Operator CALC_CHAMP

1 Goal

To create or supplement one result by calculating fields by element or with the nodes (forced, deformations,…).

The concept produced result either is created, or modified, i.e. the call to CALC_CHAMP is done in the following way:

```
resu = CALC_CHAMP   (  RESULT = resu…,  reuse = resu,…)
```

or

```
resu1 = CALC_CHAMP  (  RESULT = resu,…)
```

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2 Syntax

```
resu   [*] = CALC_CHAMP

          (  ◊  reuse = resu,
             ◊  MODEL =      Mo,                          [model]
             ◊  CHAM_MATER = chmater,                     [cham_mater]
             ◊  CARA_ELEM =  carac,                       [cara_elem]
             ◊  EXCIT = _F ( ♦  LOAD = l_charge,       [l_char_meca]
                             ◊  / COEF_MULT = cm,          [R]
                                / FONC_MULT = Fm,          [function]
                             # if result of the evol_noli type
                             ◊  TYPE_CHARGE =/   'FIXE_CSTE', [DEFECT]
                                             /  'FIXE_PILO',
                                             /  'SUIV',
                                             /  'DIDI'
                             # if not
                             ◊  TYPE_CHARGE =/   'FIXE_CSTE', [DEFECT]

                              # if result of the dyna_* type, *_gene,
*acou*
                             ◊ PHAS_DEG = / phas_deg       [R]
                                          / 0.             [DEFECT]
                             ◊ PUIS_PULS =/ puis_puls      [I]
                                          / 0              [DEFECT]
                             ◊ FONC_MULT_C =  / fonc_mult_c[function]
                             ◊ COEF_MULT_C =  / coef_mult_c[C]
                           )
             ◊  #  Selection of the meshs concerned with calculation
                /  ALL =     'YES',                       [DEFECT]
                /  GROUP_MA =   l_grma ,               [l_gr_maille]

             ◊  #  Selection of the sequence numbers
                /  TOUT_ORDRE =     'YES',
                /  NUME_ORDRE =     l_nuor ,              [l_I]
                /  LIST_ORDRE =     l_nuor ,              [listis]
                /  NUME_MODE  =     l_numo ,              [l_I]
                /  NOEUD_CMP  =     l_nomo ,              [l_K16]
                /  NOM_CAS    =     nocas  ,              [K16]
                /  INST =    l_inst ,                     [l_R]
                /  FREQ =    l_freq ,                     [l_R]
                /  LIST_INST =  l_inst ,                  [listr8]
                /  LIST_FREQ =  l_freq ,                  [listr8]

             ◊  |  CRITERION =      / 'RELATIVE',            [DEFECT]
                                    / 'ABSOLUTE',
                |  PRECISION =   / prec,
                                / 1.0E-6,                 [DEFECT]
```

 # options for linear mechanical results

```
             ♦  RESULT =  resu,
```

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options of calculation of the constraints (elements of continuous medium 2D and 3D)

◊ CONSTRAINT = | 'EFGE_ELGA'
| 'EFGE_ELNO'
| 'EFGE_NOEU'
| 'SIEF_ELGA'
| 'SIEF_ELNO'
| 'SIEF_NOEU'
| 'SIGM_ELGA'
| 'SIGM_ELNO'
| 'SIGM_NOEU'
| 'SIPM _ELNO'
| 'SIPO_ELNO'
| 'SIPO_NOEU'
| 'SIRO_ELEM'

options of calculation of the deformations

◊ DEFORMATION = | 'DEGE_ELGA'
| 'DEGE_ELNO'
| 'DEGE_NOEU'
| 'EPME_ELGA'
| 'EPME_ELNO'
| 'EPME_NOEU'
| 'EPSG_ELGA'
| 'EPSG_ELNO'
| 'EPSG_NOEU'
| 'EPSI_ELGA'
| 'EPSI_ELNO'
| 'EPSI_NOEU'
| 'EPVC_ELGA'
| 'EPVC_ELNO'
| 'EPVC_NOEU'

options of calculation of energies

◊ ENERGY = | 'DISS_ELEM'
| 'DISS_ELGA'
| 'DISS_ELNO'
| 'DISS_NOEU'
| 'ECIN_ELEM'
| 'ENEL_ELEM'
| 'ENEL_ELGA'
| 'ENEL_ELNO'
| 'ENEL_NOEU'
| 'ENTR_ELEM'
| 'EPOT_ELEM'
| 'ETOT_ELEM'
| 'ETOT_ELGA'
| 'ETOT_ELNO'
| 'ETOT_NOEU'

options of calculation of criteria

◊ CRITERIA = | 'EPEQ_ELGA'
| 'EPEQ_ELNO'
| 'EPEQ_NOEU'
| 'EPMQ_ELGA'

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```
                                    |   'EPMQ_ELNO'
                                    |   'EPMQ_NOEU'
                                    |   'SIEQ_ELGA'
                                    |   'SIEQ_ELNO'
                                    |   'SIEQ_NOEU'
```

options of interpolation and extraction of internal variables

```
◊  VARI_INTERNE =                   |   'VARC_ELGA'
```

options concerning properties calculation

```
◊  PROPRIETES =                  |   'MATT_ELGA'
                                 |   'MATT_ELEM'
```

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 # options for the nonlinear results (produced by STAT_NON_LINE or DYNA_NON_LINE):

♦ RESULT = resu, / [evol_noli]

options of calculation of the constraints (elements of continuous medium 2D and 3D)

◊ CONSTRAINT = | 'EFGE_ELGA'
| 'EFGE_ELNO'
| 'EFGE_NOEU'
| 'SIEF_ELNO'
| 'SIEF_NOEU'
| 'SIGM_ELGA'
| 'SIGM_ELNO'
| 'SIGM_NOEU'
| 'SIPO_ELNO'
| 'SIPO_NOEU'
| 'SIRO_ELEM'

options of calculation of the deformations

◊ DEFORMATION = | 'DEGE_ELGA'
| 'DEGE_ELNO'
| 'DEGE_NOEU'
| 'EPFD_ELGA'
| 'EPFD_ELNO'
| 'EPFD_NOEU'
| 'EPFP_ELGA'
| 'EPFP_ELNO'
| 'EPFP_NOEU'
| 'EPME_ELGA'
| 'EPME_ELNO'
| 'EPME_NOEU'
| 'EPMG_ELGA'
| 'EPMG_ELNO'
| 'EPMG_NOEU'
| 'EPSG_ELGA'
| 'EPSG_ELNO'
| 'EPSG_NOEU'
| 'EPSI_ELGA'
| 'EPSI_ELNO'
| 'EPSI_NOEU'
| 'EPSP_ELGA'
| 'EPSP_ELNO'
| 'EPSP_NOEU'
| 'EPVC_ELGA'
| 'EPVC_ELNO'
| 'EPVC_NOEU'

options of calculation of energies

◊ ENERGY = | 'DISS_ELEM'
| 'DISS_ELGA'
| 'DISS_ELNO'
| 'DISS_NOEU'
| 'ENEL_ELEM'
| 'ENEL_ELGA'

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```
                                |   'ENEL_ELNO'
                                |   'ENEL_NOEU'
                                |   'ENTR_ELEM'
                                |   'ETOT_ELEM'
                                |   'ETOT_ELGA'
                                |   'ETOT_ELNO'
                                |   'ETOT_NOEU'
```

options of calculation of criteria

```
◊  CRITERIA =                   |   'DERA_ELGA'
                                |   'DERA_ELNO'
                                |   'DERA_NOEU'
                                |   'ENDO_ELGA'
                                |   'ENDO_ELNO'
                                |   'ENDO_NOEU'
                                |   'EPEQ_ELGA'
                                |   'EPEQ_ELNO'
                                |   'EPEQ_NOEU'
                                |   'EPMQ_ELGA'
                                |   'EPMQ_ELNO'
                                |   'EPMQ_NOEU'
                                |   'INDL_ELGA'
                                |   'PDIL_ELGA'
                                |   'SIEQ_ELGA'
                                |   'SIEQ_ELNO'
                                |   'SIEQ_NOEU'
```

options of interpolation and extraction of internal variables

```
◊  VARI_INTERNE =               |   'VAEX_ELGA'
                                    ♦  NOM_VARI = (cf.  [#2.4.3.])
                                |   'VAEX_ELNO'
                                    ♦  NOM_VARI = (cf.  [#2.4.3.])
                                |   'VAEX_NOEU'
                                    ♦  NOM_VARI = (cf.  [ #2.4.3. ])

                                |   'VARC_ELGA'
                                |   'VARI_ELNO'
                                |   'VARI_NOEU'
```

options of calculation of hydraulic flows (elements THM)

```
◊  HYDRAULICS =                 |   'FLHN_ELGA'
```

options concerning properties calculation

```
◊  PROPRIETES =             |   'MATT_ELGA'
                            |   'MATT_ELEM'
```

 # thermal options

```
♦  RESULT =  resu,                                  /   [evol_ther]

◊  THERMIQUE=                   |   'FLUX_ELGA'
                                |   'FLUX_ELNO'
                                |   'FLUX_NOEU'
                                |   'HYDR_NOEU'
```

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```
                                |   'SOUR_ELGA'
                                |   'ETHE_ELEM'

        # acoustic options

        ♦  RESULT =  resu,                          /   [acou_harmo]
                                                        /   [mode_acou]

        ◊  ACOUSTICS =          |   'PRAC_ELNO'
                                |   'PRAC_NOEU'
                                |   'PRME_ELNO'
                                |   'INTE_ELNO'
                                |   'INTE_NOEU'


        # options for the generalized forces and nodal reactions

        ♦  RESULT =  resu,

        ◊  FORCE =              |   'FORC_NODA'
                                |   'REAC_NODA'

        # calculation of a field user

        ◊  CHAM_UTIL = _F (

           ♦  NOM_CHAM =   ncham,
           ♦  /  CRITERION =   |   'VMIS',
                               |   'INVA_2'
                               |   'TRACE',
              /  FORMULA   =   l_form,                  [formula]
              /  NORMALIZES       =   |   'L2',
                               |   'FROBENIUS'
           ♦  NUME_CHAM_RESU   =  digital,                  [I]

