RCCM01 - Summarized operator

POST_RCCM:

This test is an elementary test of validation of the command POST_RCCM.

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

More precisely, the modelization A makes it possible to test options PM_PB, SN and FATIGUE_ZH210 for results of the type EVOLUTION.

The modelization B allows to test options PM_PB, SN and TIRES for results of the type UNITAIRE.

Key word KE_MIXTE of the fatigue analysis is tested in these two modelizations.

1 Problem of reference

1.1 Material properties

the properties material are the following ones:

1) Young modulus: $E=2.E+05\,MPa$;
2) Poisson's ratio: $\nu=0.3$;
3) thermal coefficient of thermal expansion: $\alpha=1.E-05\,m.°C^{-1}$.

The characteristics suitable for computation RCC-M are:

1) constant material for the computation of Ke : $n=0.2$ $m=2$;
2) Young modulus of reference: $E_{REFE}=2.E+05\,MPa$;
3) working stress: $Sm=200\,MPa$.

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

Note:

For the validation of the taking into account of the elastoplastic concentration factor Ke *, certain computations are carried out with a weaker working stress:* $Sm=50\,MPa$ *.*

1.2 Evolution of the stresses

the stresses on the segment of analysis are not calculated but are not read directly in an array. The only non-zero component of the tensor of the stresses is σ_{yy} . Three transients are considered, with or without thermal stresses:

Time	Forced mechanical			total			Forced Thermal stresses		
	X-coordinate			*X-coordinate*			*X-coordinate*		
	0	*1*	*2*	*0*	*1*	*2*	*0*	*1*	*2*
1.100		50	0.200.250			300.300.300			300
2.100.100			100	0.100		0.100.200			100
3.100.150			200.100		- 50	-100	200.100.100		
4.100.200			300	0	0	0.100.200			300

Table 1.2-1 : Definition of the stresses σ_{yy} (in MPa) for times of situation 1 according to the curvilinear abscisse

Time	Forced mechanical		
	X-coordinate		
	0	*1*	*2*
1	0	0	0
2.200		50	-100

Table 1.2-2 : Definition of the stresses σ_{yy} (in MPa) for times of situation 2 according to the curvilinear abscisse

Time	Forced mechanical			total			Forced Thermal stresses		
	X-coordinate			*X-coordinate*			*X-coordinate*		
	0	*1*	*2*	*0*	*1*	*2*	*0*	*1*	*2*
1	0	0	0	50	50	50	50	50	50
2.200		50	-100	0	50.100. 200			100	0

Table 1.2-3 **:** Definition of the stresses σ_{yy} (in MPa) for times of situation 3 according to the curvilinear abscisse

These transients do not aim representing a specific real transient, but at covering all the possible stresses (constant, linear or nonlinear evolution of the stress in the thickness).

2 Reference solution

2.1 Results of reference

2.1.1 Computation of Pm and the Pb

parameters Pm and Pb respectively represent the primary stress of membrane and the bending stress. Criteria must also be checked on the quantity ($Pm \pm Pb$), at the origin and the end of the segment of analysis.

Each one of these parameters can be calculated analytically from the data of the tensor of the stresses on the segment. Only the primary stresses must be taken into account. The user can is to only provide directly the mechanical stresses (situation 2 below); that is to say to only provide the total thermomechanical stresses and the forced related to the thermal loading, in which case those are cut off automatically (situations 1 and 3).

One indicates in the tables below the signed value of the parameters Pm and Pb , even if it is the norm of these quantities which is to be retained finally. That makes it possible to distinguish the origin and the end in computation from $Pm \pm Pb$, and to facilitate the computation of Sn in the following paragraph.

Situation 1 :

Time	Pm	Pb	$Pm-Pb$ **(origin)**	$Pm+Pb$ **(end)**
1	50.	-50.	+100.	0.
2.100	.	0.	100.	100.
3.150	.	50.	100.	200.
4.200	.	100.	100.	300.

Situation 2 and **Situation 3** :

Time	Pm	Pb	$Pm-Pb$ **(origin)**	$Pm+Pb$ **(end)**
1	0.	0.	0.	0.
2	50.	-150.	200.	-100.

2.1.2 Computation of Sn and Sn^* (modelization A)

the parameter Sn represents the amplitude of variation of the linear stress (average constraint $\pm$ bending stress) between two times of the transient considered. The parameter Sn^* represents the amplitude Sn calculated without taking into account stresses bending thermal.

The tables below present the values of Sn and Sn^* for the various combinations of times of each situation, in the frame of the modelization A (`TYPE_RESU_MECA = "EVOLUTION"`).

