Operators AFFE_CHAR_THER and AFFE_CHAR_THER_F

1 Drank

Affecter of the loadings and the thermal boundary conditions on a model.

For the operator AFFE_CHAR_THER, the values affected do not depend on any parameter and are defined by actual values.

For operator AFFE_CHAR_THER_F, the values are function of one or two parameters to be chosen as a whole (INST, X, Y, Z) or of temperature TEMP in nonlinear thermal.

These functions must be defined beforehand by the call to one of the operators:

- DEFI_CONSTANTE [U4.31.01]
- DEFI_FONCTION [U4.31.02]
- DEFI_NAPPE [U4.31.03]
- CALC_FONC_INTERP [U4.32.01]

the product concept is of char_ther type.

2 General syntax

```
CH  [char_ther]  =AFFE_CHAR_THER

          ( ♦MODELE    =mo   ,
[model]

             ♦  |  TEMP_IMPO =       (see key word TEMP_IMPO         )
                |  FLUX_REP =        (see key word FLUX_REP       )
                |  RAYONNEMENT =     (see key word RAYONNEMENT    )
                |  ECHANGE =         (see key word ECHANGE        )
                |  SOURCE =          (see key word SOURCE         )
                |  PRE_GRAD_TEMP =   (see key word PRE_GRAD_TEMP  )
                |  LIAISON_DDL =     (see key word LIAISON_DDL    )
                |  LIAISON_GROUP =   (see key word LIAISON_GROUP  )
                |  LIAISON_MAIL =    (see key word LIAISON_MAIL      )
                |  ECHANGE_PAROI =   (see key word ECHANGE_PAROI  )
                |  LIAISON_UNIF =    (see key word LIAISON_UNIF      )
                |  LIAISON_CHAMNO=   (see key word LIAISON_CHAMNO )
                |  CONVECTION=       (see key word CONVECTION     )
          )


CH  [char_ther]  =AFFE_CHAR_THER_F

          ( ♦  MODELE =mo   ,
[model]

             ♦  |  TEMP_IMPO =       (see key word TEMP_IMPO         )
                |  FLUX_REP =        (see key word FLUX_REP       )
                |  FLUX_NL =         (see key word FLUX_NL        )
                |  RAYONNEMENT =     (see key word RAYONNEMENT    )
                |  ECHANGE =         (see key word ECHANGE        )
                |  SOURCE =          (see key word SOURCE         )
                |  PRE_GRAD_TEMP=    (see key word PRE_GRAD_TEMP  )
                |  LIAISON_DDL =     (see key word LIAISON_DDL    )
                |  LIAISON_GROUP =   (see key word LIAISON_GROUP  )
                |  ECHANGE_PAROI =   (see key word ECHANGE_PAROI  )
                |  LIAISON_UNIF =    (see key word LIAISON_UNIF      )
                |  CONVECTION =      (see key word CONVECTION     )
                |  SOUR_NL =         (see key word SOUR_NL
          )
```

3 Généralités

possible Error messages related to command AFFE_CHAR_THER

It arrives sometimes that a thermal ordering of computation (THER_LINEAIRE, THER_NON_LINE,…) stop in fatal error during the computation of the second elementary members due to the loadings defined in the AFFE_CHAR_THER_xx commands.

When the code stops during these elementary computations, important information of the error message is the name of the computation option required by the code. The name of this option is in general unknown to the user and it is thus difficult for him to understand the message.

In the table below, one gives in with respect to the names of the computation options, the command name and of the key word factor which make it possible to activate this option.

Elementary computation option	Commande	Key word factor
CHAR_THER_FLUNL	AFFE_CHAR_THER_F	FLUX_NL
CHAR_THER_FLUN_F	AFFE_CHAR_THER_F	FLUX_REP
CHAR_THER_FLUN_R	AFFE_CHAR_THER	FLUX_REP
CHAR_THER_FLUTNL	AFFE_CHAR_THER	CONVECTION
CHAR_THER_FLUTNL	AFFE_CHAR_THER_F	CONVECTION
CHAR_THER_FLUX_F	AFFE_CHAR_THER_F	FLUX_REP
CHAR_THER_FLUX_R	AFFE_CHAR_THER	FLUX_REP
CHAR_THER_GRAI_F	AFFE_CHAR_THER_F	PRE_GRAD_TEMP
CHAR_THER_GRAI_R	AFFE_CHAR_THER	PRE_GRAD_TEMP
CHAR_THER_PARO_F	AFFE_CHAR_THER_F	ECHANGE_PAROI
CHAR_THER_PARO_R	AFFE_CHAR_THER	ECHANGE_PAROI
CHAR_THER_SOUR_F	AFFE_CHAR_THER_F	SOURCE
CHAR_THER_SOUR_R	AFFE_CHAR_THER	SOURCE
CHAR_THER_TEXT_F	AFFE_CHAR_THER_F	ECHANGE
CHAR_THER_TEXT_R	AFFE_CHAR_THER	ECHANGE
CHAR_THER_SOURNL	AFFE_CHAR_THER_F	SOUR_NL

4 Opérandes

4.1 Généralités on the Les

4.1.1 operands two forms of operands under a key word factor

Les operands under a key word factor are of two forms:

- operands specifying the topological entities where the loadings are affected (key words GROUP_NO and GROUP_MA, etc…). The arguments of these operands are identical for the two operators.
- operands specifying the affected values (TEMP, COEF_H, etc…). The meaning of these operands is the same one for the two operators but the arguments of these operands are all of the real type for operator AFFE_CHAR_THER and of the standard function (created by one of operators DEFI_FONCTION, DEFI_NAPPE, DEFI_CONSTANTE or CALC_FONC_INTERP) for operator AFFE_CHAR_THER _F.

We will thus not distinguish in this document, except mention express of the opposite, two operators AFFE_CHAR_THER and AFFE_CHAR_THER_F.

4.1.2 Topological entities of assignment of the loadings

In a general way, the topological entities on which values must be affected are defined:

- by nodes and in this case:
  - either by operand GROUP_NO allowing to introduce a list of nodes group,
  - or by the operand NODE allowing to introduce a list of nodes.
- by mesh and in this case:
  - either by GROUP_MA allowing to introduce a list of mesh groups,
  - or by MESH allowing to introduce a list of meshes.

Regulate:

To define the field of assignment most simply possible, one uses the rule of overload it is the last assignment which precedes.

4.2 Operand MODELE

♦MODELE =mo ,

Product concept by operator AFFE_MODELE [U4.41.01] where the types of finite elements affected on the mesh are defined.