           ),

        ◊  TITLE = title,                                [l_Kn]
        ◊  INFORMATION =    /   1,                              [DEFECT]
                            /   2,
)
```

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2.1 Operands RESULTAT/MODELE/CHAM_MATER/CARA_ELEM/EXCIT

2.1.1 Operands RESULT

♦ RESULT = resu

Name of the structure of data result to enrich. This argument can be same as that used for the concept enriched by the operator, or a different name, which will create a new structure of data result.

NoticeS :

- *In the majority of the situations, the structure of data resu contains all the necessary information with the calculation of the options: the model, the field of material, characteristics elementary, loadings. Keywords MODEL , CHAM_MATER , CARA_ELEM and EXCIT are thus useless;*
- *An exception notable relates to however the structures of dynamic data resulting from DYNA_VIBRA for which the user must ensure itself the coherence of the keywords between the operator of calculation and CALC_CHAMP . An alarm informs some.*

2.1.2 Operands MODEL/CHAM_MATER/CARA_ELEM.

◊ MODEL = Mo

Name of the model on which the efforts are calculated, constraints, deformations, etc.
It is optional because it can be extracted the result.

◊ CHAM_MATER = chmater

Material field associated with the model Mo. This keyword is optional and must be provided only in exceptional cases (voluntary modification of material for example).

◊ CARA_ELEM = carac

Elementary characteristics associated with the model Mo if it contains elements of structure or if the isoparametric elements are affected by a local reference mark of anisotropy.
This keyword is optional because it can be extracted the result.

2.1.3 Keyword EXCIT

This keyword factor (optional) makes it possible to specify the thermal or mechanical loadings to use for the calculation of the options, instead of those which were useful in the structural analysis of data specified under the keyword RESULT.

The definition of this keyword is identical to that of the orders which built the structure of data resu : to see the orders MECA_STATIQUE [U4.51.01], STAT_NON_LINE [U4.51.03], DYNA_VIBRATED [U4.53.03].

2.2 Selection of the meshs concerned with calculation

Keywords ALL and GROUP_MA allow the user to choose the meshs on which it wishes to do his elementary calculations of postprocessing.

/ ALL = 'YES'

All the meshs (carrying finite elements) will be treated. It is the value by default.

/ GROUP_MA = l_grma

Only meshs included in l_grma will be treated.

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2.3 Selection of the sequence numbers

Use of the keywords TOUT_ORDRE, NUM_ORDRE, INST, FREQ is described in the document [U4.71.00].
If there are many sequence numbers, it can be more performing (in memory in particular) to call the order several times on sublists of the sequence numbers.

2.4 Localization of the fields

In the continuation of the document one will not explicitly specify the localization of the fields. Indeed, the localization is given in the name of the field (and thus of the option):

- Field by element: *_ELEM
- Field at the points of Gauss per element: *_ELGA
- Field with the nodes by element: *_ELNO
- Field with the nodes: *_NOEU

The fields, for the majority, are calculated natively at the points of Gauss (*_ELGA).

Fields with the nodes by element (*_ELNO) are obtained by extrapolation starting from the field at the points of Gauss (detailed method in [R3.06.03]).

Fields with the nodes (*_NOEU) are obtained starting from the fields with the nodes by element by making a simple arithmetic mean (not balanced by the size of the meshs) of the values recorded on the elements in a given node.

Notice 1:

*For the calculation of the equivalents, the fields with the nodes by element (*_ELNO) are not obtained by extrapolation starting from the field at the points of Gauss. Extrapolation is made on the stress field or of deformation then one calculates the field of equivalent.*

Notice 2:

The averages with the nodes of computed fields in local reference marks are licit only if the angles between these reference marks are weak. In the contrary case, they do not have a direction.

Notice 3:

When the keyword GROUP_MA is *informed for the calculation of an option *_NOEU, the arithmetic mean is made on the selected meshs. Thus this result is different from that obtained by doing a total calculation then restricted with the only selected meshs.*
Example: One considers a structure of which the shear stress σ_{xy} *is worth:*

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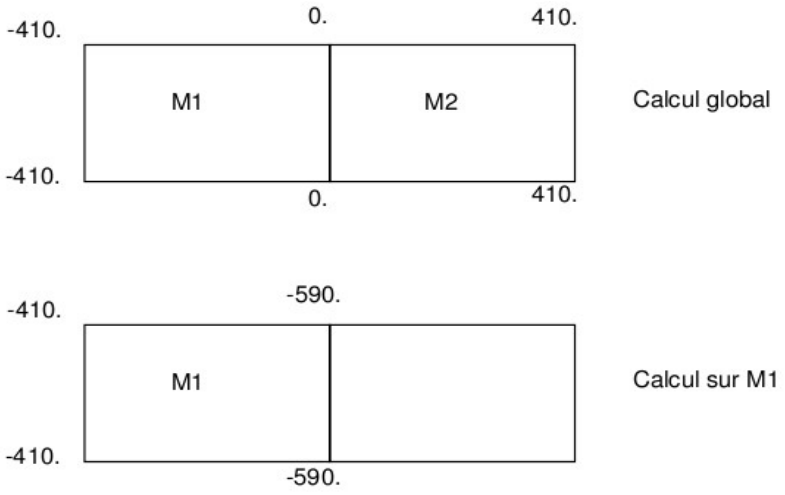

In total calculation, σ_{xy} is worthless on $M1 \cap M2$ like average of two opposite values. These values are far from being worthless, as calculation shows it on $M1$ only. The values on the border of the required field are thus to interpret with precaution.

For the elements of structures which have under-points (multifibre plates, hulls, beams, pipes), fields of the type *_ELGA and *_ELNO are calculated on all the under-points. To obtain a field on only one under-point (a layer and a level for example), an extraction should be made *via* the operator POST_CHAMP (options EXTR_COQUE, EXTR_PMF and EXTR_TUYAU). Moreover this intermediate operation is essential to calculate a field of the type *_NOEU for these elements of structure: fields of the type *_NOEU indeed never have under-point.

Finally the options of calculation of energy never produce fields under-point. Indeed for the elements of structure, the field is integrated in the thickness (integration made on the under-points).

2.5 Dependence of the fields

The calculation of a field can require the preliminary calculation of one or more other fields. Thus for example to calculate a field *_NOEU it is necessary to have the same field by element to the nodes *_ELNO and at the points of Gauss *_ELGA.

This dependence is solved by the operator CALC_CHAMP who carries out the calculation of the intermediate fields automatically. It is thus not necessary for the user to know the tree of dependence of the options.
Only the fields explicitly required by the user are saved in the structure of data result.

2.6 Operands for the mechanical options

2.6.1 Options of calculation of the constraints (Operand CONSTRAINT)

The components of the generalized effort and stress fields are detailed in the document [U2.01.05].

| 'EFGE_ELGA'
| 'EFGE_ELNO'
| 'EFGE_NOEU'

Calculation of the generalized efforts (elements of structure).

It acts is of an extraction of the efforts contained in the field SIEF_ELGA/STRX_ELGA (case of the elements of beams/pipes or discrete), that is to say of a calculation by integration of the constraints (case of the multifibre elements of beams or plates and hulls).

Notice 1:

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LE field EFGE_ELNO is not always an extrapolation of the field EFGE_ELGA ; in particular for a linear calculation where this field is calculated directly starting from displacement. This is why certain components are not calculated (put at zero) into non-linear.

Notice 2:

For the offset plates, the efforts are calculated in the "plan" of the grid. If one wishes these efforts in the average "plan" of the plate, the order should be used POST_CHAMP / COQUE_EXCENT.

| 'SIEF_ELGA'
| 'SIEF_ELNO'
| 'SIEF_NOEU'

Calculation of the state of stress (forced or efforts generalized according to modeling) starting from displacements (linear elasticity), to see [U2.01.05].

Note:

The field 'SIEF_ELGA' is calculated natively by the non-linear operators of resolution. It is always present in a structure of data result of the type evol_noli.

| 'SIGM_ELGA'
| 'SIGM_ELNO'
| 'SIGM_NOEU'

Calculation of the state of stress.

It is actually about an extraction of the constraints contained in the field SIEF_ELGA, to see [U2.01.05].

| 'SIPO_ELNO'
| 'SIPO_NOEU'

Calculation of the constraints in the section of beam broken up into contributions of each generalized effort.

List of the components of the field:

SN	Contribution of the normal effort N with σ_{xx} , $\sigma_{xx}=\frac{N}{A}$
SMFY	Contribution of the bending moment MFY with σ_{xx} , $\sigma_{xx}=z\frac{MFY}{I_Y}$
SMFZ	Contribution of the bending moment MFZ with σ_{xx} , $\sigma_{xx}=-y\frac{MFZ}{I_Z}$
