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:

\[
\text{resu} = \text{CALC\_CHAMP} \quad (\text{RESULT} = \text{resu...}, \text{reuse} = \text{resu,...})
\]

or

\[
\text{resu1} = \text{CALC\_CHAMP} \quad (\text{RESULT} = \text{resu,...})
\]
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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]
◊ TYPE_CHARGE = ‘FIXES’,
)
◊ # Selection of the meshes concerned with calculation
◊ / ALL = ‘YES’, [DEFECT]
◊ / | GROUP_MA = l_grma , [l_gr_maille]
◊ | MESH = l_mail , [l_maille]
◊ # Selection of the sequence numbers
◊ / TOUT_ORDRE = ‘YES’,
◊ / NUME_ORDRE = l_nuor, [l_I]
◊ / LIST_ORDRE = l_nuor, [l_I]
◊ / 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]
◊ | PRECISION = / prec,
◊ | # options for linear mechanical results
◊ RESULT = resu,
◊ # options of calculation of the constraints (elements of continuous medium 2D
and 3D)
◊ CONSTRAINT =
◊ | ‘EFGE_ELGA’
◊ | ‘EFGE_ELNO’
◊ | ‘EFGE_NOEU’
◊ | ‘SIGM_ELGA’
◊ | ‘SIGM_ELNO’
◊ | ‘SIGM_NOEU’
◊ | ‘SIPM_ELNO’
◊ | ‘SIPO_ELNO’
◊ | ‘SIPO_NOEU’
◊ | ‘SIRO_ELEM’
```

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# 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'  
| 'EPOT_ELEM'  
| 'ETOT_ELEM'  
| 'ETOT_ELGA'  
| 'ETOT_ELNO'  
| 'ETOT_NOEU'  

# options of calculation of criteria

◊  

CRITERIA = 'EPEQ_ELGA'  
| 'EPEQ_ELNO'  
| 'EPEQ_NOEU'  
| 'EPMQ_ELGA'  
| 'EPMQ_ELNO'  
| 'EPMQ_NOEU'  
| 'SIEQ_ELGA'  
| 'SIEQ_ELNO'  
| 'SIEQ_NOEU'  

# options of interpolation and extraction of internal variables

◊  

VARI_INTERNE = 'VARC_ELGA'
# 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'
# 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'

# thermal options

♦ RESULT = resu,       / [evol_ther]

◊ THERMIQUE=
  | 'FLUX_ELGA'
  | 'FLUX_ELNO'
  | 'FLUX_NOEU'
  | 'HYDR_NOEU'
  | 'SOUR_ELGA'
  | 'ETHE_ELEM'

# acoustic options

♦ RESULT = resu,       / [acou_harmo]
◊ 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,
2.1 Operands RESULTAT/MODELE/CHAM_MATER/CARA_ELEM/EXCIT

2.1.1 Operands RESULT

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.

Note: 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.

2.1.2 Operands MODEL/CHAM_MATER/CARA_ELEM.

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

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).

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_LINE_HARM [U4.53.11], and DYNA_LINE_TRAN [U4.53.02].

2.2 Selection of the meshes concerned with calculation

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

/ ALL = 'YES'
All the meshes (carrying finite elements) will be treated. It is the value by default.

/ | GROUP_MA = l_grma
| MESH = l_maille
Only meshes included in l_grma and/or l_maille will be treated.
Selection of the sequence numbers

Use of the keywords TOUT_ORDRE, NUM_ORDRE, INST, FREQ is described in the document [U4.71.00].

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 or MESH are well 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 $\sigma_{xy}$ is worth:

In total calculation, $\sigma_{xy}$ 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 one 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:**

**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`
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].

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

List of the components of the field:

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>SN</td>
<td>Contribution of the normal effort $N$ with $\sigma_{xx}, \sigma_{xx} = \frac{N}{A}$</td>
<td></td>
</tr>
<tr>
<td>SMFY</td>
<td>Contribution of the bending moment $MFY$ with $\sigma_{xx}, \sigma_{xx} = z \frac{MFY}{I_Y}$</td>
<td></td>
</tr>
<tr>
<td>SMFZ</td>
<td>Contribution of the bending moment $MFZ$ with $\sigma_{xx}, \sigma_{xx} = -y \frac{MFZ}{I_Z}$</td>
<td></td>
</tr>
<tr>
<td>SVY</td>
<td>Contribution of the shearing action $VY$ with $\sigma_{xy}, \sigma_{xy} = \frac{VY a_y}{A}$ where $a_y$ is the coefficient of shearing in the direction $y$</td>
<td></td>
</tr>
<tr>
<td>SVZ</td>
<td>Contribution of the shearing action $VZ$ with $\sigma_{xz}, \sigma_{xz} = \frac{VZ a_z}{A}$ where $a_z$ is the coefficient of shearing in the direction $z$</td>
<td></td>
</tr>
<tr>
<td>SMT</td>
<td>Contribution of the torque $MX$ with $\sigma_{yz}, \sigma_{yz} = \frac{MX R_y}{J_z}$</td>
<td></td>
</tr>
</tbody>
</table>

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 $\sigma_{xx}$ 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 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 $R$ .