4.3 Key word TEMP_IMPO

4.3.1 Drank

Key word factor usable to impose, on nodes or nodes groups, a temperature.

According to the name of the operator called, the values are provided directly (AFFE_CHAR_THER) or via a concept of type function (AFFE_CHAR_THER_F).

4.3.2 Syntax

- for AFFE_CHAR_THER

```
TEMP_IMPO = _F ( ♦  |  TOUT     =      'OUI',
                    |  NODE    =       lno,                  [l_noeud]
                    |  GROUP_NO =      lgno,                 [l_gr_noeud]
                    |  NET   =lma      ,                  [l_maille]
                    |  GROUP_MA =lgma       ,
[l_gr_maille]
                 ♦  /  TEMP        =    T,                   [R]
                    /  |  TEMP     =    T,                   [R]
                       |  TEMP_INF =TINF    ,                [R]
                       |  TEMP_SUP =tsup    ,                [R]
               )
```

- for AFFE_CHAR_THER_F

```
TEMP_IMPO = _F ( ♦  |  TOUT     =      'OUI',
                    |  NODE    =       lno,                  [l_noeud]
                    |  GROUP_NO =      lgno,                 [l_gr_noeud]
                    |  NET   =lma      ,                  [l_maille]
                    |  GROUP_MA =lgma       ,
[l_gr_maille]
                 ♦  /  TEMP=tf              ,
[function]
                    /  |  TEMP=tf           ,
[function]
                       |     TEMP_INF=tinf,                  [function]
                       |     TEMP_SUP=tsupf   ,
[function]

               )
```

4.3.3 Opérandes

/TEMP =

Value of **the temperature** imposed on (S) the node (S) specified (S).

/Pour the shell elements thermal only (Modelization: "SHELL"):

| TEMP

Temperature on the average layer imposed on (S) the node (S) specified (S).

| TEMP_INF

Temperature imposed on the lower wall of the shell.

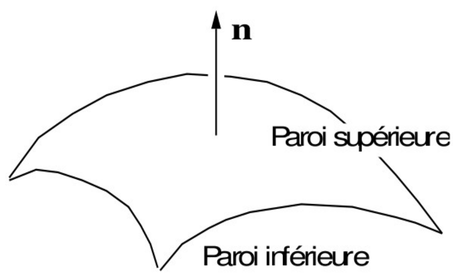
TEMP_SUP

Temperature imposed on the higher wall of the shell.

These options make it possible to represent a parabolic variation of the temperature in the thickness.

Note:

The shell is directed by the connectivity of the nodes of the associated mesh (cf [U3.01.00]). That is to say $\mathbf{n}$ *the normal vector directing the shell:*



4.4 Key word FLUX_REP

4.4.1 Drank

Key word factor usable to apply **normal flows**, with **a face** of voluminal element or thermal shell defined by one or more meshes or of the mesh groups of type **triangle** or **quadrangle**. This key word also makes it possible to apply a normal flow to an edge (in 2D PLANE or AXIS or AXIS_FOURIER) to meshes of type segment.

According to the name of the operator called, the values are provided directly (AFFE_CHAR_THER) or via a concept of type function (AFFE_CHAR_THER_F).

4.4.2 Syntax

- for AFFE_CHAR_THER

```
 FLUX_REP = _F    (  ♦ /  TOUT     =          'OUI',
                     ◊  |  NET   =lma      ,             [l_maille]
                        |  GROUP_MA =lgma      ,
[l_gr_maille]

                  ♦  /  FLUN        =FL       ,                 [R]
                     /  |  FLUN_INF =FLIN     ,              [R]
                        |  FLUN_SUP =flsup    ,              [R]
             )
```

- for AFFE_CHAR_THER_F

```
FLUX_REP = _F  (
                 ♦  /  TOUT     =          'OUI',
                    ◊  |  NET   =lma      ,             [l_maille]
                       |  GROUP_MA =lgma      ,
[l_gr_maille]


                 ♦  /  FLUN =flf              ,              [function]
                    /  |  FLUN_INF =flinf     ,              [function]
                       |  FLUN_SUP =flsupf    ,           [function]
                    /  |  FLUX_X   =flx    ,              [function]
                       |  FLUX_Y   =fly    ,              [function]
                       |  FLUX_Z   =flz    ,              [function]
             )
```

4.4.3 Opérandes

/FLUN : fl normal flow imposed on the mesh.

This loading applies to the types of meshes and the following modelizations:

Net	Modélisation
TRIA3, TRIA6, QUAD4, QUAD8, QUAD9	3D, 3D_DIAG
SEG2, PLANE	SEG3, AXIS, AXIS_FOURIER, PLAN_DIAG, AXIS_DIAG

Plus precisely the boundary condition applied is: $\lambda\left(grad\,T\cdot\boldsymbol{n}\right)$ = `fl`

where λ is thermal conductivity and $\boldsymbol{n}$ is the norm directed in the meaning of the numbers of the nodes of the mesh. The convention of directional sense is that used in `AFFE_CHAR_MECA` [U4.44.01].

```
/  |  FLUN_INF = flin
   |  FLUN_SUP = flsup
```

normal Flux imposed on the walls lower and higher of a thermal shell.

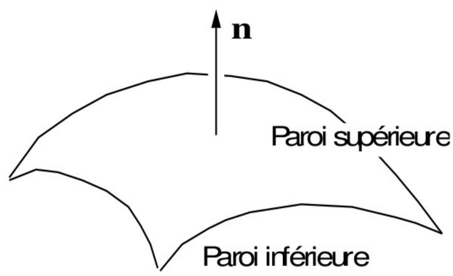
These loadings apply to the types of meshes and the following modelizations:

Net	Modélisation
TRIA3, TRIA6	SHELL

$\boldsymbol{n}$ being the norm directing surface [U4.44.01], the boundary condition applied is:

$\lambda\left(grad\,T\cdot\boldsymbol{n}\right)$ = `flin` where `flin` is the normal flow imposed on the lower wall of the shell,

$\lambda\left(grad\,T\cdot\boldsymbol{n}\right)$ = `flsup` where `flsup` is the normal flow imposed on the higher wall of the shell.




```
/  |  FLUX_X = flx
   |  FLUX_Y = fly
   |  FLUX_Z = flz
```

vectorial Flux $\boldsymbol{fl}$ in the total reference (only for `AFFE_CHAR_THER_F)` which one projects on the norm with the element (for the definition of the norm [U4.44.01]).

$$\lambda\left(grad\,T\cdot\boldsymbol{n}\right)=\boldsymbol{fl}\cdot\boldsymbol{n}=flx.nx+fly.ny+flz.nz$$

This loading applies to the types of meshes and the modelizations:

Net	Modélisation
SEG2, SEG3	PLANE
	PLAN_DIAG

Note: the rule of remanence (see U1.03.00) applies between the various quantities which one can affect: `FLUN`, `FLUN_INF`,… `FLUX_Z`.