SVY	Contribution of the shearing action VY with σ_{xy} , $\sigma_{xy}=\frac{VY\,a_Y}{A}$ a_Y coefficient of shearing in the direction y
SVZ	Contribution of the shearing action VZ with σ_{xz} , $\sigma_{xz}=\frac{VZ\,a_Z}{A}$ a_Z coefficient of shearing in the direction z
SMT	Contribution of the torque MX with σ_{yz} , $\sigma_{yz}=\frac{MX\,R_T}{J_x}$

The constraints above are expressed in the local reference mark, i.e. the principal reference mark of inertia of the cross-section [R3.08.01].

Values of σ_{xx} had at the two bending moments are the maximum values of those calculated in Y_{min} , Y_{max} on the one hand, and in Z_{min} , Z_{max} in addition (except for a general

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section where it is the user who provides the localization of the extremum with the keyword RY , RZ and RT *cf.* AFFE_CARA_ELEM [U4.42.01]).

For a rectangular section:

- one calculates the value of SMFY in $z=HZ/2$,
- one calculates the value of SMFZ in $y=HY/2$.

For a circular section, one calculates the values of SMFY and SMFZ for y and z being worth R .

| 'SIPM_ELNO'

Calculation of the constraints maximum and minimum in the section of beam starting from the generalized efforts (linear elasticity).
The same remark as for SIPO_ELNO applies a general section in the case of.

| 'SIRO_ELEM'

Calculation of the constraints projected on the skin of a volume (for example on the facings of a hydraulic work) or on the edge of a surface.

List of the components of the field:

SIG_NX SIG_NY SIG_NZ	Components σ_X , σ_Y , σ_Z in the total reference mark of $\vec{\sigma}_n$
SIG_N	Value SIG_N
SIG_TX SIG_TY SIG_TZ	Components σ_X , σ_Y , σ_Z in the total reference mark of $\vec{\sigma}_t$
SIG_T1X SIG_T1Y SIG_T1Z	Components σ_X , σ_Y , σ_Z in the total reference mark of $\vec{\sigma}_{t1}$
SIG_T1	Eigenvalue SIG_{T1}
SIG_T2X SIG_T2Y SIG_T2Z	Components σ_X , σ_Y , σ_Z in the total reference mark of $\vec{\sigma}_{t2}$
SIG_T2	Eigenvalue SIG_{T2}
SIG_TN	Value SIG_{TN}

These fields are evaluated starting from a stress field calculated on the voluminal meshs (MODELISATION= '3D' or '3D_SI') or surface (MODELISATION= 'D_PLAN' or 'D_PLAN_SI'). For voluminal meshs, the procedure is the following one:

- Identification of the voluminal meshs corresponding to the facets of the group of surface meshs. For each facet (surface mesh), one chooses the voluminal mesh located on the side "-" normal at the facet. If there is no voluminal mesh of with dimensions "-" facet, one does not calculate SIRO_ELEM on this facet;
- Recovery of the constraints 3D to assign them to the nodes faces;
- Average of each component of the tensor of the constraints in the center of the faces of elements;
- One places oneself in a reference mark composed by the normal vector $\vec{n}$ with the facet and the plan of the facet. A noted tensor is obtained $[\sigma]$.
- One evaluates $[\sigma]\vec{n}=\vec{\sigma}_n+\vec{\sigma}_t$, $\vec{\sigma}_n$ being a vector colinéaire with $\vec{n}$. $\vec{\sigma}_t$ is then a vector representing the shearing which is negligible in the case of the faces upstream/downstream of a stopping. One notes $\vec{\sigma}_n=SIG_N\vec{n}$ and SIG_N indicate the presence of traction if it is positive and of compression if it is negative.

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- One thus places oneself on the assumption of a negligible shearing $[\sigma]=\begin{bmatrix}\sigma_{2D} & 0\\ 0 & SIG_N\end{bmatrix}$ One seeks the vectors of principal constraints corresponding to σ_{2D} : the vectors are thus obtained $\vec{\sigma}_{t1}$ and $\vec{\sigma}_{t2}$ who are in the plan of the facet and the eigenvalues SIG_{T1} and SIG_{T2}

For surface meshs, the procedure of evaluation of the field SIRO_ELEM is the same one as for the voluminal meshs, by taking account of following conventions:

- $\vec{\sigma}_{t2}$ colinéaire with direction Z (a model D_PLAN being defined exclusively in the plan XY), $\vec{\sigma}_{t1}$ being thus in plan XY.
- SIG_NZ = SIG_TZ = 0. and SIG_T1Z = SIGT2X = SIGT2Y = 0.
- SIG_{TN} is the value of the shear stress in plan XY.

Notice 1:

In the case of facetsedges divings in volumesurface, the user has the possibility thanks to the order MODI_MAILLAGE/ORIE_PEAU_3D/GROUP_MA_VOLU or MODI_MAILLAGE/ORIE_PEAU_2D/GROUP_MA_SURF to reorientate this normal as it wishes it. It can thus choose the voluminal mesh which will be used for calculation.
So side "-", one finds a mesh of "joint" (which is voluminalsurface), the calculation of SIRO_ELEM is impossible because the constraints stored in the elements of joint do not allow calculation detailed above.

Notice 2:

If one informs TOUT=' OUI', the list of the meshs is filtered to keep only the meshs of skinedge.

2.6.2 Options of calculation of the deformations (Operand DEFORMATION)

The components of the fields of deformation are detailed in the document [U2.01.05].

| 'DEGE_ELGA'

Calculation of the deformations generalized starting from displacements. This option has direction only for the elements of structure of plate and pipe, not for the beams
The generalized deformations are obtained in the local reference mark of the element.

| 'DEGE_ELNO'
| 'DEGE_NOEU'

Calculation of the deformations generalized starting from displacements. This option has direction only for the elements of structure of beam, plate and pipe.
The generalized deformations are obtained in the local reference mark of the element.

| 'EPFD_ELGA'
| 'EPFD_ELNO'
| 'EPFD_NOEU'

Calculation of the deformations of creep of desiccation, for the models BETON_UMLV_FP and BETON_BURGER_FP.

| 'EPFP_ELGA'
| 'EPFP_ELNO'
| 'EPFP_NOEU'

Calculation of the deformations of clean creep associated with the model GRANGER_FP, with the model BETON_UMLV_FP or with the model BETON_BURGER_FP.

| 'EPME_ELGA'
| 'EPME_ELNO'

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| 'EPME_NOEU'

Calculation of the "mechanical" deformations starting from displacements. This calculation is done in theory of " **small displacements** ". The calculated deformations are equal to the total deflections minus the thermal deformations. The deformations of drying and hydration are also withdrawn as well as the deformations of pressure of fluid and the deformations unelastic. On the other hand the deformations of creep are not withdrawn.

$$\varepsilon_{ij}^{m}(u)=\frac{1}{2}\left(u_{i,j}+u_{j,i}\right)-\varepsilon^{th}$$

| 'EPMG_ELGA'
| 'EPMG_ELNO'
| 'EPMG_NOEU'

Calculation of the "mechanical" deformations starting from displacements. This calculation is done in theory of " **large displacements** ". The calculated deformations are equal to the total deflections minus the thermal deformations.

$$E_{ij}^{m}(u)=\frac{1}{2}\left(u_{i,j}+u_{j,i}+u_{k,i}u_{k,j}\right)-\varepsilon^{th}$$

| 'EPSG_ELGA'
| 'EPSG_ELNO'
| 'EPSG_NOEU'

Calculation of the deformations of Green-Lagrange.

$$E_{ij}(u)=\frac{1}{2}\left(u_{i,j}+u_{j,i}+u_{k,i}u_{k,j}\right)$$

| 'EPSI_ELGA'
| 'EPSI_ELNO'
| 'EPSI_NOEU'

Calculation of the deformations starting from displacements.

$$\varepsilon_{ij}(u)=\frac{1}{2}\left(u_{i,j}+u_{j,i}\right)$$

For the elements of structure, these deformations are obtained in the local reference mark of the element.

| 'EPSP_ELGA'
| 'EPSP_ELNO'
| 'EPSP_NOEU'

Calculation of the unelastic deformations starting from the field of displacement u, constraints σ, temperature T, possible unelastic deformations ε^{a}, and of the internal variables,

$$\varepsilon^{p}=\varepsilon(u)-A^{-1}\sigma-\varepsilon^{th}(T)-\varepsilon^{a}-\varepsilon^{fl}$$

where ε^{fl} is the clean deformation of creep of Granger.

| 'EPVC_ELGA'
| 'EPVC_ELNO'
| 'EPVC_NOEU'

Calculation of the deformations related to the variables of order. For the moment only the following components are defined:

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- thermal deformations: EPTHER_L, EPTHER_T, EPTHER_N such as: $\varepsilon_i^{th}=\alpha_i(T-T_{ref});i\in\{L,T,N\}$ (if the material is isotropic, the 3 components are equal), T being the temperature and α_i the thermal dilation coefficient;
- withdrawal of drying EPSECH (used for the laws describing the behavior of the concrete) $\varepsilon^{sech}=-K_{dessic}(S_{ref}-S)$, S being the variable of order drying and K_{dessic} the coefficient of withdrawal of desiccation;
