Operator POST_ELEM

1 Goal

To calculate quantities on whole or part of the structure. The calculated quantities correspond to particular options of calculation of affected modeling.

The currently available options are:

- calculation of the mass, inertias and the position of the centre of gravity,
- calculation of the potential energy,
- calculation of the kinetic energy,
- calculation of the energy of dissipation (elements DKTG),
- calculation of the work of the external efforts,
- calculation of the indicators of loss of proportionality of the loading in elastoplasticity,
- calculation of the limiting load,
- calculation of the constraint of Weibull,
- calculation of the growth rate of a spherical cavity (Rice - Tracey),
- calculation of elastic energy and total energy,
- calculation of the surface of a hole in a grid 2D,
- calculation of the integral and the average of a field,
- calculation of the distribution on the surface/volume of the value of a component of a field,
- calculation of the extrema in space of a list of components of a field,
- calculation of the standard of a field.

The turned over concept is one table.

2 Syntax

```
[table] = POST_ELEM     (
     # keyword simple
     ◊    MODELE                  =    Mo,                 [model]
     ◊    CHAM_MATER              =    chmater,            [cham_mater]
     ◊    BECAUSEA_ELEM                =    carac,              [cara_elem]
     ◊    |    NUME_COUCHE        =    /    digital,       [I]
                                       /    L,             [DEFECT]
          |    NIVE_COUCHE        =    /    'INF',
                                       /    'SUP',
                                       /    'MOY',         [DEFECT]
     ◊    MODE_FOURIER            =    /    nh,            [I]
                                       /    0,             [DEFECT]
     ◊    GEOMETRY                =    /    'DEFORMED',
                                       /    'INITIAL',     [DEFECT]
     ♦    /    CHAM_GD            =    cham,          /    [cham_no_DEPL_R]
                                                      /    [cham_no_TEMP_R]
                                                      /    [cham_elem_ENER_R]
          /    RESULT             =    resu,          /    [evol_elas]
                                                      /    [evol_noli]
                                                      /    [evol_ther]
                                                      /    [evol_char]
                                                      /    [mult_elas]
                                                      /    [fourier_elas]
                                                      /    [mode_meca]
                                                      /    [dyna_trans]
     ◊    /    TOUT_ORDRE         =    'YES',
          /    NUME_ORDRE         =    l_nuor,             [l_I]
          /    LIST_ORDRE         =    l_ordr,             [listis]
          /    NUME_MODE          =    l_numo,             [l_I]
          /    NOEUD_CMP          =    l_nomo,             [l_Kn]
          /    NOM_CAS            =    l_nocas,            [l_Kn]
          /    /    FREQ          =    l_freq,             [l_R]
               /    LIST_FREQ     =    lreel,              [listr8]
          /    /    INST          =    l_inst,             [l_R]
               /    LIST_INST     =    lreel,              [listr8]
               ◊ /  | CRITERION        =    /    'RELATIVE',    [DEFECT]
                    | PRECISION    =    /    prec,          [R]
                                       /    1.0D-6,        [DEFECT]
               /    ♦ CRITERION        =    'ABSOLUTE',
                    ♦ PRECISION    =    prec,              [R]
# keywords factor
     | MASS_INER    :    (see keyword MASS_INER  [§3.8]  )
     | ENER_POT     :    (see keyword ENER_POT       [§3.9])
     | ENER_CIN     :    (see keyword ENER_CIN       [§3.10])
     | ENER_ELAS    :    (see keyword ENER_ELAS  [§3.11])
     | ENER_ELTR    :    (see keyword ENER_ELTR  [§3.12])
     | ENER_TOTALE  :    (see keyword ENER_TOTALE    [§3.13])
     | WEIBULL      :    (see keyword WEIBULL        [§3.14])
     | RICE_TRACEY  :    (see keyword RICE_TRACEY    [§3.15])
     | INDIC_ENER   :    (see keyword INDIC_ENER [§3.16])
     | INDIC_ THRESHOLD: (see keyword INDIC_ THRESHOLD    [§3.17])
     | CHAR_LIMITE  :    (see keyword CHAR_LIMITE    [§3.18])
     | CARA_GEOM    :    (see keyword CARA_GEOM  [§3.19])
```

```
| CARA_POUTRE  :    (see keyword CARA_POUTRE     [§3.20])
| AIRE_INTERNE:     (see keyword AIRE_INTERNE    [§3.21])
| TRAV_EXT     :    (see keyword TRAV_EXT        [§3.22])
| INTEGRAL    :     (see keyword INTEGRAL   [§3.23])
| MINMAX       :    (see keyword MINMAX          [§3.24])
| ENER_DISS    :    (see keyword ENER_DISS  [§3.25])
| VOLUMOGRAMME:     (see keyword VOLUMOGRAMME    [§3.26])
| NORMALIZES       :   (see keyword NORMALIZES      [§3.27])
◊    INFORMATION                      =    /    1,            [DEFECT]
                                      /    2,
◊    TITLE                  =    Ti,

                          )
```

3 Operands

Operands MODEL, CHAM_MATER and CARA_ELEM are optional if RESULT is well informed, obligatory if it is CHAM_GD who is given.

3.1 Operand MODEL

◊ MODEL = Mo,

Name of the model on which the option is calculated. The name of the model is optional because it is contained in the structure of data result.

3.2 Operand CHAM_MATER

◊ CHAM_MATER = chmater,

Material field associated with the model Mo, optional because contained in the structure of data result.

3.3 Operand CARA_ELEM

◊ CARA_ELEM = carac,

Elementary characteristics carac necessary if there exists in the model of the elements of structure (discrete beam, plate, hull or elements), optional because are contained in the structure of data result.

3.4 Operands NUME_COUCHE/NIVE_COUCHE

◊ NUME_COUCHE = digital,

In the case of a multi-layer material, whole value ranging between 1 and the number of layers, necessary to specify the layer where one wishes to carry out elementary calculation. By convention, layer 1 is the layer **lower** (according to the normal with the element) in the case of elements of mechanical hull or thermal hull.

◊ NIVE_COUCHE =

For the layer digital defined by NUME_COUCHE, allows to specify the ordinate where one wishes to carry out elementary calculation:

'INF'	lower ordinate of the layer	(skin interns),
'SUP'	higher ordinate of the layer	(external skin),
'MOY'	average ordinate of the layer	(average layer by default).

3.5 Operand MODE_FOURIER

◊ MODE_FOURIER =

Number of the harmonic of FOURIER: positive or null entirety (defect = 0).

3.6 Operand GEOMETRY

♦ GEOMETRY = / 'INITIAL', [DEFECT]
/ 'DEFORMED',

Indicate if one works on the initial geometry or the deformation. In this last case, it is necessary to provide a field of displacements by CHAM_GD or RESULT.

3.7 Operands CHAM_GD/RESULT

Options ENER_POT and ENER_CIN are calculated starting from a field with the nodes or by elements existing or extracted from one result.

3.7.1 Operand CHAM_GD

♦ / CHAM_GD = cham,

Name of a field (for the options ENER_POT and ENER_CIN).

For the option ENER_POT, it is necessary to provide a field of displacement or a field of temperature (see [§3.9]).
For the option ENER_CIN, it is necessary to provide a field speed (without providing frequency) or a field of displacements and a frequency (see [§3.9]).

3.7.2 Operand RESULT

/ RESULT = resu,

Name of a concept result of the type evol_elas, evol_ther, mode_meca, evol_noli, mult_elas, fourier_elas or dyna_trans.

Option ENER_POT : evol_elas , evol_ther , mode_meca , mult_elas , fourier_elas evol_noli or dyna_trans .
Option ENER_CIN : mode_meca , evol_elas , evol_ther , evol_noli , or dyna_trans .
Option ENER_ELAS and ENER_TOTALE : evol_noli, evol_elas

3.7.2.1 Operands TOUT_ORDRE / NUME_ORDRE / NUME_MODE / LIST_ORDRE / NOEUD_CMP / FREQ / LIST_FREQ / INST / LIST_INST / PRECISION / CRITERION

See [U4.71.00].

3.8 Keyword MASS_INER

3.8.1 Goal

Keyword factor allowing to calculate the mass, inertias and the centre of gravity.
This option allows calculation on each element of the following characteristics:
(ρ indicating the density defined in DEFI_MATERIAU [U4.43.01] by ELAS or ELAS_FO).

