`, LE parameter S_n for the situation is defined by :

$$S_n = \max(S_{n1}, S_{n2}) ,$$

with $S_{n1} = \max_{t_1, t_2} \|\sigma_A^{lin} - \sigma_B^{lin} + \sigma_{ther}^{lin}(t_1) - \sigma_{ther}^{lin}(t_2)\|$

and $S_{n2} = \max_{t_1, t_2} \|\sigma_B^{lin} - \sigma_A^{lin} + \sigma_{ther}^{lin}(t_1) - \sigma_{ther}^{lin}(t_2)\|$.

8.2.2 Calculation of Sn*

One notes S_n^* the amplitude S_n calculated without taking into account stresses bending of origin thermal.

If a thermal transient is defined (i.e the keyword `NUME_RESU_THER` is well informed), the calculation of S_n^* for one situation is done in a way similar to that of S_n :

$$S_n^* = \max\left(\|\sigma_A^{lin} - \sigma_B^{lin} + \sigma_{ther}^{moy}(t^{\text{maxSn}}) - \sigma_{ther}^{moy}(t^{\text{minSn}})\|, \|\sigma_B^{lin} - \sigma_A^{lin} + \sigma_{ther}^{moy}(t^{\text{maxSn}}) - \sigma_{ther}^{moy}(t^{\text{minSn}})\|\right)$$

8.2.3 Ratchet thermics

See part 3.3.4.

8.3 Calculations carried out with the option `'TIREDNESS'`

8.3.1 Sn calculation

One notes σ_p (respectively σ_q) associated mechanical constraints with one stabilized state of the situation p (respectively of the situation Q).

One notes $\sigma_{tran,p}(t)$ tensor transient associated with situation p and $\sigma_{tran,q}(t)$ the transitory tensor associated with the situation Q. t_p^{maxSn} and t_p^{minSn} extreme moments DU transient situation p and t_q^{maxSn} and t_q^{minSn} extreme moments DU transient situation q such as definite with 3.3.1.

With `'METHOD'` = `'TRESCA'`, LE parameter S_n for combination of situationS p and Q is defined by :

$$S_n(p,q)=max(S_{nA},S_{nB},S_{nC},S_{nD})$$

$$\text{with } S_{nA}=\max_{p,q}\|\sigma_p^{lin}-\sigma_q^{lin}+\sigma_{tran,p}^{lin}(t_p^{maxSn})-\sigma_{tran,q}^{lin}(t_q^{minSn})\| \ ,$$

$$S_{nB}=\max_{p,q}\|\sigma_q^{lin}-\sigma_p^{lin}+\sigma_{tran,p}^{lin}(t_p^{maxSn})-\sigma_{tran,q}^{lin}(t_q^{minSn})\|$$

$$S_{nC}=\max_{p,q}\|\sigma_p^{lin}-\sigma_q^{lin}+\sigma_{tran,q}^{lin}(t_q^{maxSn})-\sigma_{tran,p}^{lin}(t_p^{minSn})\| \ ,$$

$$S_{nD}=\max_{p,q}\|\sigma_q^{lin}-\sigma_p^{lin}+\sigma_{tran,q}^{lin}(t_q^{maxSn})-\sigma_{tran,p}^{lin}(t_p^{minSn})\| \ .$$

With `'METHOD'` = `'TOUT_INST'`, LE parameter S_n for combination of situationS p and Q is defined by :

$$S_n(p,q)=max(S_{nA},S_{nB})$$

$$\text{with } S_{nA}=\max_{t_1,t_2}\|\sigma_p^{lin}-\sigma_q^{lin}+\sigma_{tran,p}^{lin}(t_1)-\sigma_{tran,q}^{lin}(t_2)\|$$

$$\text{and } S_{nB}=\max_{t_1,t_2}\|\sigma_q^{lin}-\sigma_p^{lin}+\sigma_{tran,p}^{lin}(t_1)-\sigma_{tran,q}^{lin}(t_2)\| \ .$$

Note:

In this case, $\sigma_{tran}(t)=\sigma_{ther}(t)$.

8.3.2 Calculation of Sp

One notes σ_p (respectively σ_q) associated mechanical constraints with one stabilized state of the situation p (respectively of the situation Q).

One notes $\sigma_{tran,p}(t)$ tensor transient associated with situation p and $\sigma_{tran,q}(t)$ the transitory tensor associated with the situation Q. t_p^{maxSp} and t_p^{minSp} extreme moments DU transient situation p and t_q^{maxSp} and t_q^{minSp} extreme moments DU transient situation Q such as definite with 3.3.1.

With `'METHOD'` = `'TRESCA'`, LES parameterS S_{p1} and S_{p2} for combination of situationS p and Q SoneT defined by :

$$S_p^1(p,q)=max(S_{pA},S_{pB})$$

$$S_p^2(p,q)=min(S_{pA},S_{pB})$$

While maximizing on the four possible combinations of stabilized states (σ_p,σ_q) ,

$$S_{pA}=max\left(\|\sigma_p-\sigma_q+\sigma_{tran,p}(t_p^{maxSp})-\sigma_{tran,q}(t_q^{minSp})\|,\|\sigma_q-\sigma_p+\sigma_{tran,p}(t_p^{maxSp})-\sigma_{tran,q}(t_q^{minSp})\|\right),$$

that is to say 8 possibilities.

$$S_{pB}=max\left(\|\sigma_p-\sigma_q+\sigma_{tran,q}(t_q^{maxSp})-\sigma_{tran,p}(t_p^{minSp})\|,\|\sigma_q-\sigma_p+\sigma_{tran,q}(t_q^{maxSp})-\sigma_{tran,p}(t_p^{minSp})\|\right),$$

that is to say 8 possibilities.

With `'METHOD' = 'TOUT_INST'`, LE parameter S_{p1} for combination of situationS p and Q is defined by :

$$S_p^1(p,q)=max(S_{pA},S_{pB})$$

with $S_{pA}=\max_{t_1,t_2}\|\sigma_p-\sigma_q+\sigma_{tran,p}(t_1)-\sigma_{tran,q}(t_2)\|$ and $S_{pB}=\max_{t_1,t_2}\|\sigma_q-\sigma_p+\sigma_{tran,p}(t_1)-\sigma_{tran,q}(t_2)\|$.

If t_1^p and t_1^q are the moments of the fictitious transient 1 $S_p^1(p,q)$, then one determines the moments of the fictitious transient 2 t_2^p and t_2^q according to the method described inWithnnexe 2 and size $S_p^2(p,q)$ is worth while maximizing on the four possible combinations of stabilized states (σ_p,σ_q), :

$$S_p^2(p,q)=max\left(\|\sigma_q-\sigma_p+\sigma_{tran,p}(t_2^p)-\sigma_{tran,q}(t_2^q)\|,\|\sigma_p-\sigma_q+\sigma_{tran,p}(t_2^p)-\sigma_{tran,q}(t_2^q)\|\right)$$

NoticeS :

In ittte part , $\sigma_{tran}(t)=\sigma_{ther}(t)$.