- withdrawal of hydration EPHYDR (used for the laws describing the behavior of the concrete) $\varepsilon^{hydr}=-B_{endog}h$, h being the variable of order hydration, and B_{endog} being the endogenous coefficient of withdrawal.
- Deformation related to the pressure of fluid (for thermo-hydro-mechanics with a resolution by chaining): EPPTOT such as: $\varepsilon^{ptot}=\frac{b}{3K}p_{tot}$, p_{tot} is the variable of order total pressure of fluid, b is the coefficient of Biot, K is the modulus of elasticity.

| 'EPSL_ELGA'
| 'EPSL_ELNO'
| 'EPSL_NOEU'

Calculation of the deformations logarithmic curves.

$$\boldsymbol{E}_l(u)=\frac{1}{2}\left(\ln\left(\boldsymbol{F}^{\boldsymbol{T}}\boldsymbol{F}\right)\right)$$

2.6.3 Options of extraction of the internal variables (Operand VARI_INTERNE)

| 'VAEX_ELGA'
| 'VAEX_ELNO'
| 'VAEX_NOEU'

Extraction of **internal variables in THM only**.

The goal of this option is to be able post-to treat the internal variables in THM in a more convivial way. The principle of these fields is to extract from the field VARI_ELGA (or VARI_ELNO) (one and only one) the variable intern who interests us via a keyword without having to know his name in the field VARI_*.

List of the possible components of the field (the field has only one component, that chosen by the user via NOM_VARI):

DPORO	Variation of the porosity of material
DRHOLQ	Variation of the density of material
DPVP	Variation of the steam pressure
SATLIQ	Saturation of the liquid
EVP	Cumulated voluminal plastic deformation
IND_ETA	Mechanical indicator of state
D	Value of the damage
IND_END	Indicator of damage
TEMP_MAX	Maximum temperature
GAMP	Plastic deformation déviatoire cumulated
PCR	Critical pressure
SEUIL_HYD	Hydrous threshold
IND_HYD	Hydrous indicator of irreversibility
PCOHE	Pressure of cohesion
COMP_ROC	Behavior of the rock
SEUIL_ISO	Isotropic threshold
ANG_DEV	Angle of the threshold déviatoire
X11	Components of the kinematic tensor of work hardening

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X22	Components of the kinematic tensor of work hardening
X33	Components of the kinematic tensor of work hardening
X12	Components of the kinematic tensor of work hardening
X13	Components of the kinematic tensor of work hardening
X23	Components of the kinematic tensor of work hardening
DIST_DEV	Distance standardized with the threshold déviatoire
DEV_SUR_CRIT	Relationship between the threshold déviatoire and the critical threshold deviatoric
DIST_ISO	Distance standardized with the isotropic threshold
NB_ITER	Iteration count internal
STOP	Value of the local test of stop of the iterative process
NB_REDE	Number of local recutting of the step of time
SIGN	Sign of the contracted product of the deviatoric constraint by the deviatoric plastic deformation

◊ NOM_VARI = / nom_vari, [TXM]

Name of the internal variable.

Notice 1:

When the variable to be extracted is not part of the internal variables of the laws concerned, an alarm is emitted but the field is affected all the same with R8VIDE () (number very large reality about 1.0E+308).

Notice 2:

The field VAEX_NOEU is calculated from VAEX_ELNO and not by extraction of the field VARI_NOEU.

| 'VARC_ELGA'

Calculation of the variables of orders having been used for a mechanical calculation.

List of the components of the field:

TEMP	Cf documentation of the order AFFE_MATERIAU [U4.43.03] for the definition of each component.
HYDR	
SECH	
CORR	
IRRA	
PTOT	
DIVU	
NEUT1	
NEUT2	

Note:

All the components are systematically calculated. The variables which were not defined are initialized with the value R8VIDE () (Nombre real very large about 1.0E+308).

| 'VARI_ELNO'
| 'VARI_NOEU'

Calculation of the internal variables.

List of the components of the field:

V1	Variable interns 1
...	
VI	Variable interns I
...	
Vn	Internal variable N

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The number and the type of these internal variables are specific to each model of behavior (*cf.* [U4.51.11]).

Note:
The field 'VARI_ELGA' is calculated natively by the non-linear operators of resolution. It is always present in a SD result of the type evol_noli.

2.6.4 Options of calculation of energy (Operand ENERGY)

| 'DISS_ELEM'

Calculation of the energy dissipated by the damage. The field obtained has only one component of name 'ENDO'.

List of the components of the field:

ENDO	Energy dissipated by the damage

Note:
Valid only for the elements DKTG and the law GLRC_DM. Its expression is given in [R7.01.32].

| 'DISS_ELGA'
| 'DISS_ELNO'
| 'DISS_NOEU'

Calculation of the density of energy dissipated by the damage. The field obtained has only one component of name 'ENDO'.

List of the components of the field:

ENDO	Energy dissipated by the damage

Note:
Valid only for the elements DKTG and the law GLRC_DM. Its expression is given in [R7.01.32].

| 'ECIN_ELEM'

Calculation of the kinetic energy.

$$E_c = \frac{1}{2} m v^2$$

List of the components of the field:

TOTAL	Kinetic energy
Additional components for the plates and hulls:	
MEMBRANE INFLECTION	Contributions to the kinetic energy (cf [R3.07.03])
Additional components for the curved beams:	
PLAN_XY PLAN_XZ	Contributions to the kinetic energy (cf [R3.08.01])
Additional components for the discrete ones:	
DX DY DZ DRX DRY MARTINI DRZ	Contributions to the kinetic energy

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| 'ENEL_ELEM'

Calculation of elastic energy.

$$E_p = \frac{1}{2} \sigma \, A^{-1} \sigma$$

List of the components of the field:

TOTAL	Elastic energy
Additional components for the plates and hulls: Contributions to elastic energy (cf [R3.07.03])	
MEMBRANE INFLECTIO N SHEAR COUPL_MF	Elastic energy out of membrane Elastic energy in inflection Elastic energy in shearing Elastic energy of coupling membrane-inflection

Note:

Into non-linear (STAT_NON_LINE, DYNA_NON_LINE,...) components SHEAR and COUPL_MF are worthless.

| 'ENEL_ELGA'
| 'ENEL_ELNO'
| 'ENEL_NOEU'

Calculation of the density of energy elastic.

List of the components of the field:

TOTAL	Elastic energy
Additional components for the plates and hulls: Contributions to elastic energy (cf [R3.07.03])	
MEMBRANE INFLECTIO N SHEAR COUPL_MF	Elastic energy out of membrane Elastic energy in inflection Elastic energy in shearing Elastic energy of coupling membrane-inflection

Note:

Into non-linear (STAT_NON_LINE, DYNA_NON_LINE,...) components SHEAR and COUPL_MF are worthless.

| 'ENTR_ELEM'

Calculation of the modified elastic energy of traction. In breaking process, it may be that one is need to consider an energy elastic known as of traction, thus the idea consists in calculating one modified elastic energy, allowing to destroy the participation of spherical compression and compression according to each clean directions of deformation. Thus elastic energy becomes:

$$E_{el}^{traction} = \frac{\lambda}{2} H\left(tr(\epsilon)\right) tr(\epsilon)^2 + \mu \sum_{i=1}^{3} H(\epsilon_i) \epsilon_i^2$$

where H represent the Heaviside function,
ϵ represent the tensor of the elastic strain,
ϵ_i represent the principal elastic strain.

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List of the components of the field:

TOTAL	Elastic energy modified traction

Note:

For the moment, only valid in small deformations (DEFORMATION = SMALL or DEFORMATION = PETIT_REAC).

| 'EPOT_ELEM '

Calculation of the potential energy of deformation, starting from the field of displacement u and of the fields of temperature T :

List of the components of the field:

TOTAL	Potential energy
Additional components for the plates and hulls:	
MEMBRANE INFLECTION	Contributions to the potential energy (cf [R3.07.03])
Additional components for the right beams:	
TRAC_COM TORSION FLEX_Y FLEX_Z	Contributions to the potential energy (cf [R3.08.01])
Additional components for the curved beams:	
PLAN_XY PLAN_XZ	Contributions to the potential energy (cf [R3.08.01])
Additional components for the discrete ones:	
DX DY DZ DRX DRY MARTINI DRZ	Contributions to the potential energy

- for the elements of continuous mediums 2D and 3D:

$$E_{pot}=\frac{1}{2}\int_{element}\boldsymbol{\varepsilon}(U).\mathbf{A}.\boldsymbol{\varepsilon}(U)dv-\int_{element}\boldsymbol{\varepsilon}(U).\mathbf{A}.\boldsymbol{\varepsilon}^{th}(U)dv+\frac{1}{2}\int_{element}\boldsymbol{\varepsilon}^{th}(U).\mathbf{A}.\boldsymbol{\varepsilon}^{th}(U)dv$$