Mass: $m=\int_v \rho\, dv$

Centre of gravity: $x_G=\frac{1}{m}\int_v x\,\rho\, dv\,;\, y_G=\frac{1}{m}\int_v y\,\rho\, dv\,;\, z_G=\frac{1}{m}\int_v z\,\rho\, dv$

Tensor of inertia in the centre of gravity G in the total reference mark of description of the grid:

$$I_{xx}(G)=\int_v \left(\left(y-y_G\right)^2+\left(z-z_G\right)^2\right)\rho\, dv \quad I_{xy}(G)=\int_v \left(x-x_G\right)\left(y-y_G\right)\rho\, dv$$
$$I_{yy}(G)=\int_v \left(\left(x-x_G\right)^2+\left(z-z_G\right)^2\right)\rho\, dv \quad I_{xz}(G)=\int_v \left(x-x_G\right)\left(z-z_G\right)\rho\, dv$$
$$I_{zz}(G)=\int_v \left(\left(x-x_G\right)^2+\left(y-y_G\right)^2\right)\rho\, dv \quad I_{yz}(G)=\int_v \left(y-y_G\right)\left(z-z_G\right)\rho\, dv$$

Then calculates by “summation” the quantities relating to the total structure.

The principal tensor of inertia made up of the eigenvalues of the matrix of inertia is calculated, as well as the 3 angles of Euler associated with the principal reference mark with inertia. These components are noted in the table:
IX_PRIN_G IY_PRIN_G IZ_PRIN_G ALPHA BETA GAMMA.

3.8.2 Syntax

```
|   MASS_INER =_F (

    ♦   /   ALL    =  'YES',
        /   GROUP_MA= lgrma,           [l_gr_maille]
    ◊   ORIG_INER= (xp, YP [, zp]),      [l_R]
        ),
```

Simple keywords: (see [§2])

```
    ◊   MODEL  =  Mo,                  [model]
    ◊   CHAM_MATER = chmater,          [cham_mater]
    ◊   CARA_ELEM =  carac,            [cara_elem]
    ◊   |   NUME_COUCHE =
        |   NIVE_COUCHE =
    ◊   MODE_FOURIER =
    ◊   GEOMETRY    =
        ♦   /   CHAM_GD =
            /   RESULT =
```

Foot-note

For the keyword factor MASS_INER , the material model and field are obligatory if RESULT and CHAM_GD are absent.

3.8.3 Operands

♦ GEOMETRY =/ 'INTIALE', [DEFECT]
/ 'DEFORMED',
Indicate if one works on the initial geometry or the deformation. In this last case, it is necessary
to provide a field of displacements by CHAM_GD or RESULT.

♦ / ALL = 'YES',
On all the structure.

/ GROUP_MA = lgrma,
On a list of group of meshs. If there is more than one group of meshs in the list, then a line is added to the table at exit which is the result on the union of the meshs of the groups given besides the result by group. This new line corresponds to the group of meshs 'UNION_GROUP_MA'.

◊ ORIG_INER = (xp, YP [, zp]), [l_R]
Not by report to which the tensor of inertia will be calculated.

The tensor of inertia at the point P coordinates (xp, YP, zp) starting from the tensor inertia in the centre of gravity is obtained G, mass m structure and coordinates of G by the formulas:

$$I_{xx}(P)=I_{xx}(G)+m\,x_{PG}^2$$
$$I_{yy}(P)=I_{yy}(G)+m\,y_{PG}^2$$
$$I_{zz}(P)=I_{zz}(G)+m\,z_{PG}^2$$
$$I_{xy}(P)=I_{xy}(G)+m\,x_{PG}\,y_{PG}$$
$$I_{xz}(P)=I_{xz}(G)+m\,x_{PG}\,z_{PG}$$
$$I_{yz}(P)=I_{yz}(G)+m\,y_{PG}\,z_{PG}$$

with

$$x_{PG}=x_G-x_P$$
$$y_{PG}=y_G-y_P$$
$$z_{PG}=z_G-z_P$$

3.9 Keyword ENER_POT

3.9.1 Goal

Keyword factor allowing to calculate:

- potential energy of deformation due to balance starting from displacements, in linear mechanics of the continuous mediums (thermoelasticity 2D and 3D):

$$EPOT=\frac{1}{2}\int_{élément}\varepsilon(\mathrm{U})\cdot\mathbf{A}\,\varepsilon(\mathrm{U})dv-\int_{élément}\varepsilon(\mathrm{U})\cdot\mathbf{A}\,\varepsilon^{th}(\mathrm{T})\,dv+\frac{1}{2}\int_{élément}\varepsilon^{th}(\mathrm{T})\cdot\mathbf{A}\,\varepsilon^{th}(\mathrm{T})\,dv$$

  where $\mathbf{A}$ indicate the tensor of elasticity,

- potential energy of deformation due to balance starting from displacements, in linear mechanics for the elements of structures:

$$EPOT=\frac{1}{2}\mathbf{U}^T\mathbf{K}_e\mathbf{U}-\mathbf{U}^T\mathbf{B}^T\mathbf{A}\,\varepsilon^{th}+\frac{1}{2}\varepsilon^{th}\mathbf{A}\,\varepsilon^{th}$$

where $\mathbf{K}$ indicate the matrix of rigidity
Foot-note:

In any rigour, the potential energy of a structure is the opposite of these quantities.

- the energy dissipated thermically with balance in linear thermics starting from the temperatures (cham_no_TEMP_R):

$$W_{th}=-\frac{1}{2}\int_{\Omega}\nabla T\cdot\mathbf{K}\cdot\nabla T\,d\Omega$$

Foot-note:

In the first both cases, one must give a field of displacement behind the operand RESULT or CHAM_GD . In the last case a field of temperature.

3.9.2 Syntax

```
|  ENER_POT =_F (
        ♦  /  ALL       =  'YES',
           /  GROUP_MA    =  lgrma,    [l_gr_maille]
        )
```

Simple keywords: (see [§2])

```
        ◊  MODEL          =  Mo,       [model]
        ◊  CHAM_MATER     =  chmater,  [cham_mater]
        ◊  CARA_ELEM      =  carac,    [cara_elem]
        ◊  |  NUME_COUCHE  =
           |  NIVE_COUCHE  =
        ◊  MODE_FOURIER   =
        ♦  /  CHAM_GD     =
           /  RESULT    =
```

Foot-note

For the keyword factor ENER_POT , the model, the field of materials and possibly the field of characteristics of elements of structure are obligatory obligatory (except if RESULT is provided) to determine the fields of energy as a preliminary by elements.

3.9.3 Operands

♦ / ALL = 'YES',
On all the structure.

/ GROUP_MA = lgrma,
On a list of group of meshs.

3.9.4 Produced table

The table contains, for each moment, the values of energy and the percentage on the locus concerned:

INST	PLACE	ENTITY	TOTAL	POUR_CENT
5.50000E+00	MY	ALL	4.00093E+12	1.00000E+02
5.50000E+00	GMA1	GROUP_MA	2.71323E+11	6.78151E+00

3.10 Keyword ENER_CIN

3.10.1 Goal

Keyword factor allowing to calculate the kinetic energy starting from a field speed or a field of displacement and of a frequency.

If a field speed were given, $E_C=\frac{1}{2}V^T M V$.

If one gave a field of displacement and a frequency, $E_C = \frac{1}{2}\omega^2 U^T M U$.

3.10.2 Syntax

```
|  ENER_CIN =_F (
   ◊ OPTION            =  /  'MASS_MECA',        [DEFECT]
                          /  'MASS_MECA_DIAG',
   ♦ / ALL             =  'YES',
     / GROUP_MA        =  lgrma,                 [l_gr_maille]
           )
```

Simple keywords: (see [§2])

```
◊  MODEL          =  Mo,                    [model]
◊  CHAM_MATER     =  chmater,               [cham_mater]
◊  CARA_ELEM      =  carac,                 [cara_elem]
◊  |  NUME_COUCHE =
   |  NIVE_COUCHE =
◊  MODE_FOURIER   =
♦  /  CHAM_GD     =
   /  RESULT   =
```

Foot-note 1

For the keyword factor ENER_CIN , the model, the field of materials and possibly the field of characteristics of elements of structure are obligatory (except if RESULT is provided) to determine the fields of energy as a preliminary by elements.

Foot-note 2

When one wishes to calculate energy while employing mass diagonal (to be in coherence with the option which one chose in the elementary calculation of the matrices of mass), one can specify 'MASS_MECA_DIAG' behind the key word OPTION (nonavailable in 2D). By default one uses the matrix of complete mass.

3.10.3 Operands

♦ / ALL = 'YES',

On all the structure.

/ GROUP_MA = lgrma,

On a list of group of meshs.