Calculation of the constraints maximum and minimum in the section of beam starting from the generalized efforts (linear elasticity).

The same remark as for SIPPO_ELNO applies a general section in the case of.
Calculation of the constraints projected on the skin of a volume (for example on the facings of a hydraulic work.

List of the components of the field:

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIG_NX</td>
<td>Components $\sigma_X$, $\sigma_Y$, $\sigma_Z$ in the total reference mark of $\bar{\sigma}_n$</td>
</tr>
<tr>
<td>SIG_NY</td>
<td>Value $SIG_N$</td>
</tr>
<tr>
<td>SIG_NZ</td>
<td>Components $\sigma_X$, $\sigma_Y$, $\sigma_Z$ in the total reference mark of $\bar{\sigma}_t$</td>
</tr>
<tr>
<td>SIG_TX</td>
<td>Components $\sigma_X$, $\sigma_Y$, $\sigma_Z$ in the total reference mark of $\bar{\sigma}_{t1}$</td>
</tr>
<tr>
<td>SIG_TY</td>
<td>Components $\sigma_X$, $\sigma_Y$, $\sigma_Z$ in the total reference mark of $\bar{\sigma}_{t2}$</td>
</tr>
<tr>
<td>SIG_TZ</td>
<td>Eigenvalue $SIG_{T1}$</td>
</tr>
<tr>
<td>SIG_T1X</td>
<td>Eigenvalue $SIG_{T2}$</td>
</tr>
<tr>
<td>SIG_T1Y</td>
<td></td>
</tr>
<tr>
<td>SIG_T1Z</td>
<td></td>
</tr>
<tr>
<td>SIG_T2X</td>
<td></td>
</tr>
<tr>
<td>SIG_T2Y</td>
<td></td>
</tr>
<tr>
<td>SIG_T2Z</td>
<td></td>
</tr>
</tbody>
</table>

These fields are evaluated starting from a stress field calculated on the voluminal meshes (MODELISATION= ‘3D’ or ‘3D_SI’):

- Identification of the voluminal meshes corresponding to the facets of the group of surface meshes. 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 $\left[ \sigma \right]$. One evaluates $\vec{n}=\bar{\sigma}_n+\bar{\sigma}_t$, $\bar{\sigma}_n$ being a vector colinéaire with $\vec{n}$. $\bar{\sigma}_t$ is then a vector representing the shearing which is negligible in the case of the faces upstream/downstream of a stopping. One notes $\vec{n}_{sig}=SIG_N \vec{n}$ and $SIG_N$ indicate the presence of traction if it is positive and of compression if it is negative.
- One thus places oneself on the assumption of a negligible shearing $\left[ \sigma \right]=\begin{bmatrix} \sigma_{2D} & 0 \\ 0 & SIG_N \end{bmatrix}$ One seeks the vectors of principal constraints corresponding to $\sigma_{2D}$ : the vectors are thus obtained $\bar{\sigma}_{t1}$ and $\bar{\sigma}_{t2}$ who are in the plan of the facet and the eigenvalues $SIG_{T1}$ and $SIG_{T2}$

Notice 1:
In the case of facets plunged in volume, the user has the possibility thanks to the order MODI_MAILLAGE/ORIE_PEAU_3D/GROUP_MA_VOLU 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 voluminal), 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 meshes is filtered to keep only the meshes of skin.
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' |
| '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.

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

| '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.

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

| 'EPSG_ELGA' |
| 'EPSG_ELNO' |
| 'EPSG_NOEU' |
| Calculation of the deformations of Green-Lagrange.

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

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Calculation of the deformations starting from displacements.

\[ \varepsilon_{ij}(u) = \frac{1}{2} (u_{i,j} + u_{j,i}) \]

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

Calculation of the unelastic deformations starting from the field of displacement \( u \), constraints \( \sigma \), temperature \( T \), possible unelastic deformations \( \varepsilon^a \), and of the internal variables,

\[ \varepsilon^p = \varepsilon(u) - A^{-1} \sigma - \varepsilon^{th}(T) - \varepsilon^a - \varepsilon^f \]

where \( \varepsilon^f \) is the clean deformation of creep of Granger.