- for the elements of beams:

$$E_{pot}=\frac{1}{2}u^{T.}\mathbf{K}_e.u-u^{T.}\mathbf{B}^T.\mathbf{A}.\boldsymbol{\varepsilon}^{th}+\frac{1}{2}\boldsymbol{\varepsilon}^{th.}\mathbf{A}.\boldsymbol{\varepsilon}^{th}$$

- for the elements of plates and hulls:

$$E_{pot}=\frac{1}{2}u^{T}.\mathbf{K}_e.u-u^{T}.\mathbf{B}^T.\mathbf{A}.\boldsymbol{\varepsilon}^{th}$$

| 'ETOT_ELEM '

Calculation of the increment of total deformation energy enters the moment running and the previous moment.

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List of the components of the field:

TOTAL	Increment of total deformation energy

| 'ETOT_ELGA'
| 'ETOT_ELNO'
| 'ETOT _NOEU'

Calculation of the increment of density of total deformation energy enters the moment running and the previous moment.

List of the components of the field:

TOTAL Increment of total deformation energy

2.6.5 Options of calculation of criteria (Operand CRITERIA)

| 'DERA_ELGA'
| 'DERA_ELNO'
| 'DERA_NOEU'

Calculation of the local indicator of discharge and indicator of loss of radiality [R4.20.01].

List of the components of the field:

DCHA_V	Indicator of discharge calculated on the deviative tensor of the constraints
DCHA_T	Indicator of discharge calculated on the total tensor of the constraints
IND_DCHA	Indicator allowing to know if the discharge would remain elastic or if there would be a risk of plasticization if a pure kinematic work hardening were used
VAL_DCHA	In the case of indicate the proportion of exit of the criterion abusive discharge
X11 X22 X33 X12 X13 X23	Components of the kinematic tensor used for the calculation of IND_DCHA
RADI_V	Indicator of the variation of the direction of the constraints between the moments t and $t+\Delta t$
ERR_RADI	Error η had with the discretization in time, directly connected to the rotation of the normal on the surface of load

DCHA_V and DCHA_T express, in the two cases, the relative variation of the standard of the constraints within the meaning of Von Misès: $I_1=\frac{\|\boldsymbol{\sigma}(M,t+\Delta t)\|-\|\boldsymbol{\sigma}(M,t)\|}{\|\boldsymbol{\sigma}(M,t+\Delta t)\|}$, the standard being function of the behavior (isotropic work hardening or linear kinematics)

IND_DCHA can take the following values:
- 0 : unconstrained initial value;
- 1 : if elastic load;
- 2 : if plastic load;
- -1 : if licit elastic discharge (whatever the type of work hardening);
- -2 : if abusive discharge (one would have plasticized with a kinematic work hardening).

RADI_V is given by the following relation:

$$I_2=1-\frac{|\boldsymbol{\sigma}(M,t).\Delta\boldsymbol{\sigma}|}{\|\boldsymbol{\sigma}(M,t)\|\|\Delta\boldsymbol{\sigma}\|}$$

This quantity is worthless when the radiality is preserved during the increment of time.

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ERR_RADI is the angle enters $\boldsymbol{n}^-$, the normal with the criterion of plasticity at the beginning of the step of time (urgent t^-), and $\boldsymbol{n}^+$, the normal with the criterion of plasticity calculated at the end of the step of time (urgent t^+) in the following way:

$$\eta = \frac{1}{2}\|\Delta \boldsymbol{n}\| = \frac{1}{2}\|\boldsymbol{n}^+ - \boldsymbol{n}^-\| = \left|\sin\left(\frac{\alpha}{2}\right)\right|$$

That provides a measurement of the error (also used to refine the step of time [U4.51.11]. This criterion is operational for the elastoplastic behaviors of Von Mises with work hardening isotropic, kinematic linear and mixed: VMIS_ISOT_LINE , VMIS_ISOT_TRAC , VMIS_ISOT_PUIS , VMIS_CINE_LINE , VMIS_ECMI_LINE , VMIS_ECMI_TRAC, and for the behaviors élasto-visco-plastics of Chaboche: VMIS_CIN1_CHAB, VMIS_CIN2_CHAB, VMIS_CIN2_MEMO, VISC_CIN1_CHAB, VISC_CIN2_CHAB, VISC_CIN2_MEMO.

Note:

The calculation of these options requires to compare the stress fields with the moments t_i and t_{i+1}. The result is arranged with the sequence number associated with the moment t_i.

The indicator of discharge is calculated by: $ID = \frac{\|\boldsymbol{\sigma}_{i+1}\| - \|\boldsymbol{\sigma}_i\|}{\|\boldsymbol{\sigma}_{i+1}\|}$.

By default, calculation is done for the sequence numbers 1 with $n-1$. But if one specifies the list of moment (with "holes" possibly), calculation will relate to only the required moments but it will always compare the moment t_i with the moment t_{i+1} in the list of the moments having been used to do the non-linear calculation.

| 'ENDO_ELGA'
| 'ENDO_ELNO'
| 'ENDO_NOEU'

Calculation of the damage d starting from the tensor of the constraints and cumulated plastic deformation p .

List of the components of the field:

TRIAX	Rate of triaxiality
SI_ENDO	Equivalent constraint of damage of Lemaître-Sermage
COENDO	Constraint of damage of Lemaître-Sermage standardized
DOM_LEM	Damage of Lemaître-Sermage

The rate of triaxiality α is given by the following relation:

$$\alpha = \frac{\sigma_h}{\sigma_{eq}}$$

and the equivalent constraint of damage σ^* :

$$\sigma^* = \sigma_{eq}\sqrt{\frac{2}{3}(1+\nu)+3(1-2\nu)\alpha^2}$$

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$$\mathbf{s} = \boldsymbol{\sigma} - \frac{1}{3} tr(\boldsymbol{\sigma}) \cdot \mathbf{Id}$$

with: $\sigma_{eq} = \sqrt{\frac{3}{2} \mathbf{s} : \mathbf{s}}$

$$\sigma_h = \frac{1}{3} tr(\boldsymbol{\sigma})$$

The kinetics of damage is given by the law of Lemaître-Sermage:

$$\dot{d} = \left[\frac{Y}{S} \right]^s \dot{p} \text{ if } p \geq p_{seuil} \text{ with } Y = \frac{\sigma^{*2}}{2E(1-D)^2}$$

where S and s are coefficients characteristic of material and p_{seuil} the threshold of damage related to the energy stored in material (if $s=1$ one obtains the classical law of Lemaître).

| 'EPEQ_ELGA'
| 'EPEQ_ELNO'
| 'EPEQ_NOEU'
| 'EPMQ_ELGA'
| 'EPMQ_ELNO'
| 'EPMQ_NOEU'
| 'EPGQ_ELGA'
| 'EPGQ_ELNO'
| 'EPGQ_NOEU'

Calculation of the equivalent deformations:

Fields EPEQ_* are calculated starting from the fields EPSI_* (deformations in small displacement), fields EPGQ_* are calculated starting from the fields EPSG_* (deformations of Green-Lagrange) and fields EPMQ_* are calculated starting from the fields EPME_* (mechanical deformations).

List of the components of the field:

INVA_2	Equivalent deformation of Von Mises
PRIN_1 PRIN_2 PRIN_3	Principal deformations, lines in the ascending order
INVA_2SG	Equivalent deformation of Von Mises signed by the trace of ε
VECT_1_X VECT_1_Y VECT_1_Z VECT_2_X VECT_2_Y VECT_2_Z VECT_3_X VECT_3_Y VECT_3_Z	Principal directions

The equivalent deformation of Von Mises is given by the following expression:

$$\text{INVA\_2} = \sqrt{\frac{2}{3} dev(\boldsymbol{\varepsilon})_{ij} dev(\boldsymbol{\varepsilon})_{ji}} \text{ with } dev(\boldsymbol{\varepsilon})_{ij} = \varepsilon_{ij} - \frac{1}{3} tr(\boldsymbol{\varepsilon}) \delta_{ij}$$

Note:

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It is noted that the equivalent deformations obtained from EPSI_* and EPME_* are identical. Indeed, the difference between the two tensors is a spherical tensor (thermal deformation). Like equivalent deformation is obtained starting from the second invariant of the diverter, the spherical tensor " disappears " when the diverter is taken.

| 'INDL_ELGA'

Calculation of the indicator of localization, based on the acoustic tensor (criterion of RICE).

List of the components of the field:

	Indicator of localization
INDEX	0 if $det(N.H.N)>0$
	1 if not, which corresponds has the initiation of the localization
DIR1	First normal at the zone of localization
DIR2	Second normal at the zone of localization
DIR3	Third normal at the zone of localization
DIR4	Fourth normal at the zone of localization

This indicator defines a state from which the local problem of integration of the behavior loses its character of unicity. It is defined by: $det(N.\mathbf{H}.N)\leq 0$, where $\mathbf{H}$ appoint the tangent operator and N the normal with the directions of localization.

Note:

The method is developed only in the case $2\mathrm{D}$ and for the laws of behavior of the type DRUCK_PRAGER and HUJEUX.

| 'PDIL_ELGA'

Calculation of the module of rigidity of microphone-dilation.

List of the components of the field:

A1_LC2	Module of rigidity of microphone-dilation

The option PDIL_ELGA provides within the framework of the mediums of second gradient of dilation the value of the module A1_LC2, allowing to control the periodicity of the noncommonplace solution of the initially homogeneous problem [R5.04.03].