Situation 1 :

Sn *at the origin:* Sn *at the end:*

Instant 123410 150125 200202 550307 540				

Instant 12341 01502 25020 75150 30225 40				

Sn^* *in the beginning:*

Instant1 234102 002752 502075 503025 40				

Sn^* *at the end:*

Instant 12341 01007 55020 25150 30125 40				

Situation 2 :

Sn *at the origin:*

Instant 21200	

Sn *at the end:*

Instant 21100	

Situation 3 :

Sn *at the origin:*

Instant 21250	

Sn *at the end:*

Instant 21150	

Sn^* *in the beginning:*

Instant 21200	

Sn^* *at the end:*

Instant 21100	

2.1.3 Principle of the computation of the elementary factors of use (modelization B)

One illustrates below the computation of the factors of use in the frame of the modelization B (`TYPE_RESU_MECA = "UNITAIRE"`). One considers the combination of situations 1 and 3. One details the procedure of computation of the quantities Sn and Sp , for the origin of the segment only (the procedure is exactly the same one at the end and for the other combinations of situations).

One indicates by A and B the stabilized mechanical states of each situation and one notes doncet σ_1^A σ_1^B the mechanical stresses associated with the two states stabilized with situation 1; one makes in the same way for situation 3.

The thermal stresses are used only via their extrema (within the meaning of a norm of Tresca signed). One notes $\sigma^{ther}_{p,min}$ (resp. $\sigma^{ther}_{p,max}$) the minimal stress (resp. maximum) of the thermal transient associated with the situation p .

Computation of Sn : for the six possible combinations of states $pi-qj$ ($1A-3B, 1B-3B, 1B-1B$ …), 4 quantities are calculated: $\left|\sigma^i_p-\sigma^j_q+\sigma^{ther,lin}_{p,max}-\sigma^{ther,lin}_{q,min}\right|$ $\left|-\sigma^i_p+\sigma^j_q+\sigma^{ther,lin}_{p,max}-\sigma^{ther,lin}_{q,min}\right|$, $\left|\sigma^i_p-\sigma^j_q+\sigma^{ther,lin}_{q,max}-\sigma^{ther,lin}_{p,min}\right|$ and $\left|-\sigma^i_p+\sigma^j_q+\sigma^{ther,lin}_{q,max}-\sigma^{ther,lin}_{p,min}\right|$. Sn corresponds to the maximum of all these quantities.

For the combination of situations 1 and 3, there is for example the following table:

Combination	1A-3A	1A-3B	1B-3A	1B-3B	1A-1B	3A-3B
σ^I_p	100	100	100	100	100	0
σ^j_Q	0	200	0	200	100	200
$\sigma^{ther,lin}_{p,max}$	200	200	200	200	200	-
$\sigma^{ther,lin}_{p,min}$	50	50	50	50	50	-
$\sigma^{ther,lin}_{q,max}$	50	50	50	50	-	50
$\sigma^{ther,lin}_{q,min}$	0	0	0	0	-	0
$Méca+pMax-qMin$	300	100	300	100	150	250
$-Méca+pMax-qMin$	100	300	100	300	150	150
$Méca+qMax-pMin$	100	100	100	100	-	-
$-Méca+qMax-pMin$	100	100	100	100	-	-

Sn for the combination of situations 1 and 3 is worth thus 300. The elastoplastic concentration factor Ke is worth 1 then.

Computation of Sp: one takes again the same approach while being based this time on the not linearized thermal stresses. One initially determines, for each combination, the maximum enters $\left|\sigma^i_p-\sigma^j_q+\sigma^{ther}_{p,max}-\sigma^{ther}_{q,min}\right|$ and $\left|-\sigma^i_p+\sigma^j_q+\sigma^{ther}_{p,max}-\sigma^{ther}_{q,min}\right|$, that one notes $Sp1$; then that enters $\left|\sigma^i_p-\sigma^j_q+\sigma^{ther}_{q,max}-\sigma^{ther}_{p,min}\right|$ and $\left|-\sigma^i_p+\sigma^j_q+\sigma^{ther}_{q,max}-\sigma^{ther}_{p,min}\right|$ that one notes $Sp2$.

Then one selects the maximum of each one of these quantities on all the combinations, which one names again $Sp1$ and $Sp2$. The factor of use associated with the combination of situations is equal to the sum of the factors of uses associated with $Sp1$ and $Sp2$.

Combination	Méca +pM - qm	- Méca +pM - qm	Méca +qM - pm	- Méca +qM - pm	S p 1	S p 2	S p 1_max	S p 2_max	S alt	FU
1a-3a	300.100.150			50.300.150			**300.150.225**			4.5E-4
1a-3b	100.300		50.150.300			150				
1b-3a	300.10			50.300						

	0.150			.150						
1b-3b	100.300		50.150.300			150				
1a-1b	200.200		-	-	200	-	250.200			
3a-3b	250.150		-	-	250	-				

2.1.4 Computation of the factor of total use

For the modelization A, one builds a matrix of factors of use which gives the elementary factors of use for all the combinations of times of all the situations, obtained thanks to the values of Sp corresponding and to the curve of fatigue. The factor of total use is calculated by successively adding the maximum elementary factors of use until exhaustion of the numbers of occurrences of the situations.