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

- thermal deformations: \( \varepsilon^L \), \( \varepsilon^T \), \( \varepsilon^N \) such as:
  \[ \varepsilon_i^L = \alpha_i (T - T_{ref}) \], \( i \in \{ L, T, N \} \) (if the material is isotropic, the 3 components are equal), \( T \) being the temperature and \( \alpha_i \) the thermal dilation coefficient;

- withdrawal of drying \( \varepsilon^{ech} \) (used for the laws describing the behavior of the concrete)
  \[ \varepsilon^{ech} = -K_{dissic}(S_{ref} - S) \], \( S \) being the variable of order drying and \( K_{dissic} \) the coefficient of withdrawal of desiccation;

- withdrawal of hydration \( \varepsilon^{hydr} \) (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): \( \varepsilon^{p_{tot}} \) such as:
  \[ \varepsilon^{p_{tot}} = \frac{b}{3K} p_{tot} \], \( p_{tot} \) is the variable of order total pressure of fluid, \( b \) is the coefficient of Biot, \( K \) is the modulus of elasticity.

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

- \( \varepsilon^L \)
- \( \varepsilon^T \)
- \( \varepsilon^N \)

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 \( \text{VARI} \) (one and only one) the variable intern who interests us via a keyword without having to know his name in the field \( \text{VARI}_* \).

List of the possible components of the field (the field has only one component, that chosen by the user via \( \text{NOM}_VARI \)): 

- \( \varepsilon^L \)
- \( \varepsilon^T \)
- \( \varepsilon^N \)
<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPORQ</td>
<td>Variation of the porosity of material</td>
</tr>
<tr>
<td>DRHOLQ</td>
<td>Variation of the density of material</td>
</tr>
<tr>
<td>DPVP</td>
<td>Variation of the steam pressure</td>
</tr>
<tr>
<td>SATLIQ</td>
<td>Saturation of the liquid</td>
</tr>
<tr>
<td>EVF</td>
<td>Cumulated voluminal plastic deformation</td>
</tr>
<tr>
<td>IND_ETA</td>
<td>Mechanical indicator of state</td>
</tr>
<tr>
<td>D</td>
<td>Value of the damage</td>
</tr>
<tr>
<td>IND_END</td>
<td>Indicator of damage</td>
</tr>
<tr>
<td>TEMP_MAX</td>
<td>Maximum temperature</td>
</tr>
<tr>
<td>GAMP</td>
<td>Plastic deformation deviator cumulated</td>
</tr>
<tr>
<td>PCR</td>
<td>Critical pressure</td>
</tr>
<tr>
<td>SEUIL_HYD</td>
<td>Hydrous threshold</td>
</tr>
<tr>
<td>IND_HYD</td>
<td>Hydrous indicator of irreversibility</td>
</tr>
<tr>
<td>PCOHE</td>
<td>Pressure of cohesion</td>
</tr>
<tr>
<td>COMP_ROC</td>
<td>Behavior of the rock</td>
</tr>
<tr>
<td>SEUIL_ISO</td>
<td>Isotropic threshold</td>
</tr>
<tr>
<td>ANG_DEV</td>
<td>Angle of the threshold deviator</td>
</tr>
<tr>
<td>X11</td>
<td>Components of the kinematic tensor of work hardening</td>
</tr>
<tr>
<td>X22</td>
<td>Components of the kinematic tensor of work hardening</td>
</tr>
<tr>
<td>X33</td>
<td>Components of the kinematic tensor of work hardening</td>
</tr>
<tr>
<td>X12</td>
<td>Components of the kinematic tensor of work hardening</td>
</tr>
<tr>
<td>X13</td>
<td>Components of the kinematic tensor of work hardening</td>
</tr>
<tr>
<td>X23</td>
<td>Components of the kinematic tensor of work hardening</td>
</tr>
<tr>
<td>DIST_DEV</td>
<td>Distance standardized with the threshold deviator</td>
</tr>
<tr>
<td>DEV_SUR_CRIT</td>
<td>Relationship between the threshold deviator and the critical threshold deviator</td>
</tr>
<tr>
<td>DIST_ISO</td>
<td>Distance standardized with the isotropic threshold</td>
</tr>
<tr>
<td>NB_ITER</td>
<td>Iteration count internal</td>
</tr>
<tr>
<td>STOP</td>
<td>Value of the local test of stop of the iterative process</td>
</tr>
<tr>
<td>NB_REDE</td>
<td>Number of local recutting of the step of time</td>
</tr>
<tr>
<td>SIGN</td>
<td>Sign of the contracted product of the deviatoric constraint by the deviatoric plastic deformation</td>
</tr>
</tbody>
</table>

◊ NOM_VARI = / nom_vari,

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
- HYDR
- SECH
- CORR
- INRA
- PTOT
- DIVU
- NEUT1
- NEUT2

Cf documentation of the order AFFE_MATERIAU [U4.43.03] for the definition of each component.