3.10.4 Produced table

The table contains, for each moment, the values of energy and the percentage on the locus concerned:

INST	PLACE	ENTITY	TOTAL	POUR_CENT
5.50000E+00	MY	ALL	4.00093E+12	1.00000E+02
5.50000E+00	GMA1	GROUP_MA	2.71323E+11	6.78151E+00

3.11 Keyword ENER_ELAS

3.11.1 Goal

Allows to calculate the elastic deformation energy for each moment t after an elastic design or elastoplastic, on the topological selection chosen by the user.

The user can carry out this postprocessing starting from a concept result of the type evol_noli or evol_elas. In the case of a concept evol_noli, calculation carried out depends on the choice of deformation made during calculation.

- In small deformations (DEFORMATION = SMALL or DEFORMATION = PETIT_REAC), calculation is carried out starting from the stress field of Cauchy SIEF_ELGA by the expression of Hooke:

$$E^e(t)=\frac{1}{2}\int_v^t \sigma(t) D^{-1} \sigma(t)\, dv$$

where D represent the operator of elasticity.

- in great multiplicative deformations (DEFORMATION = SIMO_MIEHE), calculation is carried out starting from the jacobien J gradient of transformation and specific measure of elastic strain $\bar{\mathbf{b}}^e$ of SIMO_MIEHE (see R5.03.21):

$$E^e(t)=\int_v^t \left[\frac{1}{2}\frac{E}{3(1-2\nu)}\left(\frac{1}{2}\left(J^2(t)-1\right)-\ln J(t)\right)+\frac{1}{2}\mu\left(tr\,\bar{\mathbf{b}}^e(t)-3\right)\right] dv$$

In the presence of thermics, a specific correction is carried out in order to as well as possible gum the effects of this one on the jacobien. This specific correction is detailed in R5.03.21.

- in great deformations logarithmic curves (DEFORMATION = GDEF_LOG), calculation is carried out starting from the specific stress field T (see R5.03.24) by the expression:

$$E^e(t)=\frac{1}{2}\int_v^t T(t) D^{-1} T(t)\, dv$$

3.11.2 Syntax

```
|   ENER_ELAS =_F (
♦   /   ALL          =   'YES',
    /   GROUP_MA     =   lgrma,     [l_gr_maille]
        )
```

Simple keywords: (see [§2])

```
◊   MODEL            =   Mo,        [model]
◊   CHAM_MATER       =   chmater,   [cham_mater]
    ◊   CARA_ELEM    =   carac,     [cara_elem]
◊   |   NUME_COUCHE  =
    |   NIVE_COUCHE  =
◊   MODE_FOURIER     =
♦   RESULT       =
```

3.11.3 Operands

♦ / ALL = 'YES',
On all the structure.

/ GROUP_MA = lgrma,
On a list of group of meshs. If there is more than one group of meshs in the list, then a line is added to the table at exit which is the result on the union of the meshs of the groups given besides the result by group. This new line corresponds to the group of meshs 'UNION_GROUP_MA'.

3.11.4 Produced table

The table contains, for each moment, the values of total energy and possibly of the energy of membrane, of the energy of inflection, the energy of shearing and the energy of coupling membrane - inflection on the locus concerned:

INST	PLACE	ENTITY	TOTAL	MEMBRANE	INFLECTION	SHEAR	COUPL_MF
1.00000E+00	MY	ALL	4.00093E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.00000E+00	GMA1	GROUP_MA	2.71323E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.00000E+00	GMA2	GROUP_MA	2.71323E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.00000E+00	UNION_GROUP_MA	GROUP_MA	5.42646E+11	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Energies of membrane, inflection, shearing and coupling membrane – inflection are available when the locus contains elements of plate or hull. The energy of shearing and coupling membrane – inflection are calculated only when the concept result is of type evol_elas, if they are not put at 0.

Note: If there is more than one group of meshs in the list, then a line is added to the table at exit which is the result on the union of the meshs of the groups given besides the result by group. This new line corresponds to the group of meshs 'UNION_GROUP_MA'.

3.12 Keyword ENER_ELTR

3.12.1 Goal

Allows to calculate the elastic deformation energy of traction for each moment t after an elastic design or elastoplastic, on the topological selection chosen by the user.
The user can carry out this postprocessing starting from a concept result of the type evol_noli or evol_elas. It is important to announce that this option is available only in small deformations. In the case of a concept evol_noli,calculation carried out must obligatorily use (DEFORMATION = SMALL).

- Only in small deformations (DEFORMATION = SMALL), calculation is carried out starting from this expression:

$$E_{el}^{traction}(t)=\int_v^t \frac{\lambda}{2} H\left(tr(\varepsilon(t))\right) tr(\varepsilon(t))^2+\mu \sum_{i=1}^{3} H(\varepsilon_i(t))\,\varepsilon_i(t)^2\,dv$$

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

3.12.2 Syntax

```
|  ENER_ELTR =_F (
♦  /  ALL          =  'YES',
   /  GROUP_MA     =  lgrma,     [l_gr_maille]
      )
```

Simple keywords: (see [§2])

```
◊  MODEL           =  Mo,        [model]
◊  CHAM_MATER      =  chmater,   [cham_mater]
   ◊  CARA_ELEM    =  carac,     [cara_elem]
◊  |  NUME_COUCHE  =
   |  NIVE_COUCHE  =
◊  MODE_FOURIER    =
♦  RESULT       =
```

3.12.3 Operands

```
♦  /  ALL    =  'YES',
```

On all the structure.

/ GROUP_MA = lgrma,
On a list of group of meshs. If there is more than one group of meshs in the list, then a line is added to the table at exit which is the result on the union of the meshs of the groups given besides the result by group. This new line corresponds to the group of meshs 'UNION_GROUP_MA'.

3.12.4 Produced table

The table contains, for each moment, the values of the elastic energy of traction (TOTAL):

INST	PLACE	ENTITY	TOTAL
1.00000E+00	MY	ALL	4.00093E+12
2.00000E+00	GMA1	GROUP_MA	2.71323E+11
2.00000E+00	GMA2	GROUP_MA	2.71323E+11
2.00000E+00	UNION_GROUP_MA	GROUP_MA	5.42646E+11

Note: If there is more than one group of meshs in the list, then a line is added to the table at exit which is the result on the union of the meshs of the groups given besides the result by group. This new line corresponds to the group of meshs 'UNION_GROUP_MA'.

3.13 Keyword ENER_TOTALE

3.13.1 Goal

Keyword factor allowing to calculate the total deformation energy for the elements of continuous mediums 2D or 3D.
For the behaviors VMIS_ISOT_LINE or VMIS_ISOT_TRAC (isotropic work hardening), energy is calculated starting from the material and internal variable, stress fields:

$$E^T = E^{el} + E^p = \frac{1}{2}\int_v \sigma^T A^{-1} \sigma \, dv + \int_v \left(\int_0^p R(q) dq \right) dv$$

P being cumulated equivalent plastic deformation.
With the option SIMO_MIEHE, this energy applies to the two models VMIS_ISOT_LINE or VMIS_ISOT_TRAC :

$$E^T = \int_{v_0} \left(\rho_0 \Psi + \int_0^t \Delta \, d\tau \right) dv$$

where Ψ and Δ are respectively the free energy and the potential of dissipation, V_0 initial volume. For more precision, to see [R5.03.21].

For the other behaviors, energy is obtained by incremental integration:

$$E^T = \int_v \left(\int_0^t \sigma . d\varepsilon \right) dv$$

Incremental integration by the method of the trapezoids implies:
- that the discretization in time is sufficiently fine,
- that the initial constraints and deformations are worthless,
- and that calculation is required as from the first moment of calculation.

3.13.2 Syntax

```
| ENER_TOTALE = _F (
    ♦ /  ALL       =  'YES',
      /  GROUP_MA    =  lgrma,    [l_gr_maille]
```

```
                )
```

Simple keywords: (see [§2]

```
◊  MODEL            =  Mo,        [model]
◊  CHAM_MATER       =  chmater,   [cham_mater]
   ◊  CARA_ELEM     =  carac,     [cara_elem]
◊  |  NUME_COUCHE   =
   |  NIVE_COUCHE   =
◊  MODE_FOURIER     =
♦  RESULT       =
```

3.13.3 Operands

♦ / ALL = 'YES',
On all the structure.

/ GROUP_MA = lgrma,
On a list of group of meshs. If there is more than one group of meshs in the list, then a line is added to the table at exit which is the result on the union of the meshs of the groups given besides the result by group. This new line corresponds to the group of meshs 'UNION_GROUP_MA'.

3.13.4 Produced table

The table contains, for each moment, the values of total energy on the locus concerned:

INST	PLACE	ENTITY	TOTAL
1.00000E+00	MY	ALL	4.00093E+12
2.00000E+00	GMA1	GROUP_MA	2.71323E+11
2.00000E+00	GMA2	GROUP_MA	2.71323E+11
2.00000E+00	UNION_GROUP_MA	GROUP_MA	5.42646E+11

Note: If there is more than one group of meshs in the list, then a line is added to the table at exit which is the result on the union of the meshs of the groups given besides the result by group. This new line corresponds to the group of meshs 'UNION_GROUP_MA'.