4.4.4 Notice

key word simple `CARA_TORSION` of this key word factor `FLUX_REP` is not documented here and does not have to be employed by the user. He is used only for macro-command `MACR_CARA_POUTRE`. The aforementioned is used to identify the geometrical characteristics of the sections of beams. For the characteristics of torsion, the command solves a problem of Laplacian by employing in an indirect way the operators of linear thermal.

4.5 Key word FLUX_NL

4.5.1 Drank

Word-key factor usable to apply **normal flows** functions of the temperature, with **a face** of voluminal element defined by one or more meshes or of the mesh groups of type **triangle** or **quadrangle**. This key word also makes it possible to apply a normal flow to an edge (in 2D PLANE or AXIS) to meshes of type segment. One can thus modelize a condition of radiation of the standard model of STEPHAN. This kind of flow is used only by commands THER_NON_LINE [U4.54.02] and THER_NON_LINE_MO [U4.54.03].

The values are provided by a concept of type function.

4.5.2 Syntax

- For AFFE_CHAR_THER_F

```
FLUX_NL = _F (
            ♦  /  TOUT    =        'OUI',
               ◊  |  NET   =lma      ,          [l_maille]
                  |  GROUP_MA =lgma     ,
[l_gr_maille]

            ♦FLUN        =fl       ,            [function]
          )
```

4.5.3 Opérandes

FLUN: normal flow imposed on the mesh.

This loading applies to the types of meshes and the following modelizations:

Net	Modélisation
TRIA3, TRIA6, QUAD4, QUAD8, QUAD9	3D, 3D_DIAG
SEG2, PLANE	SEG3, AXIS PLAN_DIAG, AXIS_DIAG

Plus precisely the boundary condition applied is:

$$\lambda \left(grad\, T \cdot \boldsymbol{n} \right) = \mathrm{fl}$$

where $\boldsymbol{n}$ is the norm directed in the meaning of the numbers of the nodes of the mesh. Directional sense used in AFFE_CHAR_MECA document [U4.44.01].

4.6 Key word RAYONNEMENT

4.6.1 Drank

Word-key making it possible to define the flow radiated ad infinitum according to the formula:

$$\Phi_{ray}=\sigma\,\epsilon\left([T+273,15]^4-[T_\infty+273,15]^4\right)$$

by the data of emissivity ε, the Boltzmann constant σ and the temperature ad infinitum T_∞ expressed as Celsius. The temperature T will be also expressed as Celsius, it is thus necessary to take care, by coherence, to use only degrees Celsius for all the study.

4.6.2 Syntax

- for AFFE_CHAR_THER

```
RAYONNEMENT = _F  (
                   ♦  /  TOUT     =          'OUI',
                      ◊  |  NET    =lma      ,          [l_maille]
                         |  GROUP_MA =lgma      ,
[l_gr_maille]

                    ♦    SIGMA   =sigma        ,           [R8]
                    ♦    EPSILON =epsilon      ,         [R8]
                    ♦    TEMP_EXT=tex        ,           [R8]
               )
```

- for AFFE_CHAR_THER_F

```
RAYONNEMENT = _F    (
                   ♦  /  TOUT     =          'OUI',
                      ◊  |  NET    =lma      ,          [l_maille]
                         |  GROUP_MA =lgma      ,
[l_gr_maille]

                   ♦SIGMA       =sigma        ,          [function]
                   ♦EPSILON      =epsilon        ,       [function]
                   ♦TEMP_EXT=tex              ,          [function]
               )
```

4.6.3 Opérandes

```
♦SIGMA     =sigma
♦EPSILON    =epsilon
♦TEMP_EXT  =tex
```

This loading applies to the following modelizations:

Net	Modélisation
TRIA3, TRIA6, QUAD4, QUAD8, QUAD9	3D, 3D_DIAG
SEG2, PLANE	SEG3, AXIS PLAN_DIAG, AXIS_DIAG

sigma : Boltzmann constant, $\sigma=5.67 10^{-8}$ in units IF ($W/m^2.K^4$) (attention with this value if the units of mesh change),

epsilon : emissivity,

tex : temperature ad infinitum in degrees Celsius.

4.7 Key word ECHANGE

4.7.1 Drank

Word-key factor usable to apply **conditions of exchange** with an outside air temperature with **a face** of voluminal elements or shells, defined by one or more meshes or of the mesh groups of type **triangle** or **quadrangle**. This key word also makes it possible to apply conditions of exchange to an edge (in 2D `PLANE` or `AXIS` or `AXIS_FOURIER`) to meshes of type segment.

According to the name of the operator called, the values are provided directly (`AFFE_CHAR_THER`) or via a concept of type `function` (`AFFE_CHAR_THER_F`).

4.7.2 Syntax

- for `AFFE_CHAR_THER`

```
ECHANGE = _F  (
                  ♦  /  TOUT     =         'OUI',
                     /  |  NET    =lma       ,            [l_maille]
                        |  GROUP_MA =lgma      ,
[l_gr_maille]

                  ♦  /  ♦COEF_H      =h        ,              [R]
                        ♦TEMP_EXT  =tex        ,            [R]

                     /  |  ♦COEF_H_INF=hin         ,            [R]
                           ♦TEMP_EXT_INF=texin       ,            [R]
                        |  ♦COEF_H_SUP=hsup        ,            [R]
                           ♦  TEMP_EXT_SUP=texsup    ,          [R]
              )
```

- for `AFFE_CHAR_THER_F`

```
ECHANGE = _F  (
                  ♦  /  TOUT     =         'OUI',
                     /  |  NET    =lma       ,            [l_maille]
                        |  GROUP_MA =lgma      ,
[l_gr_maille]

                  ♦  /  ♦COEF_H      =hf       ,              [function]
                        ♦TEMP_EXT  =texf       ,            [function]

                     /  |  ♦COEF_H_INF     =hinf  ,            [function]
                           ♦TEMP_EXT_INF =texinf  ,         [function]
                        |  ♦COEF_H_SUP     =hsupf ,            [function]
                           ♦TEMP_EXT_SUP =texsupf ,         [function]
              )
```

4.7.3 Opérandes

```
/   ♦ COEF_H = H,
    ♦ TEMP_EXT = tex,
```

This loading applies to the types of meshes and the following modelizations:

Net	Modélisation
TRIA3, TRIA6, QUAD4, QUAD8, QUAD9	3D, 3D_DIAG
SEG2, PLANE	SEG3, PLAN_DIAG AXIS, AXIS_FOURIER, AXIS_DIAG

Plus precisely the boundary condition applied is:

$$\lambda(grad\,T\cdot\boldsymbol{n})=h(tex-T)\quad(h>0)$$

where $\boldsymbol{n}$ is the norm directed in the meaning of the numbers of the nodes tops (directional sense used in AFFE_CHAR_MECA [U4.44.01]).

```
/   |  ♦ COEF_H_INF=      hin,
       ♦ TEMP_EXT_INF=       texin,
    |  ♦ COEF_H_SUP=      hsup,
       ♦ TEMP_EXT_SUP=       texsup,
```

This loading applies to the types of meshes and the following modelizations:

Net	Modélisation
TRIA3, TRIA6	SHELL

$\boldsymbol{n}$ being the norm directing surface [U2.03.03], the boundary condition applied is:

$$\lambda(grad\,T\cdot\boldsymbol{n})=hin(texin-T)$$

where hin coefficient of heat exchange on the lower wall of the shell,
and texin outside air temperature, with dimensions lower wall.

$$\lambda(grad\,T\cdot\boldsymbol{n})=hsup(texsup-T)$$

where hsup coefficient of heat exchange on the higher wall of the shell,
and texsup outside air temperature, with dimensions external wall.

Note: the rule of remanence (see U1.03.00) applies between the various quantities which one can affect: COEF_H, COEF_H_INF,… TEMP_EXT_SUP.

4.8 Key word SOURCE

4.8.1 Drank

Word-key factor usable to apply **voluminal sources** (2D or 3D) to **a field** defined by one or more meshes or of the mesh groups of the voluminal **type**.

According to the name of the operator called, the values are provided directly (AFFE_CHAR_THER) or via a concept of type function (AFFE_CHAR_THER_F).

4.8.2 Syntax

- for AFFE_CHAR_THER

```
SOURCE=_F  (
            ♦  /  TOUT      =          'OUI',
               /  | NET    =lma        ,       [l_maille]
                  | GROUP_MA =lgma      ,       [l_gr_maille]

            ♦ ..... /SOUR              =s        ,       [R]
               /SOUR_CALCULEE    =chs         ,    [cham_elem]
        )
```

- for AFFE_CHAR_THER_F

```
SOURCE=_F  (
         ♦  /  TOUT      =          'OUI',
            /  | NET    =lma        ,          [l_maille]
               | GROUP_MA =lgma      ,          [l_gr_maille]

         ♦SOUR         =sf            ,             [function]
        )
```

4.8.3 Opérandes

This loading applies to the types of meshes and the following modelizations:

Net	Modélisation
HEX A8, HEXA20, HEXA27 PYRA5, PYRA13, PENTA6, PENTA15 TETRA4, TETRA10	3D, 3D_DIAG
TRIA3, TRIA6, QUAD4, QUAD8, PLANE	QUAD9, PLAN_DIAG, AXIS, AXIS_FOURIER AXIS_DIAG

/ ♦SOUR = S,

Valeur of the presumedly constant source on the element.

/ ♦SOUR_CALCULEE = chs,

Nom of the cham_elem_sour_R containing on each element the values of the source discretized at the Gauss points (1st family).

4.9 Mot-clé PRE_GRAD_TEMP

4.9.1 Drank

Word-key factor usable to apply to an element 3D or 2D (PLANE, AXIS) a variation in presumedly uniform temperature in the element. This “initial” variation in temperature is usable for example to solve the elementary problems determining the correctors of steady linear thermal in the basic cell (2D, 3D), in periodic homogenisation.

The conductance coefficients homogenized are obtained by calculating by operator POST_ELEM [U4.81.22] key word ENER_POT the energy dissipated thermically with the equilibrium in linear thermal starting from the correctors.

Because of the thermal analogy, this step can be exploited to obtain the correctors in elasticity antiplane in basic cell 2D, as well as in electric conduction.

The assignment can be done on one or more meshes, one or more mesh groups or on all the elements of the model.

4.9.2 Syntax

• for AFFE_CHAR_THER

```
PRE_GRAD_TEMP = _F    (
                    ♦  /  TOUT      =          'OUI',
                       /  |  NET    =lma       ,              [l_maille]
                          |  GROUP_MA =lgma       ,
[l_gr_maille]
                    ♦  |  FLUX_X =FLX         ,                [R]
                       |  FLUX_Y =FLY         ,                [R]
                       |  FLUX_Z =flz         ,                [R]
                       )
```

4.9.3 Opérandes

This loading applies to the types of meshes and the following modelizations:

Net	Modélisation
TRIA3, TRIA6, QUAD4, QUAD8, PLANE	QUAD9, AXIS, PLAN_DIAG, AXIS_DIAG
HEXA8, HEXA20, HEXA27 PENTA6, PENTA15, TETRA4, TETRA10 PYRA5, PYRA13	3D, 3D_DIAG

```
♦  |   FLUX_X = flx (flxf)
   |   FLUX_Y = fly (flyf)
   |   FLUX_Z = flz (flzf) (in 3D only)
```

Component of the variation in temperature $grad\,T_{ini}$ in the total reference.

The second computed elementary member is: $\int_{V_e} grad\,T_{ini}\,K\,grad\,T^{*}\,dV_e$ where K is the tensor of thermal conductivities.

The gradients can be a function of the geometry and/or time.

* for AFFE_CHAR_THER_F

```
PRE_GRAD_TEMP = _F   (
                        ♦  /  TOUT      =      'OUI',
                           /MAILLE      =lma      ,        [l_maille]
                           /GROUP_MA  =lgma    ,         [l_gr_maille]
                        ♦  |   FLUX_X =flxf       ,        [function]
                           |   FLUX_Y =flyf       ,        [function]
                           |   FLUX_Z =flzf       ,        [function]
                      )
```

4.10 Word-key LIAISON_DDL

4.10.1 Drank

Word-key factor usable to define a linear relation between degrees of freedom of two or several nodes.

According to the name of the operator called, the values are provided directly (AFFE_CHAR_THER) or via a concept function (AFFE_CHAR_THER_F).