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

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:

<table>
<thead>
<tr>
<th>TOTAL</th>
<th>Kinetic energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Additional components for the plates and hulls:

| MEMBRANE | Contributions to the kinetic energy (cf [R3.07.03]) |
| INFLECTION | |

Additional components for the curved beams:

| PLAN_XY | Contributions to the kinetic energy (cf [R3.08.01]) |
| PLAN_XZ | |

Additional components for the discrete ones:

| DX | Contributions to the kinetic energy |
| DY | |
| DZ | |
| DRX | |
| DRY | |
| MARTINI | |
| DRZ | |

'ENEL_ELEM'

Calculation of the elastic energy.

\[ E_p = \frac{1}{2} \sigma A^{-1} \sigma \]

List of the components of the field:

<table>
<thead>
<tr>
<th>TOTAL</th>
<th>Elastic energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Additional components for the plates and hulls:

| MEMBRANE | Contributions to elastic energy (cf [R3.07.03]) |
| INFLECTION | |
| SHEAR | Elastic energy out of membrane |
| COUPL_MF | 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:

<table>
<thead>
<tr>
<th>TOTAL</th>
<th>Elastic energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Additional components for the plates and hulls:

<table>
<thead>
<tr>
<th>MEMBRANE</th>
<th>Elastic energy out of membrane</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFLECTION</td>
<td>Elastic energy in inflection</td>
</tr>
<tr>
<td>SHEAR</td>
<td>Elastic energy in shearing</td>
</tr>
<tr>
<td>COUPL_MF</td>
<td>Elastic energy of coupling membrane-inflection</td>
</tr>
</tbody>
</table>

Note:

\[ \text{into non-linear (STAT\_NON\_LINE, DYNA\_NON\_LINE,...) components SHEAR and COUPL\_MF are worthless.} \]

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:

<table>
<thead>
<tr>
<th>TOTAL</th>
<th>Potential energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Additional components for the plates and hulls:

<table>
<thead>
<tr>
<th>MEMBRANE</th>
<th>Contributions to the potential energy (cf [R3.07.03])</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFLECTION</td>
<td></td>
</tr>
</tbody>
</table>

Additional components for the right beams:

| TRAC_COM | Contributions to the potential energy (cf [R3.08.01]) |
| TORSION |                                                      |
| FLEX_Y |                                                          |
| FLEX_Z |                                                          |

Additional components for the curved beams:

| PLAN_XY | Contributions to the potential energy (cf [R3.08.01]) |
| PLAN_XZ |                                                      |

Additional components for the discrete ones:

| DX | Contributions to the potential energy |
| DY |                                           |
| DZ |                                           |
| DRX |                                          |
| DRY |                                          |
| MARTINI |                                      |
| DRZ |                                          |

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

\[
E_{pot} = \frac{1}{2} \int_{\text{element}} \varepsilon(U) . \varepsilon(U) dv - \int_{\text{element}} \varepsilon(U) . \varepsilon^t(U) dv + \frac{1}{2} \int_{\text{element}} \varepsilon^t(U) . \varepsilon^t(U) dv
\]

- for the elements of beams:

\[
E_{pot} = \frac{1}{2} u^T K_e u - u^T B^T A \varepsilon^t + \frac{1}{2} \varepsilon^t A \varepsilon^t
\]

- for the elements of plates and hulls:

\[
E_{pot} = \frac{1}{2} u^T K_e u - u^T B^T A \varepsilon^t
\]
Calculation of the increment of total deformation energy enters the moment running and the previous moment.