3.14 Keyword **WEIBULL**

3.14.1 Goal

Keyword allowing for each defined moment, the calculation of the elementary field of the power m - $ième$ constraint of Weibull of which the expression on the mesh K is given, without taking into account of the plastic deformation, by:

$$\sigma_w^m(K)=\frac{1}{V_{ref}}\int_{K_p}\sigma_1^m\,d\,K_p$$

and, with taking into account of the plastic deformation by:

$$\sigma_w^m(K)=\frac{1}{V_{ref}}\int_{K_p}\sigma_1^m\exp\left(\frac{-m}{2}\varepsilon_1^p\right)d\,K_p$$

K_p indicate the part of the mesh K who plasticized, i.e., the part of K where the cumulated plastic deformation exceeds a certain threshold; σ_1 represent the maximum principal constraint and ε_1^p represent the maximum principal plastic deformation.

The parameters material m , V_{ref} and the threshold of plasticity are defined in DEFI_MATERIAU by the relation of behavior WEIBULL (cf [R7.02.06]).

Once determined this elementary field, the option calculates by "summation" the constraint of Weibull of a field D for each definite moment:

$$\sigma_w(D)=\left(C \sum_{K\in D} \sigma_w^m(K)\right)^{\frac{1}{m}}$$

where C is a coefficient intended for the taking into account of symmetries (case Bi and three-dimensional) and thickness (in the two-dimensional case) of the structure containing the field D (keyword COEF_MULT).

Probability of rupture of the field D is then calculated by:

$$P_w(D)=1-\exp\left(-\frac{\sigma_w^m}{\sigma_u^m}\right)$$

The parameter "forced of cleavage" σ_μ is also defined in the relation of behavior WEIBULL.

Lastly, the preceding expressions of the constraint of Weibull and the probability of rupture are valid only in the case of a monotonous way of loading. This kind of postprocessing can nevertheless also be applied to a way of loading plus general, including when the constraint of cleavage depends on the temperature (relation of behavior WEIBULL_FO). The expressions of the constraint of Weibull and the probability of rupture are then different (cf [R7.02.06]).

Foot-note:

For the keyword factor WEIBULL , the material model and field are obligatory (except if RESULT is present).

Advices of use of this model are given in documentation [U2.05.08].

3.14.2 Syntax

```
|   WEIBULL = _F (
♦   /   ALL        =   'YES',
    /   GROUP_MA   =   lgrma,           [l_gr_maille]
◊  OPTION          =   /   'SIGM_ELGA', [DEFECT]
                       /   'SIGM_ELMOY',
◊   CORR_PLAST     =   /   'YES',
                       /   'NOT',       [DEFECT]
◊  COEF_MULT       =   /   coeff,       [R]
                       /   1. ,            [DEFECT]
              )
```

Simple keywords: (see [§2])

```
◊  MODEL           =   Mo,              [model]
◊  CHAM_MATER      =   chmater,         [cham_mater]
◊  CARA_ELEM       =   carac,           [cara_elem]
◊   |   NUME_COUCHE  =
    |   NIVE_COUCHE  =
◊  MODE_FOURIER    =
♦   /   CHAM_GD    =
    /   RESULT    =
```

3.14.3 Operands

3.14.3.1 Operand OPTION

◊ / OPTION = 'SIGM_ELGA',

The value of the elementary field associated with the mesh K is obtained by integration by squaring at the points of Gauss of the expression $\frac{1}{V_p}\int_{K_p}\sigma_1^m dK$.

/ OPTION = 'SIGM_ELMOY',

The value of the elementary field associated with the mesh K is obtained starting from the maximum principal value of the tensor $\frac{1}{V_p}\int_{K_p}\sigma dK$ whose value is approached by squaring at the points of Gauss.

3.14.3.2 Operand CORR_PLAST

◊ / CORR_PLAST = 'YES',

The stress field of Weibull is evaluated with taking into account of the plastic deformation.

/ CORR_PLAST = 'NOT',

The stress field of Weibull is evaluated without taking into account of the plastic deformation.

3.14.3.3 Operand COEF_MULT

/ COEF_MULT = value,

The value by default of this coefficient is 1.0.

The following table, in which the thickness is noted e, indicates typical values of the coefficient C according to the type of symmetry:

- **simple symmetry** : the symmetry plane of the grid passes by the plan of the defect and the defect is entirely with a grid,
- **double symmetry** : the symmetry plane of the grid also passes by the plan of the defect but only one half of the defect is with a grid.

	3D and 3D_SI	AXIS and AXIS_SI	D_PLAN and D_PLAN_SI	C_PLAN
SIMPLE	2	4π	2e	2e
DOUBLE	4	without object	without object	without object
NOT	1	2π	e	e

Values of the multiplying coefficient symmetry-thickness

3.14.4 Produced table

The table contains, for each moment, the values of the constraint of Weibull, the probability of rupture and the power m - $ième$ constraint of Weibull on the locus concerned:

INST	ENTITY	SIGMA_WEIBULL	PROBA_WEIBULL	SIGMA_WEIBULL ** M
1 . 0 0000E+00	ALL	2.49298E+02	0.00E+00	3.32096E+57
2.0 0000E+00	ALL	2.50473E+02	0.00E+00	3.71756E+57

3.15 Keyword RICE_TRACEY

3.15.1 Goal

This option allows, for each moment of calculation t_n defined, the calculation of growth rate $\frac{R(t_n)}{-R_0}$ of a spherical cavity compared to a field $D(R(t_n))$ and R_0 the ray running and the initial ray of the cavity indicate respectively). The law of evolution of Rice-Tracey is expressed by the relation:

$$\frac{d}{dt}\log\left(\frac{R}{R_0}\right)=0.283\,Signe\left(\frac{\sigma_M}{\sigma_{eq}}\right)\exp\left(\left|\frac{2\,\sigma_M}{2\,\sigma_{eq}}\right|\right)\frac{d\,\varepsilon_{eq}^p}{dt}$$

($\sigma_M=\frac{1}{3}Trace(\sigma)$; σ_{eq} indicate the equivalent constraint of von Mises and ε_{eq}^p indicate the equivalent deformation of von Mises).

3.15.2 Syntax

```
|   RICE_TRACEY = _F (
♦   /   ALL       = 'YES',
    /   GROUP_MA      = lgrma,            [l_gr_maille]
◊ OPTION            =   /   'SIGM_ELGA', [DEFECT]
                        /   'SIGM_ELMOY',
◊ ROOM          =   /   'YES',        [DEFECT]
        /   'NOT',
        )
```

Simple keywords: (see [§2])

```
◊   MODEL           =   Mo,             [model]
◊   CHAM_MATER      =   chmater,        [cham_mater]
◊   CARA_ELEM       =   carac,          [cara_elem]
◊   |   NUME_COUCHE  =
    |   NIVE_COUCHE  =
◊   MODE_FOURIER    =
♦   /   CHAM_GD     =
    /   RESULT    =
```

3.15.3 Operands

3.15.3.1 Operand OPTION

```
◊   OPTION =   /   'SIGM_ELGA',     [DEFECT]
```

The elementary fields of the constraints and the plastic deformations are used in their representations at the points of Gauss.

```
            /   'SIGM_ELMOY',
```

The elementary fields of the constraints and the plastic deformations are realised compared to the points of Gauss before being used.

3.15.3.2 Operand ROOM

```
◊   ROOM   =   /   'YES',          [DEFECT]
```

The law of Rice-Tracey is integrated on each mesh K field D and the result consists of the maximum value obtained on the whole of the meshs of the field.

```
        /  'NOT',
```

Fields of triaxiality $\frac{\sigma_M}{\sigma_{eq}}(t_n)$ and of variation of plastic deformation $\Delta\varepsilon_{eq}^p(t_n)$ are calculated on each mesh. Then, their respective averages, balanced by the volume of the meshs of the field, are given. Finally, the law of Rice-Tracey is integrated on these realised values.

3.15.3.3 Operands ALL / GROUP_MA

Fields of calculation D are specified by:

/ ALL = 'YES',
Only one field is defined, it coincides with the whole of the structure.

/ GROUP_MA = lgrma,
Each group of meshs of the list lgrma defined a field of calculation.