4.10.2 Syntax

- for AFFE_CHAR_THER

```
LIAISON_DDL = _F  (♦/   NODE     =lno     ,              [l_noeud]
                    /GROUP_NO     =lgno    ,              [l_gr_noeud]

                 ◊ D.O.F. =      |           "TEMP",        [DEFECT]
                                 |         "TEMP_INF",
                                 |         "TEMP_SUP",

                 ♦ COEF_MULT =             have  ,          [l_R]
                 ♦ COEF_IMPO =             B  ,           [R]
             )
```

- for AFFE_CHAR_THER_F

```
LIAISON_DDL = _F  ( ♦   /  NODE     =lno     ,           [l_noeud]
                       /GROUP_NO     =lgno    ,           [l_gr_noeud]

                 ◊ D.O.F. =      |           "TEMP",        [DEFECT]
                                 |         "TEMP_INF",
                                 |         "TEMP_SUP",

                ♦   COEF_MULT =ai              ,          [l_R]
                ♦COEF_IMPO    =bf                 ,          [function]
             )
```

4.10.3 Opérandes

the list of the nodes N_i ($i=1,r$) defined by GROUP_NO or NODE is ordered in a natural way:

- in the order of the list of nodes group, and for each nodes group, in the order of definition of the group by GROUP_NO.
- in the order of the list of nodes for NODE.

The argument of D.O.F. must be a list of degrees of freedom T_i ($i=1,r$) of r texts taken among:

"TEMP''   TEMP_SUP''   TEMP_INF"

If the key word D.O.F. is omitted, by defect the linear relation will relate to degrees of freedom "TEMP".

The argument of COEF_MULT must be a list a_i ($i=1,r$) of coefficients (of real type for AFFE_CHAR_THER and AFFE_CHAR_THER_F).

The argument of `COEF_IMPO` is a coefficient β for `AFFE_CHAR_THER`, a function of space for `AFFE_CHAR_THER_F`.

The following kinematical condition is applied: $\sum_{i=1}^{r} \alpha_i T_i = \beta$

Note:

Components "TEMP_SUP" and "TEMP_INF" can intervene only in combinations only ***assigned*** *to nodes which belong to shell elements (modelization "SHELL").*

In the case of a linear relation between the degrees of freedom of the same node, one will repeat behind the key word NODE the name of the node as many times as there are degrees of freedom in the relation. ***Example:*** *to impose $T_{\text{sup}} = T_{\text{inf}}$ on the node $N1$, one will write:*

```
LIAISON_DDL = _F  ( NOEUD=          (N1, N1),
                    DDL=                ("TEMP_SUP", "TEMP_INF"),
                    COEF_MULT=          (1. , - 1.),
                    COEF_IMPO=0       .,
                  )
```

It is important to note that to an occurrence of the key word factor LIAISON_DDL corresponds one and only one linear relation.
If one wants to impose the same relation between 2 nodes groups GRN01 and GRN02 (even temperature node with node for example) ***one cannot write:***

```
LIAISON_DDL = _F    ( GROUP_NO=      (GRN01, GRN02),
                     DDL=            ("TEMP",  "TEMP"),
                    COEF_MULT=       (1. , - 1.),
                    COEF_IMPO=0      .,                        )
```

Cette writing has meaning only if GRN01 and GRN02 contain each one one node. It will be necessary in the case to clarify each linear relation above, node by node.

Key word LIAISON_GROUP on the other hand makes it possible to condense the writing of the linear relations between 2 nodes groups in opposite.

4.11 Key word LIAISON_GROUP

4.11.1 Drank

Word-key factor usable to define linear relations between couples of nodes, these couples of nodes being obtained while putting in opposite two lists of meshes or nodes.

According to the name of the operator called N, the values are provided directly (AFFE_CHAR_THER) or via a concept function (AFFE_CHAR_THER_F).

4.11.2 Syntax

- for AFFE_CHAR_THER

```
LIAISON_GROUP=_F  ( ♦  /  ♦  /  MAILLE_1=lma1       ,    [l_maille]
                              /GROUP_MA_1      =lgma1 ,    [l_gr_maille]

                         ♦  /  MAILLE_2=lma2       ,    [l_maille]
                              /GROUP_MA_2      =lgma2 ,    [l_gr_maille]

                      /   ♦  /  NOEUD_1=lno1       ,    [l_noeud]
                              /GROUP_NO_1     =lgno1 ,    [l_gr_noeud]

                          ♦  /  NOEUD_2=lno2       ,    [l_noeud]
                              /GROUP_NO_2     =lgno2 ,    [l_gr_noeud]

                    ◊  /            SANS_NOEUD=lno   ,    [l_noeud]
                       /SANS_GROUP_NO           =lgno  ,    [l_gr_noeud]

                     ◊  DDL_1=       |     "TEMP",           [DEFECT]
                                    |    "TEMP_INF",
                                    |    "TEMP_SUP",

                     ◊  DDL_2=       |     "TEMP",           [DEFECT]
                                    |    "TEMP_INF",
                                    |    "TEMP_SUP",

                     ♦  COEF_MULT_1=      a1i ,          [l_R]
                     ♦  COEF_MULT_2=      a2i ,          [l_R]
                     ♦  COEF_IMPO=b           ,          [R]

                    ◊  |  CENTRE=lr            ,             [l_R]
                       |     ANGL_NAUT=lr      ,             [l_R]
                       |  TRAN=lr              ,             [l_R]

                    ◊SOMMET=               'OUI',

                  )
```

- for `AFFE_CHAR_THER_F`

```
LIAISON_GROUP=_F  ( ♦  /  ♦  /  MAILLE_1=lma1      ,   [l_maille]
                             /GROUP_MA_1     =lgma1 ,   [l_gr_maille]

                          ♦  /  MAILLE_2=lma2      ,   [l_maille]
                             /GROUP_MA_2     =lgma2 ,   [l_gr_maille]

                       /  ♦   /  NOEUD_1=lno1      ,   [l_noeud]
                              /GROUP_NO_1    =lgno1 ,   [l_gr_noeud]

                          ♦   /  NOEUD_2=lno2      ,   [l_noeud]
                              /GROUP_NO_2    =lgno2 ,   [l_gr_noeud]

                    ◊  /            SANS_NOEUD=lno   ,   [l_noeud]
                       /SANS_GROUP_NO          =lgno  ,   [l_gr_noeud]

                    ◊  DDL_1=       |     "TEMP",           [DEFECT]
                                |     "TEMP_INF",
                                |     "TEMP_SUP",

                    ◊  DDL_2=       |     "TEMP",           [DEFECT]
                                |     "TEMP_INF",
                                |     "TEMP_SUP",

                    ♦   COEF_MULT_1=    a1i   ,          [l_R]
                    ♦   COEF_MULT_2=    a2i   ,          [l_R]
                    ♦COEF_IMPO=             bf ,            [function]

                    ◊  |   CENTRE=lr          ,            [l_R]
                       |      ANGL_NAUT=lr    ,            [l_R]
                       |   TRAN=lr            ,            [l_R]

                    ◊SOMMET=                   'OUI'
                  )
```