8.3.3 Calculation of Sp ^{meca}

One notes σ_{p1} (respectively σ_{q1}) associated mechanical constraints with stateS stabilizedS situation p and of the situation Q which maximized the size S_p^1. One notes σ_{p2} (respectively σ_{q2}) mechanical constraints associated with the stabilized states which maximized the size S_p^2.

With `'METHOD' = 'TRESCA'` and `'METHOD' = 'TOUT_INST'` :

$S_p^{meca,1}(p,q)=\|\sigma_{p1}-\sigma_{q1}\|$ *and* $S_p^{meca,2}(p,q)=\|\sigma_{p2}-\sigma_{q2}\|$

9 AnnexE 2 : B3200 equations for situations in unit form with interpolation on the temperature

Each situation is defined by two stateS mechanicsS stabilizeds.a and B. Each state is described starting from a pressure P and of a torque of effort $\{F_X, F_Y, F_Z, M_X, M_Y, M_Z\}$ defined under the keyword 'CHAR_MECA' and corresponds to a temperature (TEMP_A or TEMP_B). In this example, the situations do not have a loading in pressure.

The user must also return the profile of temperature function of time during the situation (keyword 'TABL_TEMP' under the keyword factor ' SITUATION')

tensors of the constraints are then reconstituted by interpolation linear to leave DE this temperature function of time and the two torques. The use of this option requires the preliminary calculation of the stress fields for 6 loadings unit ('RESU_MECA_UNIT') and of the stress fields for each transient thermicsS ('RESU_THER').

For the moment, the calculation of PM_PB is not available if the data of the situations are in unit form with interpolation on the temperature.

9.1 Calculation of Sn for a situation

One notes $\sigma_A^{mom,lin}$ and $\sigma_B^{mom,lin}$ mechanical constraints linearized associated with moments of two stabilized states of the situation and $\sigma_{ther}(t)$ transient thermics associated with this situation. One has then,

$$\sigma_A^{mom,lin}(T=TEMP_A)=F_{XA}\sigma^{lin,FX}+F_{YA}\sigma^{lin,FY}+F_{ZA}\sigma^{lin,FZ}+M_{XA}\sigma^{MX,lin}+M_{YA}\sigma^{MY,lin}+M_{ZA}\sigma^{MZ,lin}$$
$$\sigma_B^{mom,lin}(T=TEMP_B)=F_{XB}\sigma^{lin,FX}+F_{YB}\sigma^{lin,FY}+F_{ZB}\sigma^{lin,FZ}+M_{XB}\sigma^{MX,lin}+M_{YB}\sigma^{MY,lin}+M_{ZB}\sigma^{MZ,lin}$$

At moments T1 and t2, one has $T(t_1)=TEMP_1$ and $T(t_2)=TEMP_2$. If $TEMP_A<TEMP_B$, by interpolation one has

$$F_X(t_1)=\frac{F_{XB}-F_{XA}}{TEMP_B-TEMP_A}*TEMP_1+\frac{F_{XA}TEMP_B-F_{XB}TEMP_A}{TEMP_B-TEMP_A}$$
$$F_X(t_2)=\frac{F_{XB}-F_{XA}}{TEMP_B-TEMP_A}*TEMP_2+\frac{F_{XA}TEMP_B-F_{XB}TEMP_A}{TEMP_B-TEMP_A}$$

The equations are similar for the five other components. One from of deduced the expression from the linearized mechanical constraints due to the moments at moments T1 and t2

$$\sigma^{mom,lin}(t_1)=F_X(t_1)\sigma^{lin,FX}+F_Y(t_1)\sigma^{lin,FY}+...+M_Z(t_1)\sigma^{MZ,lin}$$
$$\sigma^{mom,lin}(t_2)=F_X(t_2)\sigma^{lin,FX}+F_Y(t_2)\sigma^{lin,FY}+...+M_Z(t_2)\sigma^{MZ,lin}.$$

With 'METHOD' = 'TOUT_INST', LE parameter S_n for the situation is defined by :

$$S_n=\max_{t_1,t_2}\|\sigma^{mom,lin}(t_1)-\sigma^{mom,lin}(t_2)+\sigma_{ther}^{lin}(t_1)-\sigma_{ther}^{lin}(t_2)\|$$

With 'METHOD' = 'TRESCA', LE parameter S_n for the situation is defined by :

$$S_n=\|\sigma^{mom,lin}(t_{maxSn})-\sigma^{mom,lin}(t_{minSn})+\sigma_{ther}^{lin}(t_{maxSn})-\sigma_{ther}^{lin}(t_{minSn})\|$$

9.2 Calculations carried out with the option `'TIREDNESS'`

9.2.1 Sn calculation for a combination of situations p and Q

One notes $\sigma_{Ap}^{mom,lin}$ and $\sigma_{Bp}^{mom,lin}$ mechanical constraints linearized associated with moments of two stabilized states of the situation p and $\sigma_{ther,p}$ transient thermics associated with this situation.

One notes $\sigma_{Aq}^{mom,lin}$ and $\sigma_{Bq}^{mom,lin}$ mechanical constraints linearized associated with moments of two stabilized states of the situation p and $\sigma_{ther,q}$ transient thermics associated with this situation.

For the moment T_p belonging to $\sigma_{ther,p}$, one has $T(t_p)=TEMP_p$ and SI $TEMP_{Ap}<TEMP_{Bp}$, by interpolation one has

$$F_X(t_p)=\frac{F_{XBp}-F_{XAp}}{TEMP_{Bp}-TEMP_{Ap}}*TEMP_p+\frac{F_{XAp}TEMP_{Bp}-F_{XBp}TEMP_{Ap}}{TEMP_{Bp}-TEMP_{Ap}}$$

For the moment T_Q belonging to $\sigma_{ther,q}$, one has $T(t_q)=TEMP_q$ and SI $TEMP_{Aq}<TEMP_{Bq}$, by interpolation one has

$$F_X(t_q)=\frac{F_{XBq}-F_{XAq}}{TEMP_{Bq}-TEMP_{Aq}}*TEMP_q+\frac{F_{XAq}TEMP_{Bq}-F_{XBq}TEMP_{Aq}}{TEMP_{Bq}-TEMP_{Aq}}.$$

The equations are similar for the five other components. One from of deduced the expression from the linearized mechanical constraints due to the moments at the moments T_p and T_Q.

$$\sigma^{mom,lin}(t_p)=F_X(t_p)\sigma^{lin,FX}+F_Y(t_p)\sigma^{lin,FY}+...+M_Z(t_p)\sigma^{MZ,lin}$$
$$\sigma^{mom,lin}(t_q)=F_X(t_q)\sigma^{lin,FX}+F_Y(t_q)\sigma^{lin,FY}+...+M_Z(t_q)\sigma^{MZ,lin}.$$

With `'METHOD' = 'TOUT_INST'`, LE parameter S_n for combination of situationS p and Q is:

$$S_n=\max_{t_p,t_q}\|\sigma^{mom,lin}(t_p)-\sigma^{mom,lin}(t_q)+\sigma_{ther,p}^{lin}(t_p)-\sigma_{ther,q}^{lin}(t_q)\|$$

9.2.2 Calculation of Sp for a combination of situations p and Q

One notes σ_{Ap}^{mom} and σ_{Bp}^{mom} mechanical constraints associated with moments of two stabilized states of the situation p and $\sigma_{ther,p}$ transient thermics associated with this situation.