3.15.4 Produced table

The table contains, for each moment, the values of the growth rate of a spherical cavity and volume concerned on the locus concerned:

INST	PLACE	TX_CROIS_CAVITES	VOLUME_CONCERNE
1 . 0 0000E+00	MA101	1.00000E+00	3.75000E+00
2.0 0000E+00	MA101	1.00000E+00	6.23719E-01

3.16 Keyword INDIC_ENER

3.16.1 Goal

Keyword factor allowing to calculate a total indicator of loss of proportionality of the loading in elastoplasticity, founded on the density of energy. This indicator is described in detail in the document [R4.20.01].
One points out his function and his expression. This indicator is intended to detect so during the history of the structure and until the current moment T, and for a zone of the structure chosen by the modelisator, there was loss of proportionality of the loading (i.e it acts to have a total measurement of the change of the principal directions of the tensor of constraints for each point of the zone defined by the user).
This indicator is usable only for models whose material presents an isotropic work hardening and whose elements are isoparametric 2D or 3D.
This indicator has as an expression:

$$I=\frac{1}{V}\int_V\left(1-\frac{\Psi}{\Omega}\right)dv$$

where:

- V is the volume of the field defined by the user,
- Ψ is the density of total elastic energy associated with the traction diagram if non-linear elastic material were considered.
  More exactly its expression is the following one:

$$\Psi=\frac{1}{2}K\cdot tr^2(\varepsilon)+\frac{2\mu}{3}\varepsilon_{eq}^2 \qquad si \quad \sigma_{eq}<R(p)$$

$$\Psi=\frac{1}{2}K\cdot tr^2(\varepsilon)+\frac{R^2(p)}{6\mu}+\int_0^p R(s)\,ds \qquad si \quad \sigma_{eq}=R(p)$$

where:

- K is the module of compressibility,
- μ is the coefficient of shearing of Lamé,
- $R(p)$ is the threshold of the traction diagram associated with the cumulated plastic deformation p,
- Ω is the density of deformation energy defined by:

$$\Omega(t)=\int_0^t \sigma\cdot\dot{\varepsilon}\,d\tau$$

one can break up $\Omega(t)$ in an elastic part and a plastic part:

$$\Omega(t)=\Omega_{élas}(t)+\Omega_{plas}(t)$$

with:

$$\Omega_{élas}(t)=\frac{1}{2}\sigma\cdot\varepsilon^{élas}$$

$$\Omega_{plas}(t)=\int_0^t R(p)dp$$

Note:

If one has $\Omega(t)=0$, one poses $I=0$.

3.16.2 Syntax

```
|   INDIC_ENER = _F  (
    ♦   /   ALL     = 'YES',
        /   GROUP_MA  = lgrma,          [l_gr_maille]
                    )
```

Simple keywords: (see [§2])

```
◊   MODEL         =   Mo,           [model]
◊   CHAM_MATER    =   chmater,      [cham_mater]
♦   RESULT    =   resu,         [evol_noli]
```

3.16.3 Operands

The indicator is calculated on the field defined by the keywords:

```
/   ALL     = 'YES',
```

On all the elements of the model Mo.

```
/   GROUP_MA  = lgrma,
```

On the list lgrma groups of meshs of the model Mo. If there is more than one group of meshs in the list, then a line is added to the table at exit which is the result on the union of the meshs of the groups given besides the result by group. This new line corresponds to the group of meshs 'UNION_GROUP_MA'.

3.16.4 Produced table

The table contains, for each moment, the value of the total indicator of loss of proportionality of the loading in elastoplasticity on the locus concerned:

INST	PLACE	INDIC_ENER
1 . 0 0000E+00	MY	4.77299E-02
2.0 0000E+00	MY	3.33763E-02

Note: If there is more than one group of meshs in the list, then a line is added to the table at exit which is the result on the union of the meshs of the groups given besides the result by group. This new line corresponds to the group of meshs 'UNION_GROUP_MA'.

3.17 Keyword INDIC_SEUIL

3.17.1 Goal

Keyword factor allowing to calculate a total indicator of loss of proportionality of the loading in elastoplasticity.
This indicator makes it possible on the one hand to know, on average about the zone considered, if the tensor of the constraints and that of the plastic deformations have the same directions and if the plastic threshold is reached at the current moment, and on the other hand so during the history the plastic deformation changed direction.
This indicator has as an expression:

$$I=\frac{1}{V}\int_V\left(1-\frac{\sigma\cdot\varepsilon^p}{R(p)\cdot p}\right)dv$$

where:

- V is the volume of the field defined by the user,
- σ is the tensor of the constraints at the moment running,
- ε^p is the tensor of the plastic deformations at the moment running,
- $R(p)$ is the function of work hardening (with $R(o)=\sigma_y$ where σ_y is the elastic limit).
  i.e. it is the threshold of the traction diagram associated with the cumulated plastic deformation p .
- p is the cumulated plastic deformation.

Note:

If one has $R(p)\cdot p=0$, one poses $I=0$.

The scalar product $\sigma\cdot\varepsilon^p$ is associated with the standard within the meaning of von Mises.
This indicator is standardized and has a value ranging between 0 and 1.
It is null if the loading preserved its character proportional in each point of V throughout the past history.
This indicator is described in detail in the document [R4.20.01].

3.17.2 Syntax

```
INDIC_SEUIL = _F (
♦  /  ALL    =  'YES',
   /  GROUP_MA  =  lgrma,        [l_gr_maille]
      )
```

Simple keywords: (see [§2])

```
◊  MODEL        =  Mo,          [model]
◊  CHAM_MATER   =  chmater,     [cham_mater]
♦  RESULT    = resu,          [evol_noli]
```

3.17.3 Operands

The indicator is calculated on the field defined by the keywords:

```
/  ALL    = 'YES',
```

On all the elements of the model Mo.

```
/   GROUP_MA  = lgrma,
```

On the list lgrma groups of meshs of the model Mo. If there is more than one group of meshs in the list, then a line is added to the table at exit which is the result on the union of the meshs of groups given besides the result by group. This new line corresponds to the group of meshs 'UNION_GROUP_MA'.

3.17.4 Produced table

The table contains, for each moment, the value of the total indicator of loss of proportionality of the loading in elastoplasticity on the locus concerned:

INST	PLACE	INDIC_SEUIL
1 . 0 0000E+00	MY	4.77299E-02
2.0 0000E+00	MY	3.33763E-02

Note: If there is more than one group of meshs in the list, then a line is added to the table at exit which is the result on the union of the meshs of the groups given besides the result by group. This new line corresponds to the group of meshs 'UNION_GROUP_MA'.

3.18 Keyword CHAR_LIMITE

3.18.1 Goal

Postprocessing of the calculation of the limiting load [R7.07.01 §2.3].
This keyword factor allows the calculation of the limiting load of a structure by a kinematic approach. Its employment requires as a preliminary to have carried out a nonlinear calculation (see operator STAT_NON_LINE [U4.51.03]) informed by the keyword RESULT and whose characteristics are the following ones:

- law of behavior NORTON_HOFF,
- increasing list of moments of calculation corresponding to values of regularization of the law of NORTON_HOFF who tend towards 1 (in practice, one recommends to limit oneself to moments ranging between 1 and 2 who do not lead to too long calculations while allowing to obtain an upper limit of the load limits sufficiently precise),
- loading (unit) controlled corresponding to the loading by report to which one seeks to consider the limiting load, method of piloting being TYPE = 'ANA_LIM',
- possibly a constant loading whose it is then necessary imperatively to point out the existence by the keyword CHAR_CSTE = 'YES'.

The operator POST_ELEM product then a table which gives for each moment of calculation, i.e. for increasingly weak regularizations, an upper limit CHAR_LIMI_SUP limiting load supported by the structure. Moreover, in the absence of constant loading, CHAR_CSTE = 'NOT', the table also contains an estimate CHAR_LIMI_ESTIM of a lower limit of the limiting load. On the other hand, if a constant loading is present, CHAR_CSTE = 'YES', such an estimate of the lower limit is not available any more but the table contains the power then PUIS_CHAR_CSTE constant loading in the field speed solution of the problem.
A detailed example of calculation of limiting load is provided in [U2.05.04].

3.18.2 Syntax

```
|   CHAR_LIMITE = _F (
    ◊   CHAR_CSTE     =   /   'NOT', [DEFECT]
                          /   'YES',
          )
```

Simple keywords: (see [§2])

```
◊  MODEL         =  Mo,        [model]
◊  CHAM_MATER    =  chmater,   [cham_mater]
♦  RESULT    =  resu,      [evol_noli]
   ◊  CARA_ELEM =  carac,     [cara_elem]
◊  MODE_FOURIER =  nh,        [I]
```

3.18.3 Operands

```
◊  CHAR_CSTE =  /  'NOT',   [DEFECT]
                /  'YES',
```

Keyword indicating if the loading is constant or not constant (value by default).