By noting {1,2,3,4} four times of situation 1 and {5,6} two times of situation 2, one presents below the significant values of the matrix which makes it possible to obtain the factor of total use for the combination of situations 1 and 2, at the origin and the end of the segment.

Situation 1 + Situation 2 : origin

Instant_1	Instant_2	Sn	Sp	$Salt$	$N adm$	DOMMAGE	DOMMAGE_CUMU
1	5.300.300				150.3.3E3	3 E-4	3rd-4
2	3	25.100		50	1E4	1E-4	4th-4
5	6.200.200			100	5E3	2nd-4	**5th-4**

Situation 1 + Situation 2 : end

Instant_1	Instant_2	Sn	Sp	$Salt$	$N adm$	DOMMAGE	DOMMAGE_CUMU
1	6.400.400			200	2. 5E3	4th-4	4th-4
4	5.300.300			1 50.3.3	E3	3rd-4	**7th-4**

With `TYPE_KE=QUE_MIXTE`, one must obtain:

Situation 1 + Situation 2 : origin

Instant_1	Instant_2	Sn	Sp_{meca}	Sp_{ther}	Ke_{meca}	Ke_{ther}	$Salt$	DOMMAGE	DOMMAGE_CUMU
1	5.300		1 00.200		1	1.27	1.77E2	3.54E-4	3.54E-4
3	6	25.10 0.100			1	1	1E2	2nd-4	**5.54E-4**

Situation 1 + Situation 2 : end

Instant_1	Instant_2	Sn	Sp_{meca}	Sp_{ther}	Ke_{meca}	Ke_{ther}	$Salt$	DOMMAGE	DOMMAGE_CUMU
1	3.225.200			4 00	1	1.19	3..38E2	6.77E-4	6.77E-4
4	6.400.400			0	1	1.35	2E2	4 E-4	1.08E-3
2	5.150.100			0	1	1.09	5E1	1E-4	**1.18E-3**

For the modelization B and with the curve of fatigue simplified, the results of the analysis to fatigue according to RCCM_B3200 and FATIGUE must be (for 1 cycle of loading for the two situations):

Place	Situation_1	Situation_2	Sn	Sp	Ke	$Salt$	DOMMAGE

origin	1	2.250.400		1.200		4th-4
end	1	2.825	1200	2.5	1500	3rd-3

With TYPE_KE=QUE_MIXTE, one must obtain, at same times:

Place	Sn	Sp_{meca}	Sp_{ther}	Ke_{meca}	Ke_{ther}	$Salt$	**DOMMAGE**
origin	250.20 0.200			1	1.2208	222.08	4.4416E-4
end	825.70 0.400			2.5	1.5385	1182.7	2.3654E-3

2.1.5 Computation of the thermal ratchet

the criterion of the thermal ratchet gives the acceptable maximum value of the amplitude of variation of the thermal stresses σ_θ , from the data of the maximum of the membrane stress due to the pressure σ_m . It is supposed here that the stress due to the pressure is that of transient 1.

Two relations of the form $\sigma_\theta = f(\sigma_m, S_y)$ are proposed according to whether the temperature variation in the wall is supposed to be linear or parabolic. The two values are calculated.

Time	σ_m	σ_θ - linear Model	σ_θ - parabolic Model
1.100	.	400.	540.
2.150	.	200.	260.
3.100	.	400.	540.
4.200	.	0.	0.

2.2 Uncertainty on the analytical

solution Solution.

3 Modelization A

3.1 Characteristic of the modelization

No thermal computation or mechanics is carried out in this test: the tables of statements of stresses are directly provided to operator POST_RCCM .

3.2 Quantities tested and results

On this case simple test, all the results tested are in agreement with the reference solution:

- for the computation of PM and PB ;
- for the computation of SN and $SN*$;
- for the fatigue analysis with KE_MIXTE and KE_MECA ;
- with option TYPE_RESU=' VALE_MAX' as with option TYPE_RESU=' DETAILS “.

4 Modelization B

4.1 Characteristic of the modelization

No thermal computation or mechanics is carried out in this test: tables of statements of stresses are provided to operator `POST_RCCM` . Various times of the problem of reference are built by linear combination from unit stresses in the beginning, the medium and the end of the segment.

4.2 Quantities tested and results

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

- for the computation of PM and PB ;
- for the computation of SN and $SN*$;
- for the fatigue analysis with `KE_MIXTE` and `KE_MECA` ;
- with option `TYPE_RESU=' VALE_MAX'` as with option `TYPE_RESU=' DETAILS` '.

5 Summary of the results

the results are exact and show as operator POST_RCCM selects the quantities with treating correctly and correctly calculates the integrals (average on the segments) as well for the results of the type EVOLUTION as of type UNITAIRE.