The calculation of A1_LC2 is obtained via the evaluation of a function depending on the geometrical orientation of the material band considered. The angular discretization currently imposed is equal to $0.1\,°$.

Note:

The method is developed only for the laws of behavior of the type DRUCK_PRAGER and HUJEUX.

| 'SIEQ_ELGA'
| 'SIEQ_ELNO'
| 'SIEQ_NOEU'

Calculate calculated constraints equivalent starting from the stress fields.

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List of the components of the field:

VMIS	Equivalent constraint of Von Mises
TRESCA	Constraint of Tresca
PRIN_1 PRIN_2 PRIN_3	Principal constraints, lines in the ascending order
VMIS_SG	Equivalent constraint of Von Mises signed by the trace of σ
VECT_1_X VECT_1_Y VECT_1_Z VECT_2_X VECT_2_Y VECT_2_Z VECT_3_X VECT_3_Y VECT_3_Z	Principal directions
TRSIG	Trace of σ
TRIAX	Rate of triaxiality

The equivalent constraint of Von Mises is given by the following expression:

$$\text{VMIS}=\sqrt{\frac{3}{2}s_{ij}s_{ji}} \text{ with } s_{ij}=\sigma_{ij}-\frac{1}{3}tr(\boldsymbol{\sigma})\delta_{ij}$$

The rate of triaxiality is given by the following expression:

$$\text{TRIAX}=\frac{\text{TRSIG}}{3\times\text{VMIS}}$$

2.6.6 Option of calculation of hydraulic flows (Operand HYDRAULICS)

| 'FLHN_ELGA'

Calculation of hydraulic flows in THM $\Phi_{ij}=\boldsymbol{M}_{ij}.\boldsymbol{\nu}$ on the elements of edge (2D or 3D) starting from the vector flow with the nodes.
$\boldsymbol{M}_{ij}$ is the hydraulic vector flow of the component $\boldsymbol{ij}$.

List of the components of the field:

FH11	
FH22	
FH12	
FH21	

2.6.7 OptionS dependent on the parameters of calculation (Operand PROPRIETES)

| 'MATT_ELGA'
| 'MATT_ELEM'

Recovery of the values of the elastic parameters materials E , NAKED and RHO with taking into account of the dependence to the variables of order and the moment of calculation.

For the field MATE_ELGA, one calculates the values at each point of Gauss, for the field MATE_ELEM, one calculates the values with the barycentre of the element (family FPG1).

For the field MATE_ELGA and elements of absorbing border (3D_ABSO, D_PLAN_ABSO) the space coordinates taken into account are those of the barycentre of the element (as in the

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other options of calculation). The values at each point of Gauss are thus always equal between them and also with the values of the field MATE_ELEM.

2.7 Operands for the thermal options

2.7.1 Operand THERMICS

| 'FLUX_ELGA'
| 'FLUX_ELNO'
| 'FLOW_NOEU'

Calculation of the heat flows starting from the temperature.

List of the components of the field:

FLOW FLUY FLUZ	Heat flow in the three directions of space (in the average layer for the hulls)
Additional components for the hulls:	
FLUX_INF FLUY_INF FLUZ_INF	Heat flow in the three directions of space in lower skin
FLUX_INF FLUY_INF FLUZ_INF	Heat flow in the three directions of space in higher skin

| 'HYDR_NOEU'

Calculation of the hydration.

List of the components of the field:

HYDR	Hydration

Note:

The field 'HYDR_ELNO' is calculated natively by the non-linear operator of thermics THER_NON_LINE for the modeling of the concrete [R7.01.12].

| 'PENNYR_ELGA'

Calculation of a source of heat.

List of the components of the field:

SOUR	Source of heat

This source is calculated starting from an electric potential via the law of Ohm. This electric potential must be calculated by the operator THER_LINEAIRE [U4.54.01] by making the analogies necessary. This source can be then used in a thermal calculation via the keyword SOUR_CALCULEE order AFFE_CHAR_THER [U4.44.02].

| 'ETHE_ELEM'

Calculation of thermal energy to balance starting from the field of temperature T.

List of the components of the field:

TOTAL	Thermal energy

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2.8 Operands for the acoustic options

2.8.1 Operand ACOUSTICS

| 'INTE_ELNO'
| 'INTE_NOEU'

Calculation of the acoustic intensity. The definitions are in [R4.02.01].

List of the components of the field:

INTX_R	Acoustic intensity, real part according to axis X
INTY_R	Acoustic intensity, real part according to the axis there
INTZ_R	Acoustic intensity, real part according to axis Z
INTX_I	Acoustic intensity, imaginary part according to axis X
INTY_I	Acoustic intensity, imaginary part according to the axis there
INTZ_I	Acoustic intensity, imaginary part according to axis Z

| 'PRAC_ELNO'
| 'PRAC_NOEU'

Calculation of the pressure to the nodes partly real, imaginary part and decibels.

List of the components of the field:

PRES_I	Acoustic pressure, real part
PRES_R	Acoustic pressure, imaginary part
DB	Acoustic pressure in decibel

| 'PRME_ELNO'

Calculation of the pressure to the nodes for the elements FLUID.

List of the components of the field:

DB	Acoustic pressure in decibel

2.9 Operand for the nodal forces and reactions

2.9.1 Operand FORCE

| 'FORC_NODA'

Calculation of the nodal forces generalized starting from the constraints at the points of Gauss.

List of the components of the field:

DX DY DZ	Nodal forces
Additional components for the elements of structure:	
DRX DRY MARTINI DRZ	Nodal forces (moments)

The nodal forces correspond to the direction finite elements with the interior forces taking part in the equilibrium equations. The calculation of the generalized nodal forces $\mathbf{F}_K$ is done in the following way:

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$$\sum_K \mathbf{F}_K . \mathbf{v}_K = \int_\Omega \boldsymbol{\sigma} . \boldsymbol{\varepsilon}(\mathbf{v}_K) d\Omega = \sum_K \int_K \boldsymbol{\sigma}^K . \boldsymbol{\varepsilon}(\mathbf{v}_K) dK = \sum_K \int_K \boldsymbol{\sigma}^K . \mathbf{B} . \mathbf{v}_K dK$$

with $\boldsymbol{\sigma}^K$ constraints at the points of Gauss of the element K ;

$\mathbf{B}$ the operator finite elements of generalized deformations (matrix connecting the deformations of the 1er order with generalized displacements);

$\mathbf{v}_K$ generalized unit elementary displacement.

From where: $\mathbf{F}_K = \left\{ \int_K {}^t\mathbf{B} . \boldsymbol{\sigma}^K dK \right\}$.

The dimension of the nodal forces is dual of that of $\mathbf{v}_K$ to give a work (in Joules).

For the elements of beam and the elements discrete, the constraints at the points of Gauss are in fact the nodal efforts generalized in the reference mark of the element (obtained by the product of the matrix of rigidity of the element by displacement and by taking account of the efforts of thermal origin and the efforts distributed). The calculation of the nodal forces is done by projecting the nodal efforts contained in the field of reference symbol 'SIEF_ELGA' in the total reference mark. The summation above on the elements applies then. Components DX, DY and DZ the forces give and DRX, DRY MARTINI and DRZ moments.

For the axisymmetric elements, integration in θ is done on a sector of $1 radian$. If one wants the integral of the surface effort on all the disc it is thus necessary to multiply by 2π .

For the elements in plane deformation, is calculated on a tape of width unit. The calculated nodal forces are thus by way of forces per unit of length. If one wants to calculate the nodal forces being exerted on a structure of width l, it is necessary to multiply the result in D_PLAN by l, with this close the assumption of plane deformation is not valid close to the two faces. There will be thus an approximate result.

For the solid elements (3D, 2D and bars), them FORC_NODA in general have the dimension of a force. It is about a field on the nodes of the grid where the value in a node is obtained starting from the constraints calculated on the convergent elements with this node, thus their values thus vary when the grid changes. In the absence of loading distributed, balance imposes their nullity in an interior node, while they correspond to the reaction on the supports where a kinematic relation is imposed (case of an imposed displacement).

In the case of hulls, components DX, DY and DZ they give FORC_NODA (of dimension of a force) in the total reference mark of the grid. These components are built with the normal efforts and cutting-edges in the hull. Components DRX, DRY MARTINI and DRZ they give FORC_NODA (of one moment dimension) in the total reference mark of the grid, built with the bending moments in the hull. In the case of behaviors homogéinésé of standard hull ELAS_COQUE, it is preferable to look at EFGE_NOEU.