3.18.4 Produced table

The table contains, if CHAR_CSTE = 'YES':

INST	CHAR_LIMI_SUP	PUIS_CHAR_CSTE
1 . 0 0000E+00	1.46838E+01	-2.50000E-01
2.0 0000E+00	1.46838E+01	-2.50000E-01

The table contains, if CHAR_CSTE = 'NOT':

INST	CHAR_LIMI_SUP	CHAR_LIMI_ESTIM
1 . 0 0000E+00	1.46838E+01	-2.50000E-01
2.0 0000E+00	1.46838E+01	-2.50000E-01

3.19 Keyword CARA_GEOM

3.19.1 Goal

CARA_GEOM is used by the macro_commande MACR_CARA_POUTRE [U4.42.02] to calculate the geometrical characteristics (centre of inertia, moments of inertia) of a section of beam with a grid in elements of continuous medium 2D.

3.19.2 Syntax

```
|  CARA_GEOM = _F   (
♦  /  ALL    =  'YES',
   /  GROUP_MA  =  lgma,      [l_gr_maille]
◊  SYME_X       =  /  'YES',
                   /  'NOT', [DEFECT]
◊  SYME_Y       =  /  'YES',
                   /  'NOT', [DEFECT]
◊  ORIG_INER    =  (xp, YP), [l_R]
      )
```

Simple keywords: (see [§2])

```
◊  MODEL         = Mo,         [model]
◊  CHAM_MATER    = chmater,    [cham_mater]
```

3.19.3 Operands

3.19.3.1 Operands ALL / GROUP_MA

Define the place of calculation. One can in particular calculate characteristics for a set of meshs, defined by GROUP_MA.

3.19.3.2 Operands SYME_X / SYME_Y

Taking into account of a symmetry compared to X or with Y (or both). The grid provided by the user corresponds then to half of the section (or the quarter).

3.19.3.3 Operand ORIG_INER

Allows to give the punctual coordinates per report to which will be calculated the geometrical characteristics [U4.42.02].

3.19.4 Produced table

Cf [U4.42.02] §3.2

3.20 Keyword CARA_POUTRE

3.20.1 Goal

Notice
This keyword is not intended to be called directly by the user.

CARA_POUTRE is used exclusively by the macro-order MACR_CARA_POUTRE [U4.42.02] to calculate the mechanical characteristics (constant of torsion, ray of torsion, constants of shearing, position of the center of shearing, constant of warping) of a section with a grid in elements 2D.

Its employment requires the preliminary call of many orders, specific to each calculated option. The operands will thus not be here detailed. For more detail one will refer to MACR_CARA_POUTRE [U4.42.02].

3.20.2 Syntax

```
|   CARA_POUTRE = _F (
    ♦   / ALL                    =   'YES',
        / GROUP_MA               =   lgma,                  [gr_maille]
    ◊   GROUP_MA_INTE            =   lgma_inte,             [l_gr_maille]
    ◊   CARA_GEOM                =   ,                  [tabl_cara_geom]
    ◊   LAPL_PHI                 =   ΔΦ,                    [evol_ther]
    ◊   LAPL_PHI_Y               =   ΔΦy,                   [evol_ther]
    ◊   LAPL_PHI_Z               =   ΔΦz,                   [evol_ther]
    ◊   RT                       =   rt,                    [R]
            ◊       ♦   CONNECTION=  /  'KNEECAP',
                                     /  'EMBEDDING',
                    ♦   LENGTH =  L,                    [R]
                    ♦   MATERIAL  =  chechmate,                    [to
subdue]
                    ◊   OPTION    =  /  'CARA_TORSION',
                                     /  'CARA_CISAILLEMENT',
                                     /  'CARA_GAUCHI',
          )
```

Simple keywords: (see [§2])

```
◊   MODEL                        =   Mo,                    [model]
◊   CHAM_MATER                   =   chmater,               [cham_mater]
```

3.20.3 Produced table

Cf [U4.42.02] §3.2

3.21 Keyword AIRE_INTERNE

3.21.1 Goal

Keyword factor allowing the calculation of the surface of a hole in a grid 2D starting from its contour.

3.21.2 Syntax

```
|   AIRE_INTERNE = _F (♦  GROUP_MA_BORD = lgma)
```

Simple keyword: ◊ MODEL = Mo, [model]

3.21.3 Operand

♦ GROUP_MA_BORD = lgma,
List of groups of meshs of edge delimiting the hole (SEG2 or SEG3)

3.21.4 Produced table

The table contains, for each group of meshs edge, surface of the hole and the length of its contour.

GROUP_MA	SURFACE	LENGTH
GMA1	3.14128E-02	6.28303E-01
GMA 2	3.14128E-02	6.28303E-01

3.22 Keyword TRAV_EXT

3.22.1 Goal

Mot_clé factor allowing to calculate the work of the external efforts real TRAV_REEL or rubber band TRAV_ELAS such as below definite:

$$\text{TRAV\_REEL} = \int_{t_0}^{t} \int_{\Omega} \sigma \cdot \dot{\varepsilon} = \int_{t_0}^{t} F_{\text{int}} \cdot \dot{U} \qquad \textbf{éq 3.22.1-1}$$

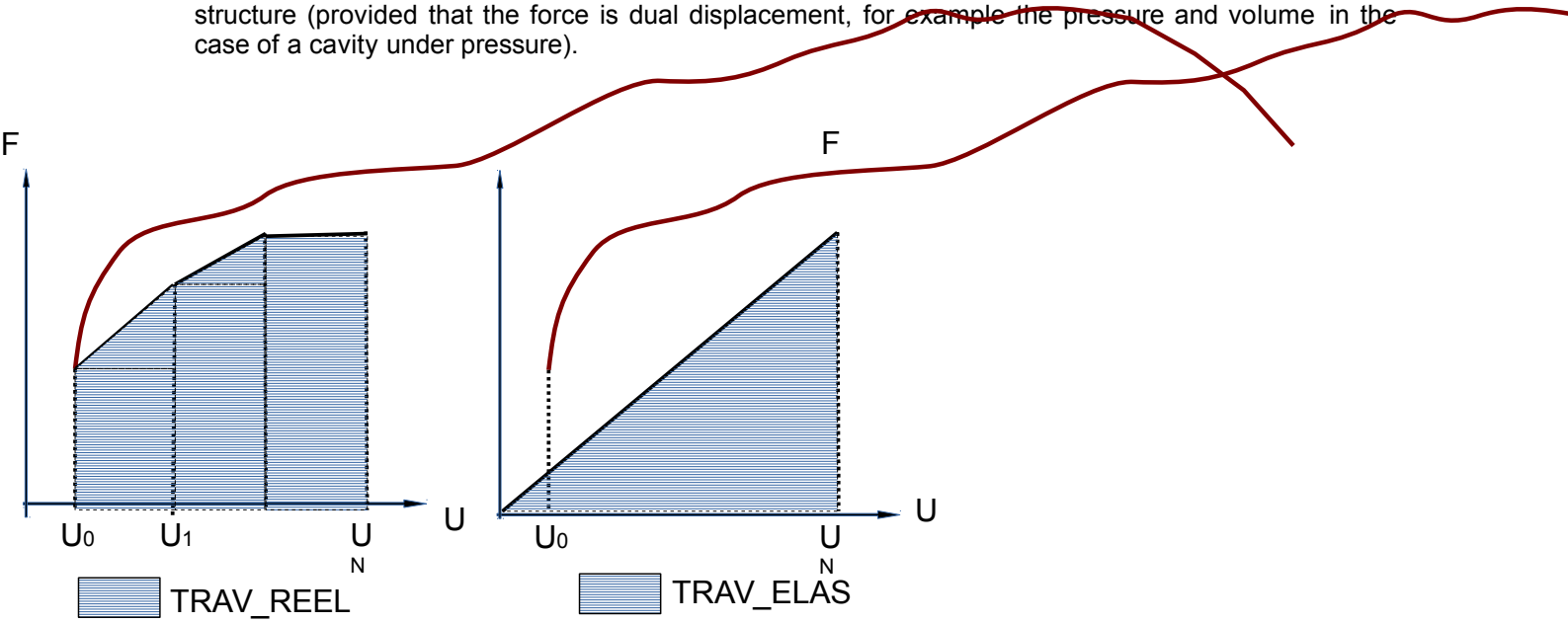
$$\text{TRAV\_ELAS} = \frac{1}{2} \int_{\Omega} \sigma \cdot \varepsilon = \frac{1}{2} F_{\text{int}} \cdot U \qquad \textbf{éq 3.22.1-2}$$

Calculation is carried out on the basis of SD result, well informed under the keyword RESULT, for which nodal forces, i.e. the interior forces, were calculated beforehand by the operator CALC_CHAMP, option 'FORC_NODA' [U4.81.04]. In the case of real work, the initial moment t_0 corresponds to the first moment filed in the SD result; integration in time is carried out by a method of trapezoids:

$$\text{TRAV\_REEL}=\sum_{i=0}^{n-1}\int_{t_i}^{t_{i+1}} \mathrm{F}(\mathrm{U}(\mathrm{t_i})).\mathrm{U}(\mathrm{t_i})\mathrm{dt}=\sum_{i=0}^{n-1}\int_{U_i}^{U_{i+1}} \mathrm{F}(\mathrm{Z})\,\mathrm{dZ}\approx\frac{1}{2}\sum_{i=0}^{n-1}(U_{i+1}-U_i)(F_{i+1}+F_i)$$
$$\approx\frac{1}{2}\sum_{i=0}^{n-1}(U_{i+1}.F_{i+1}+U_{i+1}.F_i-U_i.F_{i+1}-U_i.F_i)$$

Two sizes TRAV_REEL and TRAV_ELAS are calculated for each moment filed in the SD result.