One notes σ_{Aq}^{mom} and σ_{Bq}^{mom} mechanical constraints associated with moments of two stabilized states of the situation p and $\sigma_{ther,q}$ transient thermics associated with this situation.

For the moment T_p belonging to $\sigma_{ther,p}$, one has $T(t_p)=TEMP_p$ and SI $TEMP_{Ap}<TEMP_{Bp}$, by interpolation one has

$$F_X(t_p)=\frac{F_{XBp}-F_{XAp}}{TEMP_{Bp}-TEMP_{Ap}}*TEMP_p+\frac{F_{XAp}TEMP_{Bp}-F_{XBp}TEMP_{Ap}}{TEMP_{Bp}-TEMP_{Ap}}$$

For the moment T_Q belonging to $\sigma_{ther,q}$, one has $T(t_q)=TEMP_q$ and SI $TEMP_{Aq}<TEMP_{Bq}$, by

interpolation one has

$$F_X(t_q)=\frac{F_{XBq}-F_{XAq}}{TEMP_{Bq}-TEMP_{Aq}}*TEMP_q+\frac{F_{XAq}TEMP_{Bq}-F_{XBq}TEMP_{Aq}}{TEMP_{Bq}-TEMP_{Aq}}.$$

The equations are similar for the five other components. One from of deduced the expression from the mechanical constraints due to the moments at the moments T_p and T_Q.

$$\sigma^{mom}(t_p)=F_X(t_p)\sigma^{FX}+F_Y(t_p)\sigma^{FY}+...+M_Z(t_p)\sigma^{MZ}$$
$$\sigma^{mom}(t_q)=F_X(t_q)\sigma^{FX}+F_Y(t_q)\sigma^{FY}+...+M_Z(t_q)\sigma^{MZ}.$$

With `'METHOD' = 'TOUT_INST'`, LE parameter S_p^1 for combination of situationS p and Q is:

$$S_p^1=\max_{t_p,t_q}\|\sigma^{mom}(t_p)-\sigma^{mom}(t_q)+\sigma_{ther,p}(t_p)-\sigma_{ther,q}(t_q)\|$$

Moments of S_p^2 are given according to Appendix 5.

10 Appendix 3 : Equations for a junction of pipingS (pricking)

10.1 Type `B3200`

Situation of the unit type

One notes σ_1 and σ_2 mechanical constraints associated with the two stabilized states of the situation. Only definitions of σ_1 and σ_2 change compared to the case of only one set of external torques.

For a component, Chaque stabilized mechanical state is described starting from a pressure P and of a torque of effort $\{F_X, F_Y, F_Z, M_X, M_Y, M_Z\}$ defined under the keyword 'CHAR_MECA'. For a junction of piping, one provides two torques of efforts:

$$\{F_{X,corp}, F_{Y,corp}, F_{Z,corp}, M_{X,corp}, M_{Y,corp}, M_{Z,corp}\}$$
$$\{F_{X,tubu}, F_{Y,tubu}, F_{Z,tubu}, M_{X,tubu}, M_{Y,tubu}, M_{Z,tubu},\}.$$

The tensors of the constraints are reconstituted by linear combination starting from the tensors of the constraints associated with each unit loading. For example, ON notes $\underline{\sigma}^{F_X, tubu}$ the tensor of the constraints associated with the unit loading in effort according to direction X for the pipe. The calculation of the tensor of the constraints corresponding to a mechanical loading pertaining in a stabilized state is then obtained in the following way:

$$\begin{aligned}\underline{\sigma} = & F_{X,tubu}.\underline{\sigma}^{F_X, tubu}+F_{Y,tubu}.\underline{\sigma}^{F_Y, tubu}+F_{Z,tubu}.\underline{\sigma}^{F_Z, tubu}+M_{X,tubu}.\underline{\sigma}^{M_X, tubu}\\ & +M_{Y,tubu}.\underline{\sigma}^{M_Y, tubu}+M_{Z,tubu}.\underline{\sigma}^{M_Z, tubu}+F_{X,corp}.\underline{\sigma}^{F_X, corp}+F_{Y,corp}.\underline{\sigma}^{F_Y, corp}\\ & +F_{Z,corp}.\underline{\sigma}^{F_Z, corp}+M_{X,corp}.\underline{\sigma}^{M_X, corp}+M_{Y,corp}.\underline{\sigma}^{M_Y, corp}+M_{Z,corp}.\underline{\sigma}^{M_Z, corp}+P.\underline{\sigma}^{P}\end{aligned}$$

The calculation of the sizes S_n and S_p is then identical to only one component.

Situation of the type instantaneous

One notes $\sigma_{tran}(t)$ tensor transient associated with situation. Pour a component, one returns the thermal transient under `RESU_THER`, the transient of pressure under `RESU_PRES` and the transient due to the efforts and moments under `RESU_MECA` and $\sigma_{tran}(t)=\sigma_{ther}(t)+\sigma_{pres}(t)+\sigma_{meca}(t)$.

For a junction of piping, it is necessary to return under `RESU_MECA` the tensor summons tensors of the body and pipe.

$$\sigma_{meca}(t)=\sigma_{meca,corp}(t)+\sigma_{meca,tubu}(t)$$

The calculation of the sizes S_n and S_p is then identical to only one component.

10.2 Type `ZE200a`

One notes σ_{tran} the tensor summons transients associated with the situation and t^{maxSn} and t^{minSn}, t^{maxSp} and t^{minSp} extreme moments of this transient such as definite with 3.3.1. One index A and B sizes of the stabilized states of the situation (pressure and torque at the time). R, R_{tubu}, R_{body}, and I, I_{tubu}, I_{body} are the geometrical characteristics of piping, K_1, $K_{2,tubu}$,$K_{2,body}$, K_3, C_1, $C_{2,tubu}$, $C_{2,body}$ and C_3 are indication of constraints of the RCC-M.

The parameter S_n for a situation is defined by:

$$S_n=S_n'+S_n'' \quad \text{with}$$

$$S_n''=C_1\frac{R}{e}|P_A-P_B|+C_{2,corp}\frac{R_{corp}}{I_{corp}}\sqrt{(M_{XA,corp}-M_{XB,corp})^2+(M_{YA,corp}-M_{YB,corp})^2+(M_{ZA,corp}-M_{ZB,corp})^2}$$
$$+C_{2,tubu}\frac{R_{tubu}}{I_{tubu}}\sqrt{(M_{XA,tubu}-M_{XB,tubu})^2+(M_{YA,tubu}-M_{YB,tubu})^2+(M_{ZA,tubu}-M_{ZB,tubu})^2}$$