In (thermo) hydro-mechanical, cf § 8, [R7.01.10], the generalized nodal forces associated with each component correspond to the mechanical forces and flows. If one notes $\mathbf{Q}^T \boldsymbol{\sigma}_0$ the result of FORC_NODA, for the hydraulic equations, then for a step of time Δt, one a:

$$\int_\Omega \mathbf{Q}^T \boldsymbol{\sigma}_0 \cdot p^* d\Omega = -\Delta t \int_\Omega \mathbf{M}^- \cdot \nabla p^* d\Omega$$

Note:

To note that flows are taken at the moment t^- because of θ - diagram employed, cf [R7.01.10].

In FORC_NODA :

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- with the degree of freedom PRE1 in saturated for example is associated water flow $-\Delta t \int_{\Omega} \left(\mathbf{M}_{vp} + \mathbf{M}_{w} \right) \nabla p^{*} d\Omega$
- with the degree of freedom PRE2 in unsaturated flow with the gas component is associated $-\Delta t \int_{\Omega} \left(\mathbf{M}_{ad} + \mathbf{M}_{as} \right) \cdot \nabla p^{*} d\Omega$
- with the degree of freedom TEMP the heat flux is associated $-\Delta t \int_{\Omega} \mathbf{q} \cdot \nabla T^{*} d\Omega$

with $\mathbf{q}$ heat flux and $\mathbf{M}_{w}$, $\mathbf{M}_{vp}$, $\mathbf{M}_{as}$ and $\mathbf{M}_{ad}$ hydraulic flows of liquid water, the vapor, the air (or all other composing) dry and of the air dissolved in the liquid. These data correspond respectively to the constraints generalized of *Code_Aster* $M_1^1, M_1^2, M_2^1, M_2^2$, cf § 2.2, [R7.01.10].

| 'REAC_NODA'

Calculation of the nodal forces of reactions generalized with the nodes, the constraints at the points of Gauss and of the loadings.

List of the components of the field:

DX DY DZ	Nodal reactions
Additional components for the elements of structure:	
DRX DRY MARTINI DRZ	Nodal reactions (moments)

The generalized nodal reactions correspond to the direction finite elements with the forces exerted on the supports (boundary conditions) taking part in the equilibrium equations.

In statics, for the concepts result of the type evol_elas, mult_elas, fourier_elas or evol_noli, the calculation of the generalized nodal reactions $\mathbf{R}_K$ is done by:

$$\sum_K \mathbf{R}_K . \mathbf{v}_K = \int_{\Omega} \boldsymbol{\sigma} . \boldsymbol{\varepsilon}(\mathbf{v}_K) d\Omega - \mathbf{L}(\mathbf{v}_K)$$

with $\mathbf{v}_K$ generalized unit elementary displacement,

$$\mathbf{L}(\mathbf{v}_K) = \int_{\Omega} \mathbf{f} \cdot \mathbf{v}_K d\Omega + \int_{\Gamma} \mathbf{F}_s \cdot \mathbf{v}_K d\Gamma + \sum_i \mathbf{F}_i \cdot \mathbf{v}_{Ki}$$

where $\mathbf{f}$ are the voluminal forces,

$\mathbf{F}_s$ surface generalized forces,

$\mathbf{F}_i$ specific forces generalized with the node i.

The vector of the nodal reactions generalized on the element K is thus obtained starting from the generalized nodal forces:

$$\mathbf{R}_K = \mathbf{F}_K - \int_K \mathbf{f}\, dK - \int_{\partial K} \mathbf{F} \partial K - \sum_i \mathbf{F}_{iK}$$

in other words, one cuts off with the nodal forces the generalized external forces applied to the element K.

Note:

To note that the loading of temperature does not appear in the external forces: it intervenes in the expression of the constraints via the law of behavior.

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In dynamics, to obtain the nodal reactions, it is advisable to in addition remove the efforts of inertia (acceleration) and damping related to speed.

Note:

Currently in Code_Aster the contributions of damping directly related to speed on the nodal reactions are neglected.

For the concepts result of the type mode_meca (resulting from modal calculations) the formula is:

$$\sum_K \mathbf{R}_K . \mathbf{v}_K = \int_\Omega \boldsymbol{\sigma}(\boldsymbol{\varepsilon}(\mathbf{u})) . \varepsilon(\mathbf{v}_K) d\Omega - \omega^2 (\mathbf{M}\cdot\mathbf{u})\cdot\mathbf{v}_K$$

where $\boldsymbol{\sigma}(\boldsymbol{\varepsilon}(\mathbf{u}))$ are the generalized modal constraints,

$\mathbf{M}$ is the matrix of mass,

ω the own pulsation,

$\mathbf{u}$ the field of displacement generalized of the mode,

$\mathbf{v}_K$ generalized unit elementary displacement.

For the concepts result of the type dyna_trans resulting from linear transitory dynamic calculations (DYNA_VIBRA/TYPE_CALCUL=' TRAN'), of type dyna_harmo resulting from harmonic calculations (DYNA_VIBRA/TYPE_CALCUL=' HARM') or of type evol_noli resulting from calculation dynamic non-linear transients (DYNA_NON_LINE) the expression of the generalized nodal reactions is obtained by:

$$\sum_K \mathbf{R}_K . \mathbf{v}_K = \int_\Omega \boldsymbol{\sigma}\cdot\boldsymbol{\varepsilon}(\mathbf{v}_K) d\Omega + (\mathbf{M}\,\ddot{\mathbf{u}})\cdot\mathbf{v}_K - \mathbf{L}(\mathbf{v}_K)$$

where $\mathbf{M}$ is the matrix of mass;

$\ddot{\mathbf{u}}$ the field of generalized acceleration;

$\mathbf{L}$ the vector of the generalized external forces applied,

$\mathbf{v}_K$ generalized unit elementary displacement.

Notice 1:

The nodal reactions are worthless in any interior point of the model and are not worthless a priori in a point of the edge subjected to a kinematic boundary condition (or with efforts of contact).
However the fact of neglecting the contribution of damping in dynamics can create a light variation compared to the exact result.

Notice 2:

If the keyword GROUP_MA is informed, the options 'FORC_NODA' and 'REAC_NODA' are calculated as follows:

$\mathbf{F}_K$ *is calculated only on the elements requested then assembled. The result is different from a total calculation on all the field then reduced to the required elements. The established method makes it possible to measure the reaction of a piece of model on another.*

Caution: the calculation of 'REAC_NODA'on a subset of the model (via the keyword GROUP_MA) must be made with prudence. Example 4 below illustrates this kind of calculation.

In the current version of the code, for the results of the type dyna_harmo , it 'REAC_NODA' is calculated only on the model in entirety. Calculation on a subset of the model can be carried out manually by carrying out a calculation of 'FORC_NODA' on the group of meshs in question then by cutting off the external force from the got results.

Notice 3:

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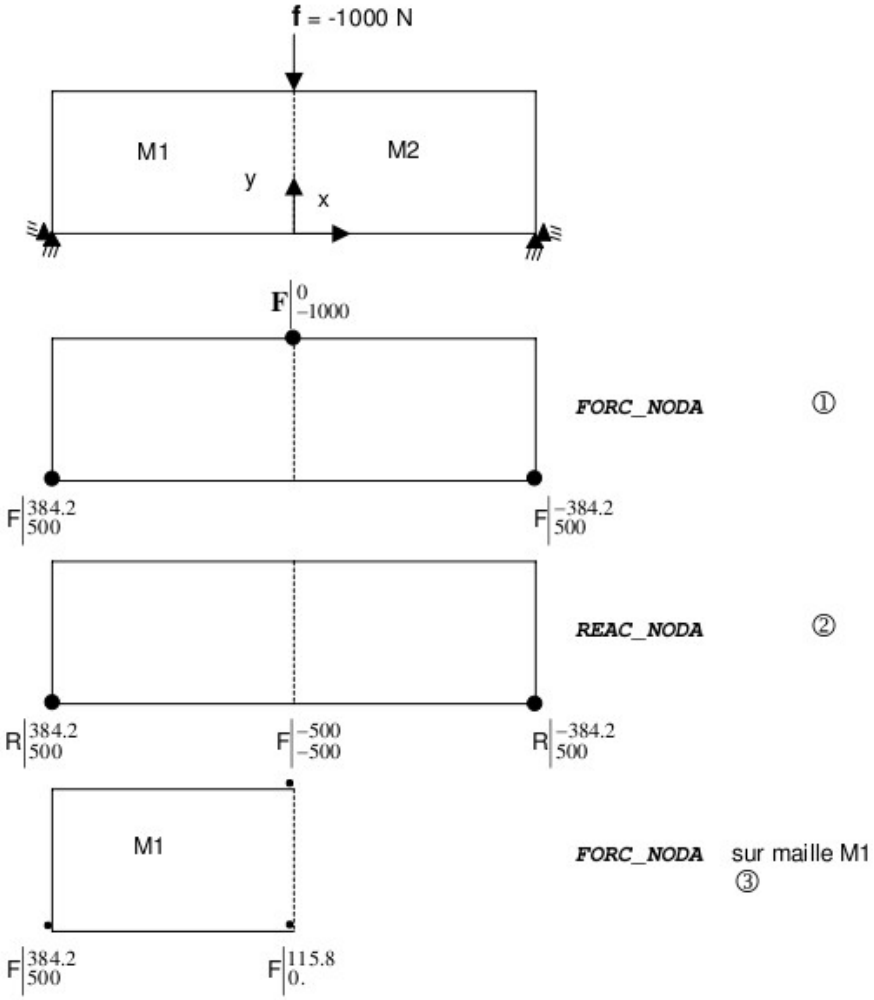
Only the resultant of the forces or the nodal reactions on a group of nodes has a physical direction (this group must correspond to at least an element of the model, for example an edge subjected to a boundary condition). It can be calculated with `POST_RELEVE_T` *[U4.81.21].*
Punctually, the field `FORC_NODA` *or* `REAC_NODA` *does not have to be interpreted because the value in a node is directly related to the smoothness of the grid. Moreover the sign of these forces on the nodes of the same element can be against-intuitive whereas it is perfectly in agreement with the theory of the finite elements (for example on meshs QUAD8 located at the interface of a pure compression zone, the signs of the nodal forces at the tops and the mediums are opposite).*

Notice 4:
The calculation of `REAC_NODA` *account of the loadings distributed on the beams takes. Since you vary this loading on a non-linear calculation (change of* `EXCIT` *of a step of time to the other), the calculation of* `REAC_NODA` *is prohibited. It is necessary to divide its postprocessing into "packages" of sequence numbers, for which the loading is constant (i.e. it uses the same concept* `AFFE_CHAR_MECA` *in* `EXCIT`*).*

2.9.2 Example 1: structure charged with nodal force (2 elements QUAD4)



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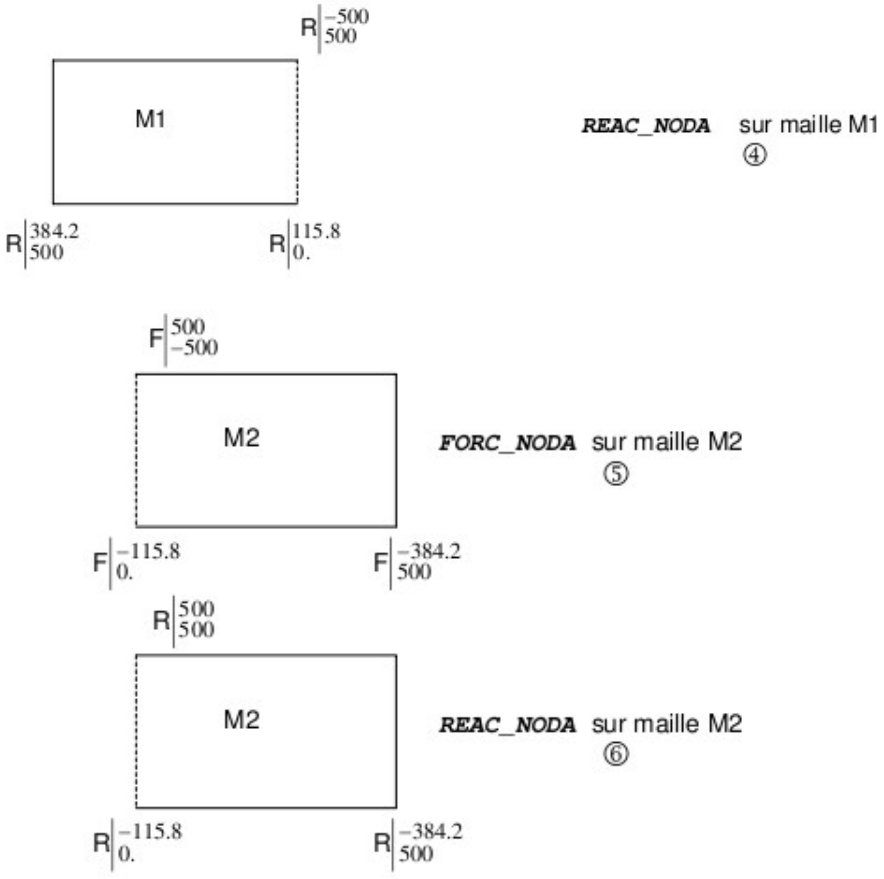

On this example, reactions to the nodes (2) are quite equal to the nodal forces (1) less the loading. They represent the reactions to the supports of the structure.

If one restricts calculation with the mesh $M1$, forces (3) to the nodes belonging to the border enters $M1$ and $M2$ are different. They represent the reaction of the model formed by $M1$ with the model formed by $M2$. To note that the nodal loading is divided by two because the two meshs contribute to it. Nodal reactions (4) are still equal to the nodal forces minus the loading.