4.11.3 Operands

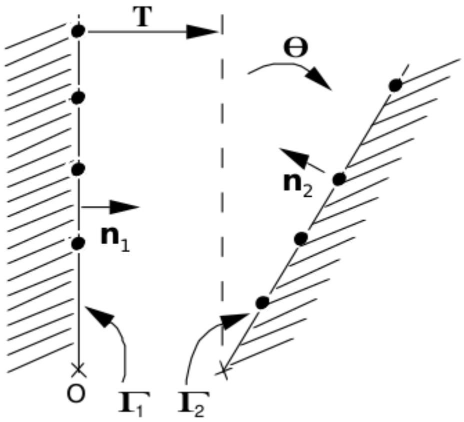


Figure 4.11.3-a: Geometrical transformation of a border in another

"general" Kinematical condition: $\sum_{i=1}^{NDDL1} \alpha_{1i} T_i \big|_{\Gamma_1} + \sum_{i=1}^{NDDL2} \alpha_{2i} T_i \big|_{\Gamma_2} = \beta$

/ ♦ / MAILLE_1 =
/GROUP_MA_1 =

These operands define Γ_1 via the meshes which compose it.

♦ / MAILLE_2 =
/GROUP_MA_2 =

These operands define Γ_2 via the meshes which compose it.

/ ♦ /NOEUD_1 =
/GROUP_NO_1 =

These operands define Γ_1 via the nodes which compose it.

♦ /NOEUD_2 =
/GROUP_NO_2 =

These operands define Γ_2 via the nodes which compose it.

◊ /SANS_GROUP_NO =:
/SANS_NOEUD =

These operands make it possible to remove list of the couples of nodes as screw - with - screw all the couples of which at least one of the nodes belongs to the list of nodes described by these operands.

That makes it possible to avoid the accumulation of linear relations on the same node during various iterations on the key word factor LIAISON_GROUP what leads most of the time to a singular matrix.

♦COEF_MULT_1 (resp. COEF_MULT_2)

List of realities dimensioned exactly with the number of degrees of freedom declared in DDL 1 (resp. DDL 2) corresponding to the multiplying coefficients of the linear relation.

♦COEF_IMPO : coefficient of blocking of the linear relation:

β : reality for AFFE_CHAR_THER
β_f : function for AFFE_CHAR_THER_F

◊CENTRE : coordinates of the centre of rotation
◊ANGL_NAUT : nautical angles in degrees defining rotation (see AFFE_CARA_ELEM [U4.42.01] key word DIRECTIONAL SENSE)
◊TRAN : components of the vector translation

Ces operands make it possible to define a virtual transformation (rotation and/or translation) approximate Γ_1 in Γ_2 order to ensuring the bijectivity of the function opposite.

◊ DDL 1 (resp. DDL 2):

List texts taken among:
"TEMP", "TEMP_INF", "TEMP_SUP"

"TEMP_INF" and "TEMP_SUP" can be used only for shell elements thermal (modelization: "SHELL").

By defect, the degree of freedom considered for all the nodes of the linear relations is "TEMP".

◊SOMMET = "OUI"

Lorsque the meshes of edge are quadratic, the use of SOMMET: "OUI" forces the algorithm of pairing to associate the top nodes with other top nodes. In the case of fine meshes, that makes it possible in certain cases to avoid the problems of conflicts of screw - with-screw.

4.11.4 Use of LIAISON_GROUP

- LIAISON_GROUP generates linear relations only between 2 nodes (one on Γ_1, one on Γ_2)

  Pour to generate linear relations on more than 2 nodes, to use key word LIAISON_DDL.

- determination of the couples of nodes in opposite:

  initially, one draws up the two lists of nodes to be put in opposite (IE to be paired), for each occurrence of the key word factor LIAISON_GROUP:

  - for key words GROUP_NO_1 and GROUP_NO_2, they are the nodes setting up the nodes groups,
  - for key words GROUP_MA_1 and GROUP_MA_2, they are the nodes of the meshes setting up the mesh groups.

  The redundancies being eliminated, the two lists of nodes obtained must have the same length.

  The determination of the couples of nodes in opposite is done in several stages:

  - for each node $N1$ of the first list, one seeks the node image $N2=f(N1)$ of the second list. If F is not injective (a node $N2$ is the image of two distinct nodes $N1$ and $N1'$), the following error message is transmitted:

    ```
    <F> <AFFE_CHAR_THER> <PACOAP> CONFLICT IN WITH RESPECT TO
    NODES
    LE NODE N2 IS LE WITH RESPECT TO THE NODES N1 AND N1'
    ```

  - for each node $N2$ of the second list, one seeks the node image $N1=g(N2)$ of the first list. If G is not injective (a node $N1$ is the image of two distinct nodes $N2$ and $N2'$), the following error message is transmitted:

    ```
    <F> <AFFE_CHAR_MECA> <PACOAP> CONFLICT IN WITH RESPECT TO
    NODES
    LE N1 NODE IS LE WITH RESPECT TO THE NODES N2 AND N2'
    ```

  - it is checked that $g=f^{-1}$, i.e. the couples obtained by the stages a) and b) are the same ones (one wants to have a bijection f between the two lists of nodes). If F is not surjective, the following error message is transmitted:

    ```
    <F> <AFFE_CHAR_MECA> <PACOAP> CONFLIT DANS LES VIS-À-VIS GENERES
    SUCCESSIVEMENT A PARTIR DES LISTES LIST1 AND LIST2
    LE NODE DE LA PREMIERE LISTE N1 EST the IMAGE Of AUCUN NODE PAR
    CORRESPONDANCE INVERSE
    ```

  Pour a given N node, one calls node image $f(N)$ the node of the other list of nodes which carries out the minimum of distance with N. To facilitate pairing, in particular in the case of particular geometries (where the borders Γ_1 and Γ_2 could "almost" result one from the other by the composition of a translation and a rotation), one makes it possible to make a virtual geometrical transformation of the first nodes group (translation and rotation (cf [Figure 4.11.3-a]) before calculating the distances (key words TRAN, CENTRE and ANGL_NAUT).

  For each occurrence of the key word factor LIAISON_GROUP, one thus builds the list of the new couples in opposite. When all the occurrences were swept, one removes list the couples in double.