With 'METHOD' = 'TRESCA' ,

$$S_n'=\|\sigma_{tran}^{lin}(t^{maxSn})-\sigma_{tran}^{lin}(t^{minSn})\|$$

With 'METHOD' = 'TOUT_INST' ,

$$S_n'=\max_{t_1,t_2}\|\sigma_{tran}^{lin}(t_1)-\sigma_{tran}^{lin}(t_2)\|$$

For the two methods,

$$S_p=S_p^1{}'+S_p''+S_p''' \text{ and } S_p^{meca}=S_p'' \text{ with}$$
$$S_p''=K_1C_1\frac{R}{e}|P_A-P_B|+S_{p,moments}''$$
$$S_{p,moments}''=K_{2,corp}C_{2,corp}\frac{R_{corp}}{I_{corp}}\sqrt{(M_{XA,corp}-M_{XB,corp})^2+(M_{YA,corp}-M_{YB,corp})^2+(M_{ZA,corp}-M_{ZB,corp})^2}$$
$$+K_{2,tubu}C_{2,tubu}\frac{R_{tubu}}{I_{tubu}}\sqrt{(M_{XA,tubu}-M_{XB,tubu})^2+(M_{YA,tubu}-M_{YB,tubu})^2+(M_{ZA,tubu}-M_{ZB,tubu})^2}$$
$$\text{and } S_p'''=(K_3C_3-1)S_{n,ther}'$$

With 'METHOD' = 'TRESCA' ,

$$S_{n,ther}'=\|\sigma_{ther}^{lin}(t^{maxSn})-\sigma_{ther}^{lin}(t^{minSn})\| \text{ and}$$
$$S_p^1{}'=\|\sigma_{ther}(t^{maxSp})-\sigma_{ther}(t^{minSp})\| .$$

With 'METHOD' = 'T OUT_INST ' ,

- one takes again the moments t_p^1 and t_p^2 who maximize the size S_n' and $S_{n,ther}'=\|\sigma_{ther}^{lin}(t_p^1)-\sigma_{ther}^{lin}(t_p^2)\|$,
- the size is calculated $S_p^1{}'$ such as $S_p^1{}'=\max_{t_1,t_2}\|\sigma_{ther}(t_1)-\sigma_{ther}(t_2)\|$.

Note:

In it paragraph , $\sigma_{tran}(t)=\sigma_{ther}(t)$.

10.3 Type ' ZE200b '

One notes σ_{tran} the tensor summons transients associated with the situation and t^{maxSn} and t^{minSn}

, t^{maxSp} and t^{minSp} extreme moments of this transient such as definite with 3.3.1. One index A and B sizes of the stabilized states of the situation (pressure and torque at the time). R, R_{tubu}, R_{body}, and I, I_{tubu}, I_{body} are the geometrical characteristics of piping, K_1, $K_{2,tubu}$,$K_{2,body}$, K_3, C_1, $C_{2,tubu}$, $C_{2,body}$ and C_3 are indication of constraints of the RCC-M.

The parameter S_n for a situation is defined by:

$$S_n = S_n' + S_n''$$

$$S_n'' = C_{2,corp} \frac{R_{corp}}{I_{corp}} \sqrt{(M_{XA,corp} - M_{XB,corp})^2 + (M_{YA,corp} - M_{YB,corp})^2 + (M_{ZA,corp} - M_{ZB,corp})^2}$$
$$+ C_{2,tubu} \frac{R_{tubu}}{I_{tubu}} \sqrt{(M_{XA,tubu} - M_{XB,tubu})^2 + (M_{YA,tubu} - M_{YB,tubu})^2 + (M_{ZA,tubu} - M_{ZB,tubu})^2}$$

With `'METHOD' = 'TRESCA'`, $S_n' = \|\sigma_{tran}^{lin}(t^{maxSn}) - \sigma_{tran}^{lin}(t^{minSn})\|$ and with `'METHOD' = 'TOUT_INST'`, $S_n' = \max_{t_1, t_2} \|\sigma_{tran}^{lin}(t_1) - \sigma_{tran}^{lin}(t_2)\|$.

For the two methods,

$$S_p = S_p^1{}' + S_p'' + S_p''' \text{ and } S_p^{meca} = S_p^{meca,1}{}' + S_p'' + S_p^{meca}{}''' \text{ with}$$

$$S_p'' = K_{2,corp} C_{2,corp} \frac{R_{corp}}{I_{corp}} \sqrt{(M_{XA,corp} - M_{XB,corp})^2 + (M_{YA,corp} - M_{YB,corp})^2 + (M_{ZA,corp} - M_{ZB,corp})^2}$$
$$+ K_{2,tubu} C_{2,tubu} \frac{R_{tubu}}{I_{tubu}} \sqrt{(M_{XA,tubu} - M_{XB,tubu})^2 + (M_{YA,tubu} - M_{YB,tubu})^2 + (M_{ZA,tubu} - M_{ZB,tubu})^2}$$

and $S_p''' = (K_3 C_3 - 1) S_{n,ther}' + (K_1 C_1 - 1) S_{n,pres}'$, $S_p^{meca}{}''' = (K_1 C_1 - 1) S_{n,pres}'$.

With `'METHOD' = 'TRESCA'` ,

$$S_{n,ther}' = \|\sigma_{ther}^{lin}(t^{maxSn}) - \sigma_{ther}^{lin}(t^{minSn})\| \text{ and } S_{n,pres}' = \|\sigma_{pres}^{lin}(t^{maxSn}) - \sigma_{pres}^{lin}(t^{minSn})\|$$
$$S_p^1{}' = \|\sigma_{tran}(t^{maxSp}) - \sigma_{tran}(t^{minSp})\| \text{ and } S_p^{meca,1}{}' = \|\sigma_{pres}(t^{maxSp}) - \sigma_{pres}(t^{minSp})\|$$

With `'METHOD' = 'T OUT_INST '` , one takes again the moments t_p^1 and t_p^2 who maximize the size S_n' : $S_{n,ther}' = \|\sigma_{ther}^{lin}(t_p^1) - \sigma_{ther}^{lin}(t_p^2)\|$ and $S_{n,pres}' = \|\sigma_{pres}^{lin}(t_p^1) - \sigma_{pres}^{lin}(t_p^2)\|$.

$S_p^1{}' = \max_{t_1, t_2} \|\sigma_{tran}(t_1) - \sigma_{tran}(t_2)\|$ and $S_p^{meca,1}{}' = \|\sigma_{pres}(t_p^3) - \sigma_{pres}(t_p^4)\|$ (one takes the moments t_p^3 and t_p^4 who maximize the size $S_p^1{}'$).

Note:

In it tte part, $\sigma_{tran}(t) = \sigma_{ther}(t) + \sigma_{pres}(t)$.

11 AnnexE 4 : Calculation of the SP and of the SP^meca of a situation only (`'B3200'`, `'ZE200a'` and `'ZE200b'`)

11.1 Type `'B3200'`

Situation of the unit type

One notes σ_{p1} σ_{p2} and associated mechanical constraints with stateS stabilizedS situation p.

$$S_p^{meca}(p,p)=\|\sigma_{p1}-\sigma_{p2}\|$$

With `'METHOD' = 'TRESCA'`, LE parameter $S_p(p,p)$ for the situation p is defined by:

$$S_p(p,p)=max(S_{pA},S_{pB})$$

with $S_{pA}=\|\sigma_{p1}-\sigma_{p2}+\sigma_{ther,p}(t_p^{maxSp})-\sigma_{ther,p}(t_p^{minSp})\|$ and
$S_{pB}=\|\sigma_{p2}-\sigma_{p1}+\sigma_{ther,p}(t_p^{maxSp})-\sigma_{ther,p}(t_p^{minSp})\|$,

With `'METHOD' = 'TOUT_INST'` , the parameter $S_p(p,p)$ for the situation p is defined by:

$$S_p(p,p)=max(S_{pA},S_{pB})$$

with $S_{pA}=\max_{t_1,t_2}\|\sigma_{p1}-\sigma_{p2}+\sigma_{ther,p}(t_1)-\sigma_{ther,p}(t_2)\|$ and
$S_{pB}=\max_{t_1,t_2}\|\sigma_{p2}-\sigma_{p1}+\sigma_{ther,p}(t_1)-\sigma_{ther,p}(t_2)\|$.