These quantities can graphically be interpreted on the response curve force-displacement of the structure (provided that the force is dual displacement, for example the pressure and volume in the case of a cavity under pressure).



3.22.2 Syntax

```
TRAV_EXT = _F (   )
```

Simple keyword:

♦ RESULT = resu / [evol_elas]
/ [evol_noli]
/ [dyna_trans]

Name of the structure of data result of calculation.

3.22.3 Produced table

The table contains, for each moment, elastic work and the work of the external forces real.

INST	TRAV_ELAS	TRAV_REEL
0.00000E+00	1.16070E+00	1.16070E+00
1.00000E+00	4.64279E+00	4.64279E+00

3.23 Operand INTEGRAL

3.23.1 Goal

Allows to calculate the integral of a component of a field on a field defined by the keywords ALL, GROUP_MA.
One produces a table containing the value of the integral as well as the average (equal to the integral divided by volume).

3.23.2 Syntax

```
| INTEGRAL =_F (
♦   / ALL      =  'YES',
    / GROUP_MA  =  lgrma,    [l_gr_maille]
 ◊  NOM_CMP     =  nocmp,                [KN]
 ◊  NOM_ VARI   =   novari ,             [KN]
♦   TYPE_MAILLE =  /'1D',
                   /'2D',
                   /'3D',
◊   DEJA_INTEGRE =  /  'YES'
                   /  'NOT'
       )
```

Simple keywords: (see [§2])

```
◊   MODEL        =  Mo,          [model]
◊   CHAM_MATER   =  chmater,  [cham_mater]
♦   /  CHAM_GD   =  cham,     [cham_gd]
    /   RESULT=  resu,     [result]
```

```
# selection of the moments of calculation
```

to see TOUT_ORDRE, NUME_ORDRE, LIST_ORDRE, INST, LIST_INST in [U4.71.00]

3.23.3 Operands

♦ / ALL = 'YES',
On all the structure.

/ GROUP_MA = lgrma,
On a list of group of meshs. If there is more than one group of meshs in the list, then a line is added to the table at exit which is the result on the union of the meshs of the groups given besides the result by group. This new line corresponds to the group of meshs 'UNION_GROUP_MA'

♦ TYPE_MAILLE
Allows to filter according to the mesh size
(obligatory in order to ensure the homogeneity of the meshs in dimension).

◊ DEJA_INTEGRE = /'YES'
/'NOT'

Is useful only for cham_elem constant by element. In this case, this keyword is obligatory and is used to differentiate really constant fields of the fields integrated on the element (like energies potential or kinetic for example). This distinction is important for the calculation of the integral because one does not make the same "amount".

◊ NOM_CMP = nocmp, [KN]

Name of the component which one wishes to calculate L 'integral .

◊ NOM_ VARI = novari , [KN]

For the fields of the internal variables (VARI_*), one can give the name of the variable interns which one wishes to calculate the integral (see [U4.51.11] for the rules of naming of the internal variables).

3.23.4 Produced table

The table contains, for each moment, the integral and the average:

INST	INTE_PRES	MOYE_PRES
0.00000E+00	1.16070E+00	1.16070E+00
1.00000E+00	4.64279E+00	4.64279E+00

Note: If there is more than one group of meshs in the list, then a line is added to the table at exit which is the result on the union of the meshs of the groups given besides the result by group. This new line corresponds to the group of meshs 'UNION_GROUP_MA'.

3.24 Operand MINMAX

3.24.1 Goal

Allows to calculate the extremums in space of a list of components of a field, for every moment specified on a field defined by the keywords ALL, GROUP_MA.
One produces a table containing the value of the min, the max, and their localization: name of the mesh and the point of Gauss, name node.

3.24.2 Syntax

```
MINMAX  = _F (
    ♦  /  ALL       =  'YES',
       /  GROUP_MA  =  lgrma,     [l_gr_maille]
    ◊  MODEL     =  Mo,        [model]
    ♦  /  CHAM_GD   =  cham,      [cham_gd]
       /  RESULT =  resu,      [result]
          NOM_CHAM  =
       # selection of the moments of calculation
to see TOUT_ORDRE, NUME_ORDRE, LIST_ORDRE, INST, LIST_INST in [U4.71.00]
     ♦     NOM_CMP   =  lcmp   )
```

3.24.3 Operands

♦ / ALL = 'YES',
Calculation of the extremums on all the structure.

/ GROUP_MA = lgrma,
Calculation of the extremums on a list of group of meshs, If there is more than one group of meshs in the list, then a line is added to the table at exit which is the result on the union of the meshs of the groups given besides the result by group. This new line corresponds to the group of meshs 'UNION_GROUP_MA'

3.24.4 Produced table

The table contains, for each moment, the values of the max, min for each component like their localization:

CHAM_GD	INST	MAX_EPXX	MA_MAX_EPXX	PT_MAX_EPXX
EPMAX	0.0	6.90232E+02	M121	4

MIN_EPXX	MA_MIN_EPXX	PT_MIN_EPXX
0.00000E+00	M1080	1

Note: If there is more than one group of meshs in the list, then a line is added to the table at exit which is the result on the union of the meshs of the groups given besides the result by group. This new line corresponds to the group of meshs 'UNION_GROUP_MA'.

3.25 Keyword ENER_DISS

3.25.1 Goal

Allows to calculate the energy of dissipation (integral on the field of the density of energy DISS_ELGA calculated by CALC_CHAMP). This option is for the calculable moment only in the following case:

- element DKTG and lawS of behavior GLRC_DM and DHRC.

3.25.2 Syntax

```
|  ENER_DISS =_F(
♦    /  ALL          =  'YES',
     /  GROUP_MA     =  lgrma,     [l_gr_maille]
        )

Simple keywords: (see [§2])
◊    MODEL           =  Mo,        [model]
◊    CHAM_MATER      =  chmater,   [cham_mater]
     ◊  CARA_ELEM    =  carac,     [cara_elem]
◊    |  NUME_COUCHE  =
     |  NIVE_COUCHE  =
♦    RESULT          =
```

3.25.3 Operands

♦ / ALL = 'YES',
On all the structure.

/ GROUP_MA = lgrma,
On a list of group of meshs. If there is more than one group of meshs in the list, then a line is added to the table at exit which is the result on the union of the meshs of the groups given besides the result by group. This new line corresponds to the group of meshs 'UNION_GROUP_MA'.

3.25.4 Produced table

The table contains, for each moment, the values of the energy of dissipation on the locus concerned:

INST	PLACE	ENTITY	TOTAL
1.00000E+00	MY	ALL	4.00093E+12
2.00000E+00	GMA1	GROUP_MA	2.71323E+11
2.00000E+00	GMA2	GROUP_MA	2.71323E+11
2.00000E+00	UNION_GROUP_MA	GROUP_MA	5.42646E+11

Note: If there is more than one group of meshs in the list, then a line is added to the table at exit which is the result on the union of the meshs of the groups given besides the result by group. This new line corresponds to the group of meshs 'UNION_GROUP_MA'.

3.26 Operand VOLUMOGRAMME

3.26.1 Goal

Allows to calculate the distribution on the surface or volume of the value of a component of a field at various moments on a field defined by the keywords ALL or GROUP_MA.

One produces a table containing:
- terminals of the intervals defined by the values minimum and maximum of the component and amongst intervals wished,
- percentage of the structure corresponding to each interval.