List of the components of the field:

<table>
<thead>
<tr>
<th>TOTAL</th>
<th>Increment of total deformation energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>'ETOT_ELGA'</td>
<td></td>
</tr>
<tr>
<td>'ETOT_ELNO'</td>
<td></td>
</tr>
<tr>
<td>'ETOT_NOEU'</td>
<td></td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>DCHA_V</th>
<th>Indicator of discharge calculated on the deviative tensor of the constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCHA_T</td>
<td>Indicator of discharge calculated on the total tensor of the constraints</td>
</tr>
<tr>
<td>IND_DCHA</td>
<td>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</td>
</tr>
<tr>
<td>VAL_DCHA</td>
<td>In the case of indicate the proportion of exit of the criterion abusive discharge</td>
</tr>
<tr>
<td>X11, X22, X33, X12, X13, X23</td>
<td>Components of the kinematic tensor used for the calculation of IND_DCHA</td>
</tr>
<tr>
<td>RADI_V</td>
<td>Indicator of the variation of the direction of the constraints between the moments $t$ and $t + \Delta t$</td>
</tr>
<tr>
<td>ERR_RADI</td>
<td>Error $\eta$ had with the discretization in time, directly connected to the rotation of the normal on the surface of load</td>
</tr>
</tbody>
</table>

$DCHA_V$ and $DCHA_T$ express, in the two cases, the relative variation of the standard of the constraints within the meaning of Von Mises: $I_1 = \frac{\|\sigma(M, t + \Delta t)\| - \|\sigma(M, t)\|}{\|\sigma(M, t + \Delta t)\|}$, 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:
\[ I_2 = 1 - \frac{\| \sigma(M, t) \Delta \sigma \|}{\| \sigma(M, t) \| \| \Delta \sigma \|} \]

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

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

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

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_ISO_PUIS, VMIS_CINE_LINE, VMIS_ECM1_LINE, VMIS_ECM1_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:

\[
ID = \frac{\| \sigma_{i+1} \| - \| \sigma_{i} \|}{\| \sigma_{i+1} \|}.
\]

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.

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

**List of the components of the field:**

<table>
<thead>
<tr>
<th>TRIAX</th>
<th>Rate of triaxiality</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI_ENDO</td>
<td>Equivalent constraint of damage of Lemaître-Sermage</td>
</tr>
<tr>
<td>COENDO</td>
<td>Constraint of damage of Lemaître-Sermage standardized</td>
</tr>
<tr>
<td>DOM_LEM</td>
<td>Damage of Lemaître-Sermage</td>
</tr>
</tbody>
</table>

The rate of triaxiality \( \alpha \) is given by the following relation:

\[
\alpha = \frac{\sigma_b}{\sigma_{eq}}
\]

and the equivalent constraint of damage \( \sigma^* \):

\[
\sigma^* = \sigma_{eq} \left( \frac{2}{3} (1 + \nu) + 3 (1 - 2 \nu) \alpha^2 \right)
\]
\[
s = \sigma - \frac{1}{3} \operatorname{tr}(\sigma) \cdot \text{Id}
\]

with:

\[
\sigma_{eq} = \sqrt{\frac{3}{2} \mathbf{s} : \mathbf{s}}
\]

\[
\sigma_{b} = \frac{1}{3} \operatorname{tr}(\sigma)
\]

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

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

where \(S\) and \(s\) are coefficients characteristic of material and \(p_{\text{seuil}}\) 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' |

Calculation of the calculated deformations equivalent starting from the fields \(\text{EPSI}_{*}\), or \(\text{EPME}_{*}\).

List of the components of the field:

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

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

\[
\text{INVA}_2 = \left( \frac{2}{3} \operatorname{dev} (\varepsilon)_ij \operatorname{dev} (\varepsilon)^{ij} \right) \text{ with } \operatorname{dev} (\varepsilon)_ij = \varepsilon_{ij} - \frac{1}{3} \operatorname{tr}(\varepsilon) \delta_{ij}
\]

**Note:** It is noted that the equivalent deformations obtained from \(\text{EPSI}_{*}\) and \(\text{EPME}_{*}\) 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: $\det(N.H.N) \leq 0$, where $H$ appoint the tangent operator and $N$ the normal with the directions of localization.

**Note:**

The method is developed only in the case 2D 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 $0.1^\circ$.