Situation of the instantaneous type

With `'METHOD' = 'TRESCA'` , the parameter $S_p(p,p)$ for the situation p is defined by:

$$S_p(p,p)=\|\sigma_{ther+pres+meca,p}(t_p^{maxSp})-\sigma_{ther+pres+meca,p}(t_p^{minSp})\| ,$$

$$S_p^{meca}(p,p)=\|\sigma_{pres+meca,p}(t_p^{maxSp})-\sigma_{pres+meca,p}(t_p^{minSp})\|$$

With `'METHOD' = 'TOUT_INST'` , the parameter $S_p(p,p)$ for the situation p is defined by:

$$S_p(p,p)=\max_{t_1,t_2}\|\sigma_{ther+pres+meca,p}(t_1)-\sigma_{ther+pres+meca,p}(t_2)\| .$$

If t_p^1 and t_p^2 are the moments which maximize S_p , then

$$S_p^{meca}(p,p)=\|\sigma_{pres+meca,p}(t_p^1)-\sigma_{pres+meca,p}(t_p^2)\|$$

11.2 Type `' ZE200a '`

$S_p(p,p)=S_p^1{}'+S_p{}''+S_p{}'''$ and $S_p^{meca}(p,p)=S_p{}''$ with

$S_p{}''=K_1C_1\frac{R}{e}|P_{p1}-P_{p2}|+K_2C_2\frac{R}{I}\sqrt{(M_{Xp1}-M_{Xp2})^2+(M_{Yp1}-M_{Yp2})^2+(M_{Zp1}-M_{Zp2})^2}$ and

$$S_p{}'''=(K_3C_3-1)S_{n,ther}{}'$$

With `'METHOD' = 'TRESCA'` ,

$$S_{n,ther}'=\|\sigma_{ther,p}^{lin}(t_p^{maxSn})-\sigma_{ther,p}^{lin}(t_p^{minSn})\| \ .$$

$$S_p^1{}'=\|\sigma_{ther,p}(t_p^{maxSp})-\sigma_{ther,p}(t_p^{minSp})\|$$

With `'METHOD' = 'T OUT_INST '` ,

$$S_{n,ther}'=\max_{t_1,t_2}\|\sigma_{ther,p}^{lin}(t_1)-\sigma_{ther,p}^{lin}(t_2)\| \ ,$$

$$S_p^1{}'=\max_{t_1,t_2}\|\sigma_{ther,p}(t_1)-\sigma_{ther,p}(t_2)\|$$

11.3 Type `' ZE200b '`

$$S_p(p,p)=S_p^1{}'+S_p{}''+S_p{}'''$$

$$S_p^{meca}(p,p)=S_p^{meca,1}{}'+S_p{}''+S_p^{meca}{}'''$$

with $S_p{}''=K_2C_2\frac{R}{I}\sqrt{(M_{Xp1}-M_{Xp2})^2+(M_{Yp1}-M_{Yp2})^2+(M_{Zp1}-M_{Zp2})^2}$ and $S_p{}'''=(K_3C_3-1)S_{n,ther}'+(K_1C_1-1)S_{n,pres}'$ and $S_p^{meca}{}'''=(K_1C_1-1)S_{n,pres}'$

One notes $\sigma_{tran}(t)=\sigma_{ther}(t)+\sigma_{pres}(t)$

With `'METHOD' = 'TRESCA'` ,

$$S_p^1{}'=\|\sigma_{tran,p}(t_p^{maxSp})-\sigma_{tran,p}(t_p^{minSp})\|$$

$$S_p^{meca,1}=\|\sigma_{pres,p}(t_p^{maxSp})-\sigma_{pres,p}(t_p^{minSp})\|$$

$S_{n,ther}'=\|\sigma_{ther,p}^{lin}(t_p^{maxSn})-\sigma_{ther,p}^{lin}(t_p^{minSn})\|$ and $S_{n,pres}'=\|\sigma_{pres,p}^{lin}(t_p^{maxSn})-\sigma_{pres,p}^{lin}(t_p^{minSn})\|$.

With `'METHOD' = 'TOUT_INST '`,

$$S_p^1{}'=\max_{t_1,t_2}\|\sigma_{tran,p}(t_1)-\sigma_{tran,p}(t_2)\|$$

If t_p^1 and t_p^2 are the moments which maximize $S_p^1{}'$, then

$$S_p^{meca,1}{}'=\|\sigma_{pres,p}(t_p^1)-\sigma_{pres,p}(t_p^2)\|$$

If t_p^3 and t_p^4 are the moments which maximize $S_n{}'$, then

$S_{n,ther}'=\|\sigma_{ther,p}^{lin}(t_p^3)-\sigma_{ther,p}^{lin}(t_p^4)\|$ and $S_{n,pres}'=\|\sigma_{pres,p}^{lin}(t_p^3)-\sigma_{pres,p}^{lin}(t_p^4)\|$.

12 Appendix 5 : Method of calculating of the fictitious transient 2 with 'TOUT_INST'

One notes $\sigma_{tran,p}$ the tensor summons transients associated with the situation p and $\sigma_{tran,q}$ the tensor summons transients associated with the situation Q.

One notes If t_1^p and t_1^q are the moments of the fictitious transient 1 $S_p^1(p,q)$, then one determines the moments of the fictitious transient 2 t_2^p and t_2^q.

One seeks t_2^p who maximizes the size S_{pA} such as

$$S_{pA}=\max_t \|\sigma_{tran,p}(t_1^p)-\sigma_{tran,p}(t)\|=\|\sigma_{tran,p}(t_1^p)-\sigma_{tran,p}(t_2^p)\| .$$

One seeks t_2^q who maximizes the size S_{pB} such as

$$S_{pB}=\max_t \|\sigma_{tran,q}(t_1^q)-\sigma_{tran,q}(t)\|=\|\sigma_{tran,q}(t_1^q)-\sigma_{tran,q}(t_2^q)\| .$$

Moments t_2^p and t_2^q . are then used for the calculation of the size $S_p^2(p,q)$ whatever it `TYPE_RESU_MECA` chosen (`ZE200a, ZE200b, B3200`).

13 Appendix 6 : Method 'B3200' with indices of constraints

The user has the possibility of returning of the indices of constraints under the keyword `IN DI_SIGM` in order to compare the results got with ' `ZE200a`' or '`ZE200b`' or to integrate the effects of a not modelled welding . Equations with indices of constraints for '`B3200` ' appear below. This is not possible that with situations of the instantaneous type.