Notice

The number of intervals is defined by the user, the terminals are determined by Code_Aster in the following way:
That is to say n *the number of intervals, and* $Vmin$ *and* $Vmax$ *extreme values of the component.*
That is to say $p=(Vmax-Vmin)/n$ *the length of each interval.*
The intervals are:
$[Vmin, Vmin+p], [Vmin+p, Vmin+2p], ..., [Vmin+(n-1)p, Vmax]$

3.26.2 Syntax

```
|  VOLUMOGRAMME =_F (
♦    / ALL      =  'YES',
     / GROUP_MA   =  grma,          [gr_maille]
◊    TYPE_MAILLE  =  /'2D',
                     /'3D',
◊    NOM_CHAM     =  field,         [KN]
♦    NOM_CMP      =  cmp,           [KN]
◊    LIMITS       =  (bmin, bmax), [l_R]
◊    NORMALIZES          =  /'RELATIVE'   [defect]
                     /'ABSOLUTE'
◊    |  NB_INTERV    = nb_int      [I]
     |  THRESHOLD       = threshold      [R]
        )
```

Simple keywords: (see [§2])

```
◊  MODEL        =  Mo,        [model]
◊  CHAM_MATER   =  chmater,   [cham_mater]
◊  CARA_ELEM    =  carac,     [cara_elem]
♦  /  CHAM_GD   =  cham,      [cham_gd]
   /   RESULT=  resu,      [result]
```

```
# selection of the moments of calculation
```
to see `TOUT_ORDRE, NUME_ORDRE, LIST_ORDRE, INST, LIST_INST` in [U4.71.00]

3.26.3 Operands

♦ `/ ALL = 'YES',`
On all the structure.

`/ GROUP_MA = lgrma,`
On a group of meshs.

◊ `TYPE_MAILLE`
Allows to filter according to the mesh size.

◊ `| NB_INTERV = nb_int [I]`
Many desired intervals

`| THRESHOLD = threshold [R]`
Allows to choose a threshold. In this case the number of intervals is equal to two.

◊ `NORMALIZES = /'RELATIVE' [defect]`

/'ABSOLUTE'

With NORME=' RELATIF', results displayed in the column DISTRIBUTION produced table are percentages (between 0 and 100) of calculated total volume.
With NORME=' ABSOLU', this adimensionnalisation is not made and the displayed results are the effective volumes, interval by interval, expressed in the unit defined by the grid.

◊ LIMITS = (bmin, bmax), [l_R]
Allows to limit the values of the fields used for the calculation of the volumogramme.

3.26.4 Produced table

The table contains the terminals of the intervals and the percentage of the structure corresponding to each interval.

INST	NOM_CMP	GROUP_MA	BORNE_INF	BORNE_SUP	DISTRIBUTION
1 . 0 0000E+00	M 11	LEFT	-9.99990E-07	-8.99947E-07	1.95000E+01
1 . 0 0000E+00	M 11	LEFT	-8.99947E-07	-7.99947E-07	2 . 000 00E+0 1
1 . 0 0000E+00	M 11	LEFT	-7.99947E-07	- 6 .99947E-07	2 . 0 5 0 00E+0 1

3.27 Operand NORMALIZES

3.27.1 Goal

Allows to calculate the standard of a field on a field defined by the keywords ALL, GROUP_MA for elements continuous mediums only. Currently, one can calculate the standard L_2 and normalizes it of Frobenius (see the documentation of CALC_CHAMP).
One produces a table containing the standard of the field.

3.27.2 Syntax

```
| =_F NORMALIZES   (
  ◊  TYPE_NORM    =  |' L2',       [KN]
                     |' FROBENIUS'
  ♦  / ALL     =  'YES',
     / GROUP_MA   =  lgrma,    [l_gr_maille]
  ◊  TYPE_MAILLE  =  / '2D',    [KN]
                     / '3D',
  ♦  NOM_CHAM     =  field,     [KN]
  #Si CHAM_GD is indicated
  ◊  COEF_MULT    =  coeff,     [l_R]
        )
```

Simple keywords: (see [§2])

```
  ◊  MODEL     =  Mo,           [model]
  ◊  CHAM_MATER   =  chmater,   [cham_mater]
   ♦ / CHAM_GD    =  cham,      [cham_gd]
     / RESULT  =  resu,      [result]
```

```
# selection of the moments of calculation
```

to see TOUT_ORDRE, NUME_ORDRE, LIST_ORDRE, INST, LIST_INST in [U4.71.00]

3.27.3 Operands

♦ / ALL = 'YES',
On all the structure.

/ GROUP_MA = lgrma,
On a list of group of meshs.

◊ TYPE_MAILLE
Allows to filter according to the mesh size.

♦ / CHAM_GD = cham, [cham_gd]
Fields cham accepted are the fields DEPL, TEMP, NEUT_R, FLOW, SIEF and EPSI.

◊ COEF_MULT = coeff,
Allows to give a list of real coefficients to balance the components of a field of the type NEUT_R .
If this list is not indicated, these coefficients are put at 1.
If the size of this list is lower than the component count of the field, this list is supplemented by zero values.

3.27.4 Produced table

The table contains the type of the standard (L2 currently) and its value:

GROUP_MA	TYPE_NORM	VALE_NORM
GMA1	L2	4.64719E-03
GMA 2	L2	2.71323E -02

3.28 Operand TITLE

◊ TITLE = Ti,

Title attached to the concept produced by this operator [U4.03.01].

3.29 Operand INFORMATION

◊ INFORMATION =/ 1, [DEFECT]
/ 2,

Parameter of impression.

4 Example

The example which follows applies to the calculation of total quantities to a dynamic modeling of a building engine. Are modelled: the external enclosure, the interior enclosure, internal structures, the well of tank.

The modeling of a half building is carried out by elements of beams, elements discrete representing the connections on the ground, the additional masses and the connections between nodes.

It is on this model of beams that the operator POST_ELEM will calculate:

- mass of the structure,
- coordinates of the centre of gravity,
- the tensor of inertia,
- potential energy of certain modes and its distribution in the structure,
- kinetic energy of certain modes and its distribution in the structure.

4.1 Calculation of the mass, the centre of gravity and inertias

- for all the structure (ALL = 'YES')
- for the group of meshs containing the beams (GROUP_MA = 'pou_d_t')
- for the group of meshs containing the connections on the ground (GROUP_MA = 'liai_sol')
- for the group of meshs containing the additional masses (GROUP_MA = 'masses')
- for the group of meshs containing the connections between nodes (GROUP_MA = 'liai_noe')

Order

```
massestr = POST_ELEM ( MODEL =  stickmod,
                       CHAM_MATER = chmater,
                       CARA_ELEM = caraelem,
                       MASS_INER = _F (GROUP_MA= (   'pou_d_t', 'liai_sol',
                                                     'masses', 'liai_noe'),
                       TOUT= 'YES',),
                       TITRE=' masses, center of revolves and inertias of
the structure');
```

4.2 Calculation of the potential energy of modes 1.2 and 7

- for all the structure (ALL = 'YES')
- for the group of meshs containing the beams (GROUP_MA = 'pou_d_t')
- for the group of meshs containing the connections on the ground (GROUP_MA = 'liai_sol')
- for the group of meshs containing the additional masses (GROUP_MA = 'masses')
- for the group of meshs containing the connections between nodes (GROUP_MA = 'liai_noe')

Order

```
enerpot = POST_ELEM (  RESULT = modes,
```

```
                    MODEL = stickmod,
                    NUME_MODE = (1,2,7,),
                    CHAM_MATER = chmater,
                    CARA_ELEM = caraelem,
                    ENER_POT = _F ( ALL = 'YES',
                                    GROUP_MA = ( 'pou_d_t', 'liai_sol',
                                                 'masses', 'liai_noe'),
                                  ),
                    TITRE= 'potential energies of modes 1.2 and 7',
                  )
```

4.3 Calculation of the kinetic energy of modes 1.2 and 7

- for all the structure (TOUT= 'YES')
- for the group of meshs containing the beams (GROUP_MA = 'POU_D_T')
- for the group of meshs containing the connections on the ground (GROUP_MA = 'LIAI_SOL')
- for the group of meshs containing the additional masses (GROUP_MA = 'MASSES')
- for the group of meshs containing the connections between nodes (GROUP_MA = 'LIAI_NOE')

Order

```
enercin = POST_ELEM (   RESULTAT= modes,
                        MODELE= stickmod,
                        NUME_MODE= (1,2,7,),
                        CHAM_MATER= chmater,
                        CARA_ELEM= caraelem,
                        ENER_CIN= _F (  TOUT= 'YES',
                                        GROUP_MA= ('pou_d_t', 'liai_sol',
                                                   'masses', 'liai_noe',),
                                     ),
                        TITRE= '  kinetic energies of modes 1.2 and 7 ',
                      )
```