**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.
List of the components of the field:

<table>
<thead>
<tr>
<th>VMIS</th>
<th>Equivalent constraint of Von Mises</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRESCA</td>
<td>Constraint of Tresca</td>
</tr>
<tr>
<td>PRIN_1</td>
<td>Principal constraints, lines in the ascending order</td>
</tr>
<tr>
<td>PRIN_2</td>
<td></td>
</tr>
<tr>
<td>PRIN_3</td>
<td></td>
</tr>
<tr>
<td>VMIS_SG</td>
<td>Equivalent constraint of Von Mises signed by the trace of $\sigma$</td>
</tr>
<tr>
<td>VECT_1_X</td>
<td>Principal directions</td>
</tr>
<tr>
<td>VECT_1_Y</td>
<td></td>
</tr>
<tr>
<td>VECT_1_Z</td>
<td></td>
</tr>
<tr>
<td>VECT_2_X</td>
<td></td>
</tr>
<tr>
<td>VECT_2_Y</td>
<td></td>
</tr>
<tr>
<td>VECT_2_Z</td>
<td></td>
</tr>
<tr>
<td>VECT_3_X</td>
<td></td>
</tr>
<tr>
<td>VECT_3_Y</td>
<td></td>
</tr>
<tr>
<td>VECT_3_Z</td>
<td></td>
</tr>
<tr>
<td>TRSIG</td>
<td>Trace of $\sigma$</td>
</tr>
<tr>
<td>TRIAX</td>
<td>Rate of triaxiality</td>
</tr>
</tbody>
</table>

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

$$VMIS = \sqrt{\frac{3}{2}} s_{ij} s_{ji}$$

with $s_{ij} = \sigma_{ij} - \frac{1}{3} tr(\sigma) \delta_{ij}$

The rate of triaxiality is given by the following expression:

$$TRIAX = \frac{TRSIG}{VMIS}$$

### 2.6.6 Option of calculation of hydraulic flows (Operand HYDRAULICS)

| 'FLHN_ELGA' |

Calculation of hydraulic flows in THM $\Phi_{ij} = M_{ij} \cdot \mathbf{V}$ on the elements of edge (2D or 3D) starting from the vector flow with the nodes.

$M_{ij}$ is the hydraulic vector flow of the component $ij$.

List of the components of the field:

| FH11 |
| FH22 |
| FH12 |
| FH21 |

### 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.

Warning: The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

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List of the components of the field:

<table>
<thead>
<tr>
<th>FLOW</th>
<th>Heat flow in the three directions of space (in the average layer for the hulls)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLUY</td>
<td></td>
</tr>
<tr>
<td>FLUZ</td>
<td></td>
</tr>
</tbody>
</table>

Additional components for the hulls:

<table>
<thead>
<tr>
<th>FLUX_INF</th>
<th>Heat flow in the three directions of space in lower skin</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLUY_INF</td>
<td></td>
</tr>
<tr>
<td>FLUZ_INF</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FLUX_INF</th>
<th>Heat flow in the three directions of space in higher skin</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLUY_INF</td>
<td></td>
</tr>
<tr>
<td>FLUZ_INF</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>'HYDR_NOEU'</th>
</tr>
</thead>
</table>

Calculation of the hydration.

List of the components of the field:

<table>
<thead>
<tr>
<th>HYDR</th>
<th>Hydration</th>
</tr>
</thead>
</table>

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].

<table>
<thead>
<tr>
<th>'PENNYR_ELGA'</th>
</tr>
</thead>
</table>

Calculation of a source of heat.

List of the components of the field:

<table>
<thead>
<tr>
<th>SOUR</th>
<th>Source of heat</th>
</tr>
</thead>
</table>

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].

<table>
<thead>
<tr>
<th>'ETHE_ELEM'</th>
</tr>
</thead>
</table>

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

List of the components of the field:

<table>
<thead>
<tr>
<th>TOTAL</th>
<th>Thermal energy</th>
</tr>
</thead>
</table>

### 2.8 Operands for the acoustic options

#### 2.8.1 Operand ACOUSTICS

<table>
<thead>
<tr>
<th>'INTE_ELNO'</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>'INTE_NOEU'</th>
</tr>
</thead>
</table>

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

List of the components of the field:

<table>
<thead>
<tr>
<th>INTX_R</th>
<th>Acoustic intensity, real part according to axis X</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTY_R</td>
<td>Acoustic intensity, real part according to the axis there</td>
</tr>
<tr>
<td>INTZ_R</td>
<td>Acoustic intensity, real part according to axis Z</td>
</tr>
<tr>
<td>INTX_I</td>
<td>Acoustic intensity, imaginary part according to axis X</td>
</tr>
<tr>
<td>INTY_I</td>
<td>Acoustic intensity, imaginary part according to the axis there</td>
</tr>
<tr>
<td>INTZ_I</td>
<td>Acoustic intensity, imaginary part according to axis Z</td>
</tr>
</tbody>
</table>
Calculation of the pressure to the nodes partly real, imaginary part and decibels.