Note:

In the couples of nodes in opposite, the order of the nodes is important. So for the first occurrence of `LIAISON_GROUP`, a node N belonged to the first nodes group and a node M with the second nodes group, and that for the second occurrence of `LIAISON_GROUP`, it is the reverse, one will obtain at the conclusion of pairing the couples (N, M) and (M, N). They will not be eliminated during detection of the redundancies; on the other hand, the matrix obtained will be singular. Thus, one advises to keep same logic during the description of edges as screw - with - screw.

4.12 Key word LIAISON_MAIL

4.12.1 Drank

Word-key factor making it possible "to thermically restick" two edges of a structure. These edges can be with a grid differently (incompatible meshes) but must deduct one of the other by rotation and/or translation.

4.12.2 Syntax

- in AFFE_CHAR_THER only

```
LIAISON_MAIL =_F  ( ♦  |  GROUP_MA_MAIT =lgma_mait          ,
                       |  MAILLE_MAIT   =lma_mait        ,

                    ♦  |  GROUP_MA_ESCL =lgma_escl          ,
                       |  MAILLE_ESCL   =lma_escl        ,
                       |  GROUP_NO_ESCL =lgno_escl          ,
                       |  NOEUD_ESCL    =lno_escl        ,

                    ◊  |  ♦TRAN     =       (tx, ty, [tz]),         [l_R]
                       |  ♦CENTRE    =      (xc, yc, [zc]),         [l_R]
                          ♦ANGL_NAUT    =  (alpha, [beta, gamma]),
[l_R]
                    )
```

face 1 is called face "Master"; face 2 is called face "slave".

4.12.3 Operands

4.12.3.1 GROUP_MA_ESCL / MAILLE_ESCL / GROUP_NO_ESCL / NOEUD_ESCL

Ces key words make it possible to define all the nodes of the face slave. One takes all the nodes specified by key words GROUP_NO_ESCL and NOEUD_ESCL more possibly the nodes carried by the meshes specified by key words GROUP_MA_ESCL and MAILLE_ESCL.

4.12.3.2 GROUP_MA_MAIT / MAILLE_MAIT

Ces key words make it possible to define the group of the meshes where they with respect to the nodes of the face slave will be sought.

One should not give the meshes of surface (in 3D) composing the adjacent face Master, but voluminal meshes with the face Master. The specified meshes are candidates for the search of opposite. One can give too much of it.

4.12.3.3 CENTRE / ANGL_NAUT / TRAN

Ces operands make it possible to define the geometrical transformation (rotation and/or translation) making it possible to pass from the face main slave to the face. The command carries out initially rotation then the translation.

Caution: the transformation is in the meaning slave-Master.

This boundary condition applies to the plane modelizations ("PLANE" or "AXIS") or voluminal ("3D").

4.13 Key word ECHANGE_PAROI

4.13.1 Drank

Word-key factor usable to apply conditions of heat exchange between 2 definite walls each one by one or more meshes or one or more mesh groups.

4.13.2 Syntax

- for AFFE_CHAR_THER

```
ECHANGE_PAROI=_F  ( ♦   /   GROUP_MA_1 =lgma       ,       [l_gr_maille]
                        /MAILLE_1  =lma        ,       [l_maille]

                    ♦   /   GROUP_MA_2 =lgma       ,       [l_gr_maille]
                        /MAILLE_2  =lma        ,       [l_maille]

                    ♦COEF_H        =h          ,          [R]

                    ◊TRAN      =lr                 ,          [l_R]
                  )
```

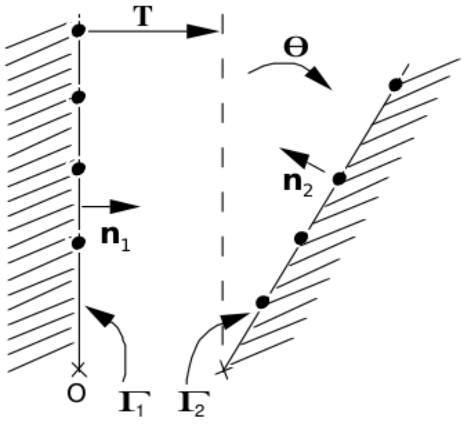
- for AFFE_CHAR_THER_F

```
ECHANGE_PAROI=_F  ( ♦   /   GROUP_MA_1 =lgma       ,       [l_gr_maille]
                        /MAILLE_1  =lma        ,       [l_maille]

                    ♦   /   GROUP_MA_2 =lgma       ,       [l_gr_maille]
                        /MAILLE_2  =lma        ,       [l_maille]

                    ♦COEF_H        =hf                 ,          [function]

                    ◊TRAN      =lr                     ,       [l_R]
                  )
```

4.13.3 Opérandes

♦ / GROUP_MA_1
/MAILLE_1

♦ / GROUP_MA_2
/MAILLE_2



Appear 4.13.3-a

Ces operands allow to define the 2 lists of meshes representing for the subscripted list "_1" the wall Γ_1 for the subscripted list "_2" the wall Γ_2.

The walls are in correspondence and must comprise the same number of meshes and nodes.

The limiting condition applied between these 2 walls is:

on Γ_1: $k\dfrac{\partial T_1}{\partial n_1}=h\left(T_2-T_1\right)$ n_1 norm external with Γ_1

on Γ_2: $k\dfrac{\partial T_2}{\partial n_2}=h\left(T_1-T_2\right)$ n_2 norm external with Γ_2

where $\begin{array}{ll} T_1|_{\Gamma_1}=T & T_2|_{\Gamma_1}=T\circ f \\ T_1|_{\Gamma_2}=T\circ f^{-1} & T_2|_{\Gamma_2}=T \end{array}$

f representing the bijection which puts in opposite a node of Γ_1 and a node of Γ_2.

♦ / COEF_H =

constant Coefficient of heat exchange enters the 2 walls:
reality for the operator AFFE_CHAR_THER, function for operator AFFE_CHAR_THER_F.

◊TRAN= component of the vector translation

Cette operand makes it possible to define a virtual transformation (translation) approximate of Γ_1 in Γ_2 order to ensuring the bijectivity of the function as screw - - screw.

TRAN: characterize a translation T

in 2D one thus has : TRAN = (tx, ty)
in 3D one a: TRAN = (tx, ty, tz)

4.13.4 Utilisation of ECHANGE_PAROI

the user gives two lists of meshes from which the couples from paired nodes will result. These lists are initially sorted by type of mesh: the paired nodes will come from meshes of the identical type. For each mesh of the first list, one determines the mesh nearest in the second list by computing all the distances from the nodes taken two to two (one traverses all the possible permutations). The distance minimum obtained defines at the same time the mesh in opposite and the couples of nodes paired for the two meshes concerned. As in LIAISON_GROUP [§4.11], it is possible to carry out a virtual geometrical transformation (rotation and/or translation) before calculating the distances.