Parameters $S_p^1(p,q)$ and $S_p^2(p,q)$ were given in the part 3.4.1.3. The size is added to them S_p'''.

$$S_p^1(p,q)=S_p^1(p,q)+S_p'''$$
$$S_p^2(p,q)=S_p^2(p,q)+S_p'''$$

$$S_p'''=(K_1C_1-1)S_{n,pres}'+(K_2C_2-1)S_{n,meca}'+(K_3C_3-1)S_{n,ther}'$$

With '`METHOD`' = '`TRESCA`', LE parameter S_n for combination of situationS p and Q is defined by:

$$S_n=max(S_{nA},S_{nB}) \text{ with}$$
$$S_{nA}=\|\sigma_{tran,p}^{lin}(t_p^{maxSn})-\sigma_{tran,q}^{lin}(t_q^{minSn})\| \text{ and } S_{nB}=\|\sigma_{tran,q}^{lin}(t_q^{maxSn})-\sigma_{tran,p}^{lin}(t_p^{minSn})\| .$$

If $S_n=S_{nA}$, then $S_{n,ther}'=\|\sigma_{ther,p}^{lin}(t_p^{maxSn})-\sigma_{ther,q}^{lin}(t_q^{minSn})\|$, $S_{n,pres}'=\|\sigma_{pres,p}^{lin}(t_p^{maxSn})-\sigma_{pres,q}^{lin}(t_q^{minSn})\|$ and $S_{n,meca}'=\|\sigma_{meca,p}^{lin}(t_p^{maxSn})-\sigma_{meca,q}^{lin}(t_q^{minSn})\|$.

If $S_n=S_{nB}$, then $S_{n,ther}'=\|\sigma_{ther,q}^{lin}(t_q^{maxSn})-\sigma_{ther,p}^{lin}(t_p^{minSn})\|$, $S_{n,pres}'=\|\sigma_{pres,q}^{lin}(t_q^{maxSn})-\sigma_{pres,p}^{lin}(t_p^{minSn})\|$ and $S_{n,meca}'=\|\sigma_{meca,q}^{lin}(t_q^{maxSn})-\sigma_{meca,p}^{lin}(t_p^{minSn})\|$.

With '`METHOD`' = '`T OUT_INST` ', one uses the moments which intervene in the size S_n for the calculation of $S_{n,pres}'$, $S_{n,ther}'$ and $S_{n,meca}'$.

If $Sn=\|\sigma_{tran,p}^{lin}(t_p)-\sigma_{tran,q}^{lin}(t_q)\|$, then

$$S_{n,ther}'=\|\sigma_{ther,p}^{lin}(t_p)-\sigma_{ther,q}^{lin}(t_q)\| ,$$
$$S_{n,pres}'=\|\sigma_{pres,p}^{lin}(t_p)-\sigma_{pres,q}^{lin}(t_q)\|$$
$$S_{n,meca}'=\|\sigma_{meca,p}^{lin}(t_p)-\sigma_{meca,q}^{lin}(t_q)\| .$$

14 Appendix 7 : Equations with taking into account of the earthquake

14.1 Calculation of the sizes for a situation

14.1.1 Type `'B3200'`

Situation of the unit type

One notes σ_1 and σ_2 mechanical constraints associated with the two stabilized states of the situation and $\sigma_{tran}(t)$ tensor transient associated with this situation. t^{maxSp} , t^{minSp} , t^{maxSn} and t^{minSn} extreme moments of this transient such as definite with 3.3.1.

The earthquake is described by one stabilized mechanical state (S) and the corresponding torque $\{F_X^S, F_Y^S, F_Z^S, M_X^S, M_Y^S, M_Z^S\}$ under `CHAR_ETAT`, the keyword `'RESU_MECA_UNIT'` must be well informed.

With `'METHOD' = 'TRESCA'`, one tests all the possibilities of sign on the components of the earthquake and LES parameterS S_n and S_p for one situation SoneT defined by :

$$S_n = max(S_{nA}, S_{nB})$$

$$S_{nA1} = \sigma_1^{lin} - \sigma_2^{lin} + \sigma_{tran}^{lin}(t^{maxSn}) - \sigma_{tran}^{lin}(t^{minSn})$$

$$S_{nB1} = \sigma_2^{lin} - \sigma_1^{lin} + \sigma_{tran}^{lin}(t^{maxSn}) - \sigma_{tran}^{lin}(t^{minSn})$$

$$S_{nA} = \max_S \| S_{nA1} \ \pm 2F_X^S \sigma_{FX}^{lin} \pm 2F_Y^S \sigma_{FY}^{lin} \pm 2F_Z^S \sigma_{FZ}^{lin} \pm 2M_X^S \sigma_{MX}^{lin} \pm 2M_Y^S \sigma_{MY}^{lin} \pm 2M_Z^S \sigma_{MZ}^{lin} \|$$ (64 possibilities)

$$S_{nB} = \max_S \| S_{nB1} \ \pm 2F_X^S \sigma_{FX}^{lin} \pm 2F_Y^S \sigma_{FY}^{lin} \pm 2F_Z^S \sigma_{FZ}^{lin} \pm 2M_X^S \sigma_{MX}^{lin} \pm 2M_Y^S \sigma_{MY}^{lin} \pm 2M_Z^S \sigma_{MZ}^{lin} \|$$ (64 possibilities)

$$S_p = max(S_{pA}, S_{pB})$$

$$S_{pA1} = \sigma_1 - \sigma_2 + \sigma_{tran}(t^{maxSp}) - \sigma_{tran}(t^{minSp})$$

$$S_{pB1} = \sigma_2 - \sigma_1 + \sigma_{tran}(t^{maxSp}) - \sigma_{tran}(t^{minSp})$$

$$S_{pA} = \max_S \| S_{pA1} \ \pm 2F_X^S \sigma_{FX} \pm 2F_Y^S \sigma_{FY} \pm 2F_Z^S \sigma_{FZ} \pm 2M_X^S \sigma_{MX} \pm 2M_Y^S \sigma_{MY} \pm 2M_Z^S \sigma_{MZ} \|$$ (64 possibilities)

$$S_{pB} = \max_S \| S_{pB1} \ \pm 2F_X^S \sigma_{FX} \pm 2F_Y^S \sigma_{FY} \pm 2F_Z^S \sigma_{FZ} \pm 2M_X^S \sigma_{MX} \pm 2M_Y^S \sigma_{MY} \pm 2M_Z^S \sigma_{MZ} \|$$ (64 possibilities)