List of the components of the field:

<table>
<thead>
<tr>
<th>PRES_I</th>
<th>Acoustic pressure, real part</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRES_R</td>
<td>Acoustic pressure, imaginary part</td>
</tr>
<tr>
<td>DB</td>
<td>Acoustic pressure in decibel</td>
</tr>
</tbody>
</table>

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

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

List of the components of the field:

<table>
<thead>
<tr>
<th>DX</th>
<th>DY</th>
<th>DZ</th>
<th>Nodal forces</th>
</tr>
</thead>
</table>

Additional components for the elements of structure:

<table>
<thead>
<tr>
<th>DX</th>
<th>DY</th>
<th>MARTINI</th>
<th>DRX</th>
<th>DRY</th>
<th>DRZ</th>
<th>Nodal forces (moments)</th>
</tr>
</thead>
</table>

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 $F_K$ is done in the following way:

$$\sum_{k} F_K \cdot v_K = \int_{\Omega} \sigma \cdot \varepsilon (v_K) d\Omega = \sum_{k} \int_{K} \sigma^k \cdot \varepsilon (v_K) dK = \sum_{k} \int_{K} \sigma^k \cdot B \cdot v_K dK$$

with $\sigma^k$ constraints at the points of Gauss of the element $K$;

$B$ the operator finite elements of generalized deformations (matrix connecting the deformations of the 1st order with generalized displacements);

$v_K$ generalized unit elementary displacement.

From where:

$$F_K = \left[ \int_{K} \sigma^k \cdot v_K dK \right]$$

The dimension of the nodal forces is dual of that of $v_K$ 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 $DRX$, $DRY$, $DRZ$ moments.

For the axisymmetric elements, integration in $\theta$ 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 $2\pi$.

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 $DRX$, $DRY$, $DRZ$ 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 (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 $Q^T \sigma_{\theta}$ the result of $FORC\_NODA$, for the hydraulic equations, then for a step of time $\Delta t$, one a:

$$
\int_{\Omega} Q^T \sigma_{\theta} \cdot p \, d\Omega = -\Delta t \int_{\Omega} M \cdot \nabla p \, d\Omega
$$

Note:

To note that flows are taken at the moment $\theta$ because of $\theta$-diagram employed, cf [R7.01.10].

In $FORC\_NODA$:

- with the degree of freedom $PRE1$ in saturated for example is associated water flow $-\Delta t \int_{\Omega} (M_{wp} + M_w) \cdot \nabla p^* \, d\Omega$

- with the degree of freedom $PRE2$ in unsaturated flow with the gas component is associated $-\Delta t \int_{\Omega} (M_{ad} + M_{ar}) \cdot \nabla p^* \, d\Omega$

- with the degree of freedom $TEMP$ the heat flux is associated $-\Delta t \int_{\Omega} q \cdot \nabla T^* \, d\Omega$

with $q$ heat flux and $M_{wp}$, $M_{ad}$, $M_{ar}$ and $M_{ad}$ 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:

<table>
<thead>
<tr>
<th>DX</th>
<th>DY</th>
<th>DZ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nodal reactions</td>
</tr>
</tbody>
</table>

Additional components for the elements of structure:

<table>
<thead>
<tr>
<th>DRX</th>
<th>DRY</th>
<th>MARTINI</th>
<th>DRZ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nodal reactions (moments)</td>
<td></td>
</tr>
</tbody>
</table>

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 $R_K$ is done by:

$$\sum_K R_K \cdot v_K = \int_{\Omega} \sigma \cdot \varepsilon (v_K) \, d\Omega - L(v_K)$$

with $v_K$ a generalized unit elementary displacement,

$$L(v_K) = \int_{\Omega} f \cdot v_K \, d\Omega + \int_{\Gamma} F_s \cdot v_K \, d\Gamma + \sum_i F_i \cdot v_{Ki}$$

where $f$ are the voluminal forces,

$F_s$ surface generalized forces,

$F_i$ 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:

$$R_K = F_K - \int_K f \, dK - \int_{\partial K} F \partial K - \sum_i F_{iK}$$

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.

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:

$$\sum_K R_K \cdot v_K = \int_{\Omega} \sigma (\varepsilon(u)) \cdot \varepsilon (v_K) \, d\Omega - \omega^2 (M \cdot u) \cdot v_K$$

where $\sigma (\varepsilon(u))$ are the generalized modal constraints,

$M$ is the matrix of mass,

$\omega$ the own pulsation,

$u$ the field of displacement generalized of the mode,

$v_K$ generalized unit elementary displacement.