4.13.5 Meshes and modelizations supporting this loading:

Net Modélisation	edge	Nets coupling generated
SEG2, PLANE	SEG3, PLAN_DIAG AXIS, AXIS_DIAG	SEG22, SEG33
TRIA3, TRIA6, QUAD4, QUAD8, QUAD9	3D, 3D_DIAG	TRIA33, TRIA66, QUAD44, QUAD88, QUAD99

4.14 Word-key LIAISON_UNIF

4.14.1 Drank

Word-key factor allowing to impose the same value (unknown) on the temperatures of a set of nodes.

These nodes are defined by the mesh groups, the meshes, the nodes groups or the list of nodes to which they belong.

4.14.2 Syntax

- for AFFE_CHAR_THER and AFFE_CHAR_THER_F

```
LIAISON_UNIF =_F  (
                        ♦  /   MAILLE=lma              ,
[l_maille]
                           /GROUP_MA     =lgma  ,              [l_gr_maille]
                           /NOEUD          =lno   ,              [l_noeud]
                           /GROUP_NO       =lgno  ,              [l_gr_noeud]

                        ♦   D.O.F. = |   "TEMP" ,               [DEFECT]
                                     |   'TEMP_INF',
                                     |   'TEMP_SUP',
                  )
```

4.14.3 Operands

♦ / NET
/GROUP_MA
/NOEUD
/GROUP_NO

These operands make it possible to define a list of n nodes N_i from which one eliminated the redundancies (for MESH and GROUP_MA, they is connectivities of the meshes).

♦DDL

Cet operand makes it possible to define a list of degrees of freedom $T_i(i=1,r)$ of r texts taken among: "TEMP", "TEMP_INF", "TEMP_SUP".

$r\times(n-1)$ The "kinematical" conditions resultants are:

$T_i(N_1)=T_i(N_k)$ for $k\in(2,\dots,n)$, $i\in(1,\dots,r)$

Remarque:

Components "TEMP_SUP", "TEMP_INF" can intervene only for nodes of shell elements.

4.15 Key word LIAISON_CHAMNO

4.15.1 Drank

Word-key factor usable to define a linear relation between all the temperatures present in a concept CHAM_NO.

4.15.2 Syntax

```
LIAISON_CHAMNO = _F  ( ♦   CHAM_NO    =chamno    ,              [cham_no]
                       ♦   COEF_IMPO =    B,                   [R]
                       ◊NUMÉRIQUE_LAGR   = /   "NORMAL",          [DEFECT]
                                           /   "APRES",
                     )
```

4.15.3 Opérandes

CHAM_NO =

Nom of the chamno which is used to define the linear relation. The temperatures connected are all those present in the chamno. The coefficients to be applied to the temperatures are the values of these temperatures in the chamno.

Example:

Let us suppose that one has a bearing chamno on 3 nodes of names $N01$, $N02$ and $N03$.

Let us suppose that the values of the temperatures in these 3 nodes in the chamno are respectively 2. , 5.4 and 9.1. The linear relation that one will impose is:
$$2.T(NO1)+5.4T(NO2)+9.1T(NO3)=\beta$$

COEF_IMPO =

It is the value of the real coefficient β to the second member of the linear relation.

NUME_LAGR =

If "NORMAL", the 2 Lagrange multipliers associated with the relation will be such as the first will be located before all the terms implied in the relation and the second after, in the assembled matrix.

If "APRES", the 2 Lagrange multipliers associated with the relation will be located after all the terms implied in the relation, in the assembled matrix.

This choice has the advantage of having an assembled matrix whose overall dimension is weaker but has the disadvantage to be able to reveal a singularity in the matrix.

4.16 Key word CONVECTION

4.16.1 Drank

Word-key usable to take into account the term of transport of heat by convection whose statement is $\rho C_p . V \, grad \, T$, appearing in the form of particulate derivative $\rho C_p \frac{dT}{dt} : \rho C_p \frac{dT}{dt} = \rho C_p \frac{\partial T}{\partial t} + \rho C_p V \, grad \, T$.

In the case of a liquid medium, V indicates the velocity imposed of the fluid particle on the current point.

In the case of a mobile solid medium, V indicates the velocity of solid. In all the cases, it is supposed that the velocity field is known a priori. The case of a mobile solid is rather frequent in practice. It relates to in particular the applications of welding or surface treatment which bring into play a heat source moving in a given direction and at a velocity.

The thermal problem is then studied in a reference frame related to the source (cf THER_NON_LINE_MO [U4.54.03]).

4.16.2 Syntax

```
CONVECTION = _F  ( ♦VITESSE    =v                    [cham_no_sdaster])
```

4.16.3 Opérande

Pour AFFE_CHAR_THER and AFFE_CHAR_THER_F,

VELOCITY =

Nom of the velocity field at time when computation is carried out.

This field is a concept cham_no of the cham_no_depl_r type. It must have been defined on all models it for which one carries out computation.

4.17 Mot-clé SOUR_NL

4.17.1 Drank

Word-key factor usable to apply **voluminal sources depending on temperature** (2D or 3D) to **a field** defined by one or more meshes or on the mesh groups of the voluminal **type**.

This loading is available only in command `AFFE_CHAR_THER_F`. The values are provided via a tabulated function of the temperature of type `function`. The heat source, argument of key word `SOUR`, is a function of the temperature, other than any other parameter. Moreover, it is necessarily of a tabulated function and not about a formula.

4.17.2 Syntax

```
SOUR_NL=_F     (
             ♦  /  TOUT      =          'OUI',
                /  |  NET    =lma        ,          [l_maille]
                   |  GROUP_MA =lgma      ,            [l_gr_maille]
             ♦SOUR          =sf           ,               [function]
          )
```

4.17.3 Opérandes

This loading applies to the types of meshes and the following modelizations:

Net	Modélisation
HEX A8, HEXA20, HEXA27 PYRA5, PYRA13, PENTA6, PENTA15 TETRA4, TETRA10	3D
TRIA3, TRIA6, QUAD4, QUAD8, PLANE	QUAD9, AXIS
HEX A8, PYRA5, PENTA6, TETRA4	3D_DIAG
TRIA3, QUAD4	PLAN_DIAG, AXIS_DIAG

/ ♦SOUR = S,

Valeur of the source depending on the temperature and presumedly constant on the element.