With `'METHOD' = 'TOUT_INST'` , one tests all the possibilities of sign on the components of the earthquake and the parameters S_n and S_p for a situation are defined by:

$$S_n = max(S_{nA}, S_{nB}) ,$$

$$S_{nA1} = \sigma_1^{lin} - \sigma_2^{lin} + \sigma_{tran}^{lin}(t_1) - \sigma_{tran}^{lin}(t_2)$$

$$S_{nB1} = \sigma_2^{lin} - \sigma_1^{lin} + \sigma_{tran}^{lin}(t_1) - \sigma_{tran}^{lin}(t_2)$$

$$S_{nA} = \max_{t_1, t_2, S} \| S_{nA1} \ \pm 2F_X^S \sigma_{FX}^{lin} \pm 2F_Y^S \sigma_{FY}^{lin} \pm 2F_Z^S \sigma_{FZ}^{lin} \pm 2M_X^S \sigma_{MX}^{lin} \pm 2M_Y^S \sigma_{MY}^{lin} \pm 2M_Z^S \sigma_{MZ}^{lin} \|$$ (64

possibilities)

$$S_{nB}=\max_{t_1,t_2,S}\|S_{nB1}\ \pm 2F_X^S\sigma_{FX}^{lin}\pm 2F_Y^S\sigma_{FY}^{lin}\pm 2F_Z^S\sigma_{FZ}^{lin}\pm 2M_X^S\sigma_{MX}^{lin}\pm 2M_Y^S\sigma_{MY}^{lin}\pm 2M_Z^S\sigma_{MZ}^{lin}\|$$ (64 possibilities)

$$S_p=\max(S_{pA},S_{pB})$$

$$S_{pA1}=\sigma_1-\sigma_2+\sigma_{tran}(t_1)-\sigma_{tran}(t_2)$$

$$S_{pB1}=\sigma_2-\sigma_1+\sigma_{tran}(t_1)-\sigma_{tran}(t_2)$$

$$S_{pA}=\max_{t_1,t_2,S}\|S_{pA1}\ \pm 2F_X^S\sigma_{FX}\pm 2F_Y^S\sigma_{FY}\pm 2F_Z^S\sigma_{FZ}\pm 2M_X^S\sigma_{MX}\pm 2M_Y^S\sigma_{MY}\pm 2M_Z^S\sigma_{MZ}\|$$ (64 possibilities)

$$S_{pB}=\max_{t_1,t_2,S}\|S_{pB1}\ \pm 2F_X^S\sigma_{FX}\pm 2F_Y^S\sigma_{FY}\pm 2F_Z^S\sigma_{FZ}\pm 2M_X^S\sigma_{MX}\pm 2M_Y^S\sigma_{MY}\pm 2M_Z^S\sigma_{MZ}\|$$ (64 possibilities)

For the two methods, the parameter S_p^{meca} for a situation is defined by:

$$S_p^{meca}=\max_{S}\|\pm(\sigma_1-\sigma_2)\ \pm 2F_X^S\sigma_{FX}\pm 2F_Y^S\sigma_{FY}\pm 2F_Z^S\sigma_{FZ}\pm 2M_X^S\sigma_{MX}\pm 2M_Y^S\sigma_{MY}\pm 2M_Z^S\sigma_{MZ}\|$$

Note:

In this part, $\sigma_{tran}(t)=\sigma_{ther}(t)$.

<u>Situation of the type instantaneous</u>

One notes $\sigma_{tran}(t)$ tensor transient associated with situation. t^{maxSp} , t^{minSp} , t^{maxSn} and t^{minSn} extreme moments DU transient situation such as definite with 3.3.1.

The earthquake is described by six tensors corresponding to the efforts and moments $\sigma_{FX,S}$, $\sigma_{FY,S}$, $\sigma_{FZ,S}$, $\sigma_{MX,S}$, $\sigma_{MY,S}$, $\sigma_{MZ,S}$.

With `'METHOD' = 'TRESCA'` , one tests all the possibilities of sign on the components of the earthquake and the parameters S_n and S_p for a situation are defined by:

$$S_n=\max_{S}\|\sigma_{tran}^{lin}(t^{maxSn})-\sigma_{tran}^{lin}(t^{minSn})\pm\sigma_{FX,S}^{lin}\pm\sigma_{FY,S}^{lin}\pm\sigma_{FZ,S}^{lin}\pm\sigma_{MX,S}^{lin}\pm\sigma_{MY,S}^{lin}\pm\sigma_{MZ,S}^{lin}\|$$ (64 possibilities)

$$S_p=\max_{S}\|\sigma_{tran}(t^{maxSp})-\sigma_{tran}(t^{minSp})\pm\sigma_{FX,S}\pm\sigma_{FY,S}\pm\sigma_{FZ,S}\pm\sigma_{MX,S}\pm\sigma_{MY,S}\pm\sigma_{MZ,S}\|$$ (64 possibilities)

$$S_p^{meca}=\max_{S}\|\sigma_{pres+meca}(t^{maxSp})-\sigma_{pres+meca}(t^{minSp})\pm\sigma_{FX,S}\pm\sigma_{FY,S}\pm\sigma_{FZ,S}\pm\sigma_{MX,S}\pm\sigma_{MY,S}\pm\sigma_{MZ,S}\|$$

With `'METHOD' = 'T OUT_INST '` , one tests all the possibilities of sign on the components of the earthquake and the parameters S_n and S_p for a situation are defined by:

$$S_n=\max_{S,t_1,t_2}\|\sigma_{tran}^{lin}(t_1)-\sigma_{tran}^{lin}(t_2)\pm\sigma_{FX,S}^{lin}\pm\sigma_{FY,S}^{lin}\pm\sigma_{FZ,S}^{lin}\pm\sigma_{MX,S}^{lin}\pm\sigma_{MY,S}^{lin}\pm\sigma_{MZ,S}^{lin}\|$$ (64 possibilities)

$$S_p=\max_{S,t_1,t_2}\|\sigma_{tran}(t_1)-\sigma_{tran}(t_2)\pm\sigma_{FX,S}\pm\sigma_{FY,S}\pm\sigma_{FZ,S}\pm\sigma_{MX,S}\pm\sigma_{MY,S}\pm\sigma_{MZ,S}\|$$ (64 possibilities)

One takes the moments t_p^1 and t_p^2 who maximize S_p

$$S_p^{meca}=\max_S\|\sigma_{pres+meca}(t_p^1)-\sigma_{pres+meca}(t_p^2)\pm\sigma_{FX,S}\pm\sigma_{FY,S}\pm\sigma_{FZ,S}\pm\sigma_{MX,S}\pm\sigma_{MY,S}\pm\sigma_{MZ,S}\|$$

Note:

In it tte part, $\sigma_{tran}(t)=\sigma_{ther}(t)+\sigma_{pres}(t)+\sigma_{meca}(t)$.

14.1.2 Type `ZE200a`

One notes σ_{ther} the tensor transient thermics associated with the situation and t^{maxSn} and t^{minSn} extreme moments of this transient such as definite with 3.3.1. One index A and B sizes of the stabilized states of the situation (pressure and torque at the time). R, E, and I am the geometrical characteristics of piping, K_1, K_2, K_3, C_1, C_2 and C_3 are indication of constraints of the RCC-M.