For the concepts result of the type *dyna_trans* resulting from linear transitory dynamic calculations (*DYNA_LINE_TRAN*, or *DYNA_TRAN_MODAL* by the means of *REST_GENE_PHYS*), of type *dyna_harmo* resulting from harmonic calculations (*DYNA_LINE_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:

\[ \sum K R_k \cdot v_k = \int_\Omega \sigma \cdot \varepsilon (v_k) d\Omega + (M \ddot{u}) \cdot v_k - L(v_k) \]

where \( M \) is the matrix of mass;
\( \ddot{u} \) the field of generalized acceleration;
\( L \) the vector of the generalized external forces applied,
\( v_k \) 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:

\( F_k \) 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.

**Notice 3:**

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 meshes 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)
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 meshes 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:**

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

**Results:**

$$F_y = -3.410^4 \text{ N}$$  
$$F_{1x} = 7.810^3 \text{ N}$$  
$$F_{2x} = -1.210^3 \text{ N}$$

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*: The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.*

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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 $F_3$).

\[ F_1 = -\frac{\rho g S L}{8} \]
\[ F_2 = -\frac{\rho g S L}{4} \]
\[ F_3 = -\frac{\rho g S L}{8} \]
\[ F_4 = 0 \]
\[ F_5 = +\frac{\rho g S L}{2} \]
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')

\[
\begin{align*}
F_1 &= -\frac{\rho \ g \ SL}{8} \\
F_2 &= -\frac{\rho \ g \ SL}{4} \\
F_3 &= -\frac{\rho \ g \ SL}{8} + \frac{\rho \ g \ SL}{2} = + \frac{3 \ \rho \ g \ SL}{8}
\end{align*}
\]

\[
\begin{align*}
F_1 &= 0 \\
F_2 &= 0 \\
F_3 &= +\frac{\rho \ g \ SL}{2}
\end{align*}
\]
Comments:

- Illustration 1 shows that when the keyword is not used \texttt{GROUP\_MA}, the reaction of support are nonworthless only on the edge of the model where one imposes displacements here (AB).
- Illustration 2 shows that if one calculates \texttt{REAC\_NODA} on the only group \texttt{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 \texttt{REAC\_NODA} on the groups \texttt{STOPPING} and \texttt{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 \texttt{REAC\_NODA} while specifying exactly all meshes of the stopping and all meshes 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.
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.

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 $\Omega_e$. For a tensor $A$, the standard $L_2$ is worth:

$$N_{L_2} = \int_{\Omega_e} \sqrt{(A:A)} \, d\Omega_e$$  \hspace{1cm} (1)

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

$$N_F = \int_{\Omega_e} \sqrt{\sum_{i,j} |A_{ij}|^2} \, d\Omega_e$$  \hspace{1cm} (2)
Each one of these standards produces a component (named $X_1$) 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).

2.10.5Operand 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 thus be of the type $UT01_ELGA$, $UT22_NOEU$, etc.

2.10.6Example of calculation of a field user

Product the field $UT02_ELGA$ with two components. $X_1$ is the trace of $SIGM_ELGA$ (comparable to the component $TRSIG$ of $SIEQ_ELGA$) and $X_2$ is the equivalent constraint of Von Mises (component $VMIS$ of $SIEQ_ELGA$).

$f_{Trace} = FORMULA\ (NOM\ PARA=\ (\textquoteleft\textquoteleft SIZZ\textquoteright\textquoteright,\ \textquoteleft\textquoteleft SIYY\textquoteright\textquoteright),\\ VALE=\ "\textquoteright\textquoteright\ SIZZ+SIYY+SIZZ\ "\textquoteright)\)$

$f_{VonMis} = FORMULA\ (NOM\ PARA=\ (\textquoteleft\textquoteleft SIZZ\textquoteright\textquoteright,\ \textquoteleft\textquoteleft SIYY\textquoteright\textquoteright,\ \textquoteleft\textquoteleft SIZZ\textquoteright\textquoteright,\ \textquoteleft\textquoteleft SIXY\textquoteright\textquoteright,\ \textquoteleft\textquoteleft SIXZ\textquoteright\textquoteright,\ \textquoteleft\textquoteleft SIYZ\textquoteright\textquoteright),\\ VALE=\ "\textquoteright\textquoteright\ sqrt\ (3.\ /2.\ *\ (SIZZ\ **\ 2\ +\ SIYY\ **\ 2\ +\ SIZZ\ **\ 2\ +\ SIXY\ **\ 2\ +\ SIXZ\ **\ 2\ +\ SIYZ\ **\ 2))\ "\textquoteright)\)$

$LMBO = CALC_CHAMP\ (reuse=RES,\\ RESULTAT=RES,\\ CHAM_UTIL=F\ (NOM\ CHAM='SIGM_ELGA',\\ FORMULE=(f_{Trace},\ f_{VonMis}),\\ NUME_CHAM_RESU=2),))$