On the calculation restricted with the mesh $M2$, nodal forces (5) according to OX are of contrary sign to the calculation restricted with the mesh $M1$, illustrating the principle of the action and the reaction.

2.9.3 Example 2: structure with loading of temperature

Data:

$E=1.10^{9}\,\mathrm{Pa}$
$\nu=0.3$
$\alpha=1.10^{-6}$

Results:

$F_{y}=-3.410^{4}\,N$
$F_{1x}=7.8\,10^{3}\,N$
$F_{2x}=-1.2\,10^{3}\,N$

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On this example, the nodal forces and the nodal reactions coincide because the only loading is a loading temperature.

If one restricts calculation with the mesh $M2$, forces according to OY remain the same ones but are different according to OX.

2.9.4 Example 3: structure under loading distributed (beam)

One considers a structure of type beam fixed and subjected to a loading of gravity on his higher half.

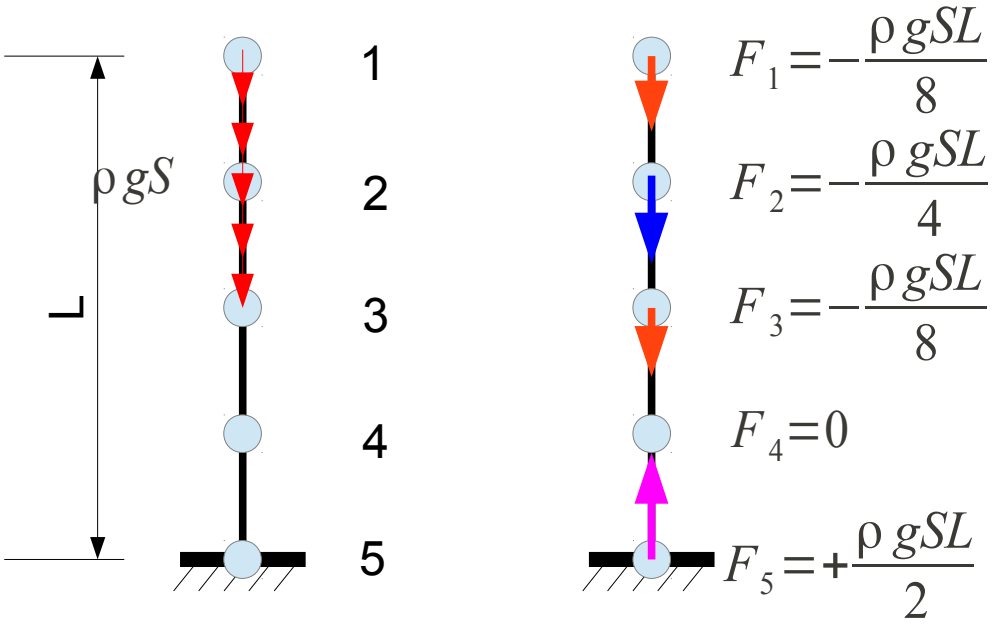

Figure 2.9.4-1: structure under loading distributed (left), FORC_NODA (right-hand side)

On this kind of structure, if one restricts the calculation of the forces and the nodal reactions to a under-part of the elements, FORC_NODA and REAC_NODA will not give the same result on the interface between the part isolated and the rest from the structure as shown in the figure 2.9.4-2 (on the force F_3).

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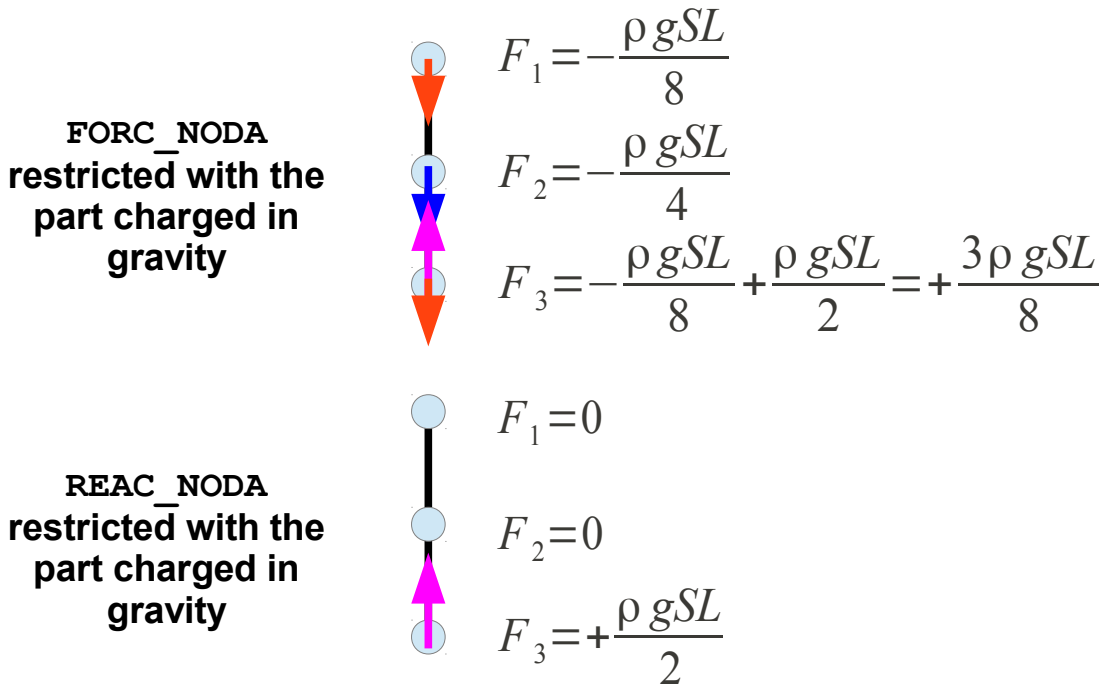

Figure 2.9.4-2: insulation of part of the structure

2.9.5 Example 4: calculation of the reactions of support at the bottom of a stopping

In this example, one schematizes (very coarsely!) a stopping in 2D. The stopping is represented by a triangle DEF posed on a foundation represented by a rectangle ABCG (see diagram below).

One would like to calculate the reactions of support of the stopping on his foundation.

The loadings are:
- Gravity (which applies to the stopping and its foundation)
- The loading of pressure of to the water reserve (side upstream) applied to the edges CD and OF.
- The foundation is embedded on AB.

On the following illustrations, one represented the standard of the field REAC_NODA when the keyword is used GROUP_MA various ways:
- Illustration 1: one does not use GROUP_MA (TOUT=' OUI')
- Illustration 2: GROUP_MA=' BARRAGE'
- Illustration 3: GROUP_MA= ('STOPPING', 'OF')
- Illustration 4: GROUP_MA= ('STOPPING', 'OF', 'CD')

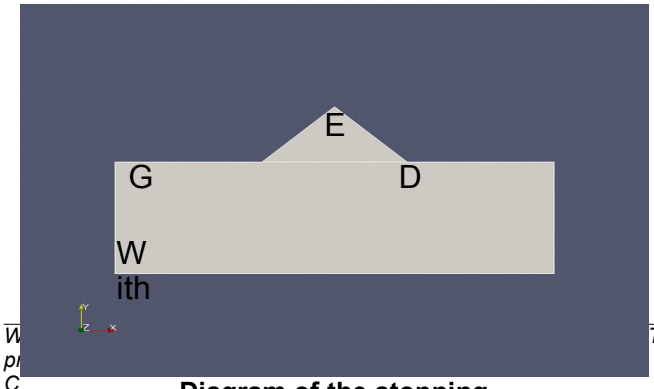

Diagram of the stopping

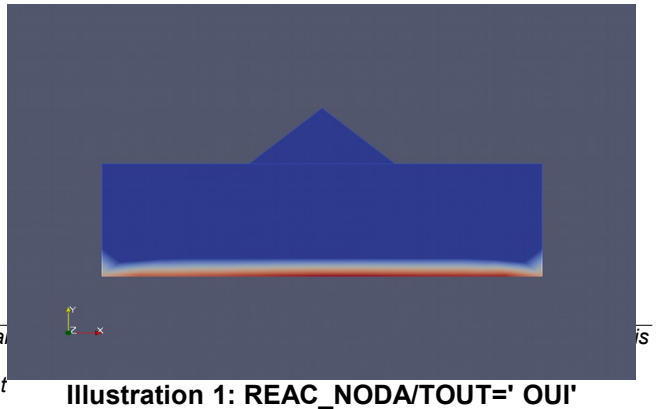

Illustration 1: REAC_NODA/TOUT=' OUI'

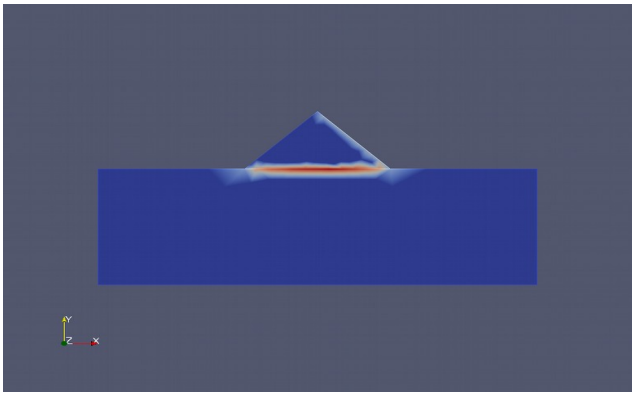

Illustration 2: REAC_NODA/GROUP_MA=' BARRAGE'

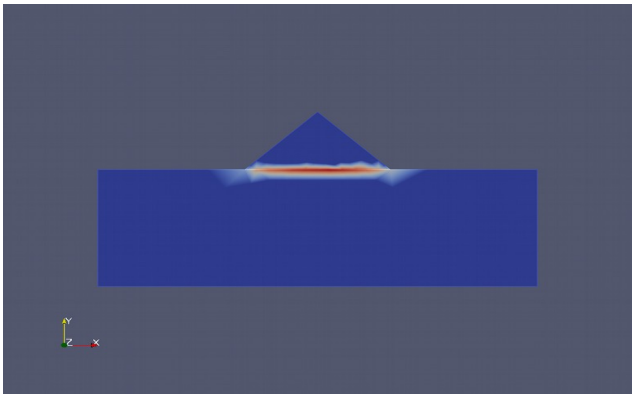

Illustration 3: REAC_NODA/GROUP_MA= ('STOPPING', 'OF')

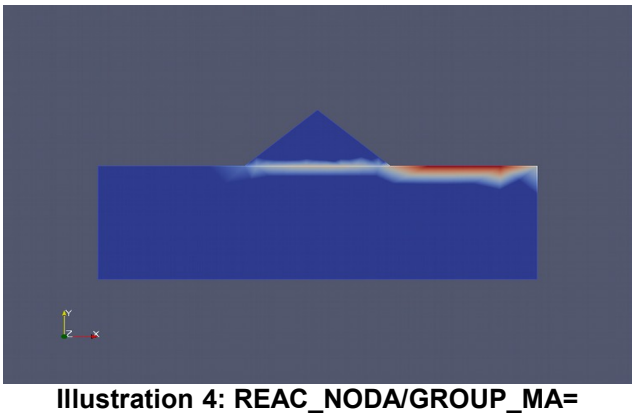

Illustration 4: REAC_NODA/GROUP_MA= ('STOPPING', 'OF', 'CD')

Comments:

- Illustration 1 shows that when the keyword is not used GROUP_MA, the reaction of support are not-worthless only on the edge of the model where one imposes displacements here (AB).
- Illustration 2 shows that if one calculates REAC_NODA on the only group STOPPING (formed only of "voluminal" elements) of the nonworthless reactions appear on DF (what one seeks) but also on OF, which must alert us. The reason of this behavior is that the loading of pressure on OF was not calculated, because the elements of edge which calculate this loading are not part of the group STOPPING.
- Illustration 3 shows that if one calculates REAC_NODA on the groups STOPPING and OF, the reactions are those which one seeks: they are nonworthless only on DF. Note: the image seems to show that nonworthless reactions exist on part of CD and FG, but it is an illusion due to visualization: nodal forces in D and F "dribble" on the adjacent elements.
- Illustration 4 shows that one should not add too many groups of edge here (CD). It is seen that nonworthless reactions of supports appear on CD. In this case, reaction on the point D is false.

Conclusion

*If one wants to calculate the reactions of support of the stopping on his foundation, it is necessary to ask the calculation of REAC_NODA while specifying exactly **all** meshs of the stopping and **all** meshs of its edge subjected to a loading distributed.*
It is highly advised to visualize the reactions calculated to check that they are nonworthless only on the interface between the stopping and its foundation.

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2.10 Calculation of a field user

The keyword factor CHAM_UTIL allows to calculate fields unspecified, known as “user” because of the name which will be affected for them in the concept result.
There can be several occurrences of CHAM_UTIL in order to connect the calculation of several fields.
Treatment being carried out at the end of the order CALC_CHAMP, computed fields by the preceding keywords (CONSTRAINT, DEFORMATION…) are available here.
Either one asks for the calculation of a preset criterion, or one applies one or more formulas to calculate another field.

2.10.1 Operand NOM_CHAM

It is a question of the field from which the calculations are done. The produced field will have the same type: ELGA, ELNO or NOEU.

2.10.2 Operand CRITERION

Request the calculation of a preset criterion. The criteria are (the paragraph 2.6.5 provides the expressions of each criterion):
- VMIS (for the stress fields),
- INVA_2 (for the fields of deformations),
- TRACE (for the deformation or stress fields).

Each one of these criteria produces a component (named X1).
One of the interests is to be able to calculate INVA_2 of any field of deformations.

2.10.3 Operand FORMULA

This makes it possible to calculate any expression function of the components of the field provided for NOM_CHAM.
The produced field will contain as many components as of provided formulas: to the first formula the component will correspond X1, with the second X2, etc To 30 components can be thus created.
The field at exit is systematically prolonged to zero on the other components and where the field as starter is not defined.

Examples of formulas allowing to find the criteria VMIS and INVA_2 can be found in the second part of the test sslv104a.

2.10.4 Operand NORMALIZES

Request the calculation of a preset standard. The standards are:
- L2: normalizes L_2 of a tensor
- FROBENIUS : normalizes of Frobenius of a tensor

The calculated standard is a quantity integrated (with the weak direction) on an element Ω_e . For a tensor $\boldsymbol{A}$, the standard L_2 is worth:

$$N_{L_2} = \int_{\Omega_e} \sqrt{(\boldsymbol{A} : \boldsymbol{A})} . d\Omega_e \quad (1)$$

The standard of Frobenius on the components A_{ij} of a tensor $\boldsymbol{A}$:

$$N_F = \int_{\Omega_e} \sum_{i,j} |A_{ij}| . |A_{ij}| . d\Omega_e \quad (2)$$

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Each one of these standards produces a component (named X1) on an element. It is thus about one field ELEM. It should be noted that the difference between the two standards comes from the terms cross (except diagonal).

2.10.5 Operand NUME_CHAM_RESU

The produced field must be arranged, in a single way, in the concept result. The fields “user” are thus numbered while using NUME_CHAM_RESU and the type of the field.
The name of the field will be thus of the type UT01_ELGA, UT22_NOEU, etc.

2.10.6 Example of calculation of a field user

Product the field UT02_ELGA with two components. X1 is the trace of SIGM_ELGA (comparable to the component TRSIG of SIEQ_ELGA) and X2 is the equivalent constraint of Von Mises (component VMIS of SIEQ_ELGA).

```
fTrace = FORMULA (NOM_PARA= ('SIXX', 'SIYY', 'SIZZ'),
                  VALE= """ SIXX+SIYY+SIZZ """)

fVonMis = FORMULA (NOM_PARA= ('SIXX', 'SIYY', 'SIZZ', 'SIXY', 'SIXZ',
'SIYZ'),
                   VALE= """ sqrt (3. /2. * (SIXX ** 2 + SIYY ** 2 + SIZZ **
2
                              + 2*SIXY ** 2 + 2*SIXZ ** 2 + 2*SIYZ ** 2)
                              - 1. /2. * fTrace (SIXX, SIYY, SIZZ) ** 2) """)

LMBO = CALC_CHAMP (reuse=RES,
                   RESULTAT=RES,
                   CHAM_UTIL=_F (NOM_CHAM=' SIGM_ELGA',
                                 FORMULE= (fTrace, fVonMis),
                                 NUME_CHAM_RESU=2,),)
```

2.11 Operand TITLE

◊ TITLE = title
Title which one wants to give to the result of the order [U4.02.01].

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