The earthquake is described by one stabilized mechanical state (S) and the corresponding torque $\{M_X^S, M_Y^S, M_Z^S\}$ under `CHAR_STATE`. ON tests all the possibilities of sign on the components of the earthquake and the parameter S_n for a situation is defined by:

$$S_n=S_n'+S_n''$$

$$S_n''=\max_S[C_1\frac{R}{e}|P_A-P_B|+C_2\frac{R}{I}\sqrt{(M_{XA}-M_{XB}\pm 2M_X^S)^2+(M_{YA}-M_{YB}\pm 2M_Y^S)^2+(M_{ZA}-M_{ZB}\pm 2M_Z^S)^2}]$$

With `'METHOD' = 'TRESCA'`, $S_n'=\|\sigma_{ther}^{lin}(t^{maxSn})-\sigma_{ther}^{lin}(t^{minSn})\|$.

With `'METHOD' = 'TOUT_INST'`, $S_n'=\max_{t_1,t_2}\|\sigma_{ther}^{lin}(t_1)-\sigma_{ther}^{lin}(t_2)\|$.

For the two methods,

$$S_p=S_p^1{}'+S_p''+S_p''' \text{ and } S_p^{meca}=S_p'' \text{ with}$$

$$S_p''=K_1C_1\frac{R}{e}|P_A-P_B|+\max_S[S_{p,moments}'']$$

$$S_{p,moments}''=K_2C_2\frac{R}{I}\sqrt{(M_{XA}-M_{XB}\pm 2M_X^S)^2+(M_{YA}-M_{YB}\pm 2M_Y^S)^2+(M_{ZA}-M_{ZB}\pm 2M_Z^S)^2}$$

$$\text{and } S_p'''=(K_3C_3-1)S_{n,ther}'$$

With `'METHOD' = 'TRESCA'` ,

$$S_{n,ther}'=\|\sigma_{ther}^{lin}(t^{maxSn})-\sigma_{ther}^{lin}(t^{minSn})\| \text{ . and } S_p^1{}'=\|\sigma_{ther}(t^{maxSp})-\sigma_{ther}(t^{minSp})\|$$

With `'METHOD' = 'T OUT_INST '` ,

One takes the moments t_p^1 and t_p^2 who maximize S_n'

$$S_{n,ther}'=\|\sigma_{ther}^{lin}(t_p^1)-\sigma_{ther}^{lin}(t_p^2)\| \text{ and } S_p^1{}'=\max_{t_1}(\max_{t_2}\|\sigma_{ther}(t_1)-\sigma_{ther}(t_2)\|)$$

14.1.3 Type ` ZE200b `

One notes σ_{tran} the tensor summons transients associated with the situation and t^{maxSn} and t^{minSn} extreme moments of this transient such as definite with 3.3.1. One index A and B sizes of the stabilized states of the situation (pressure and torque at the time). R, E, and I am the geometrical characteristics of piping, K_1, K_2, K_3, C_1, C_2 and C_3 are indication of constraints of the RCC-M.

The earthquake is described by one stabilized mechanical state (S) and the corresponding torque $\{M_X^S, M_Y^S, M_Z^S\}$ under `CHAR_ETAT`.

One tests all the possibilities of sign on the components of the earthquake and the parameter S_n for a situation is defined by:

$$S_n = S_n' + S_n'' \quad \text{with}$$

$$S_n'' = \max_S \left[C_2 \frac{R}{I} \sqrt{(M_{XA} - M_{XB} \pm 2 M_X^S)^2 + (M_{YA} - M_{YB} \pm 2 M_Y^S)^2 + (M_{ZA} - M_{ZB} \pm 2 M_Z^S)^2} \right]$$

With `'METHOD' = 'TRESCA'`, $S_n' = \|\sigma_{tran}^{lin}(t^{maxSn}) - \sigma_{tran}^{lin}(t^{minSn})\|$.

With `'METHOD' = 'TOUT_INST'`, $S_n' = \max_{t_1, t_2} \|\sigma_{tran}^{lin}(t_1) - \sigma_{tran}^{lin}(t_2)\|$.

For the two methods,

$$S_p = S_p^1{}' + S_p'' + S_p''' \quad \text{and} \quad S_p^{meca} = S_p^{meca,1}{}' + S_p'' + S_p^{meca}{}''' \quad \text{with}$$

$$S_p'' = \max_S \left[K_2 C_2 \frac{R}{I} \sqrt{(M_{XA} - M_{XB} \pm 2 M_X^S)^2 + (M_{YA} - M_{YB} \pm 2 M_Y^S)^2 + (M_{ZA} - M_{ZB} \pm 2 M_Z^S)^2} \right]$$

and $S_p''' = (K_3 C_3 - 1) S_{n,ther}' + (K_1 C_1 - 1) S_{n,pres}'$, $S_p^{meca}{}''' = (K_1 C_1 - 1) S_{n,pres}'$.

With `'METHOD' = 'TRESCA'` ,

$$S_{n,ther}' = \|\sigma_{ther}^{lin}(t^{maxSn}) - \sigma_{ther}^{lin}(t^{minSn})\| \quad \text{and} \quad S_{n,pres}' = \|\sigma_{pres}^{lin}(t^{maxSn}) - \sigma_{pres}^{lin}(t^{minSn})\|$$

$$S_p^1{}' = \|\sigma_{tran}(t^{maxSp}) - \sigma_{tran}(t^{minSp})\| \quad \text{and} \quad S_p^{meca,1}{}' = \|\sigma_{pres}(t^{maxSp}) - \sigma_{pres}(t^{minSp})\|$$

With `'METHOD' = 'T OUT_INST '` , one takes again the moments t_p^1 and t_p^2 who maximize the size S_n' and

$$S_{n,ther}' = \|\sigma_{ther}^{lin}(t_p^1) - \sigma_{ther}^{lin}(t_p^2)\| \quad \text{and} \quad S_{n,pres}' = \|\sigma_{pres}^{lin}(t_p^1) - \sigma_{pres}^{lin}(t_p^2)\| \; .$$

$$S_p^1{}' = \max_{t_1} \left(\max_{t_2} \|\sigma_{tran}(t_1) - \sigma_{tran}(t_2)\| \right) .$$

One takes again the moments t_p^3 and t_p^4 who maximize the size $S_p^1{}'$ and

$$S_p^{meca,1}{}' = \|\sigma_{pres}(t_p^3) - \sigma_{pres}(t_p^4)\|$$

Note:

In it tte part, $\sigma_{tran}(t) = \sigma_{ther}(t) + \sigma_{pres}(t)$.

15 Bibliography

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16 Description of the versions of the document

Version Aster	Author (S) Organization (S)	Description of the modifications
5	J.M. Proix, EDF-R&D/AMA	Initial text
7.4	J.M. Proix, EDF-R&D/AMA	Addition of the unit method
8.4	E. Crystal, EDF-R&D/AMA	Addition of `B3200_UNIT`
9.4	E. Crystal, EDF-R&D/AMA	- Addition of the calculation of the factor of starting (card 10429) - Modification of the formulation in fatigue for `B3200_UNIT` (card 12297)
10.4	E. Crystal, Chau H.T., EDF-R&D/AMA	- Addition of the method `KE_MIXTE` for `EVOLUTION` (card 12818)
13.1	S. Plessis, EDF-R&D/AMA	- Addition of `ZE200has` and `ZE200b` - Addition of environmental tiredness `EFAT`
13.3	S. Plessis, EDF-R&D/AMA	Creation of `B3200` who absorbs `B3200_UNIT` and allows to return of other forms of loading at the time