ZZZZ297 – Validation of key word LIAISON_PROJ of order AFFE_CHAR_MECA

Summary:
The objective is to test and validate the possibilities of the key word LIAISON_PROJ order AFFE_CHAR_MECA. LIAISON_PROJ allows to define linear relations between the nodes of the same model. The coefficients of the linear relations are given using the order PROJ_CHAMP who turns over a concept which corresponds to the matrix of the coefficients of influence determined starting from the functions of form of the elements.
The cases tests validate several configurations:

- relations between voluminal groups of meshs: voluminal meshs Masters, meshs voluminal slaves: modeling A;
- relations between groups of meshs voluminal and surface meshs: voluminal meshs Masters, meshs surface slaves: modeling B;
- relations between groups of meshs voluminal and linear meshs: voluminal meshs Masters, meshs linear slaves: modeling C;
- relations between surface groups of meshs: surface meshs Masters, meshs surface slaves with and without offsetting: modelings D and E;
- relations between groups of surface and linear meshs: surface meshs Masters, meshs linear slaves with offsetting: modeling F.

1 Problem of reference

1.1 Geometries used for modelings A, B, C

Several geometries are used to test the various combinations.

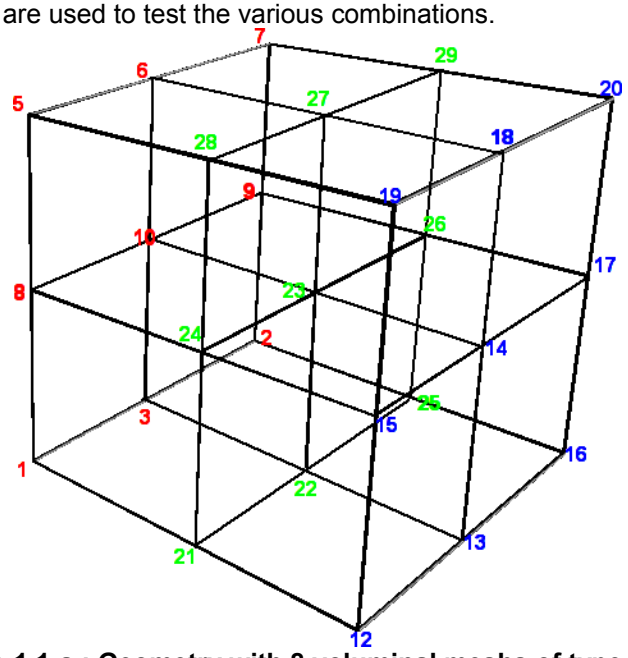

Figure 1.1-a : Geometry with 8 voluminal meshs of type HEXA8.

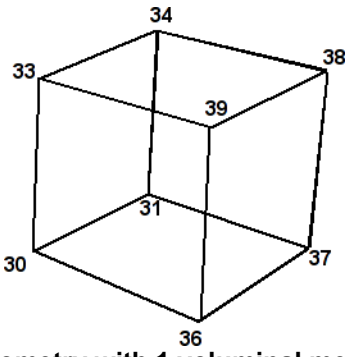

Figure 1.1-b : Geometry with 1 voluminal mesh of type HEXA8.

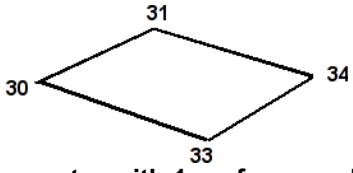

Figure 1.1-c : Geometry with 1 surface mesh of type QUAD4.

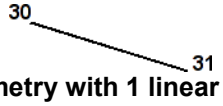

Figure 1.1-d : Geometry with 1 linear mesh of type SEG2.

Dimensions:

- The voluminal meshs have edges length $1.0\,m$.
- The surface meshs have edges length $1.0\,m$.
- The linear mesh has a length of $1.0\,m$.

1.2 Geometries used for modelings D, E, F

Several geometries are used to test the various combinations.

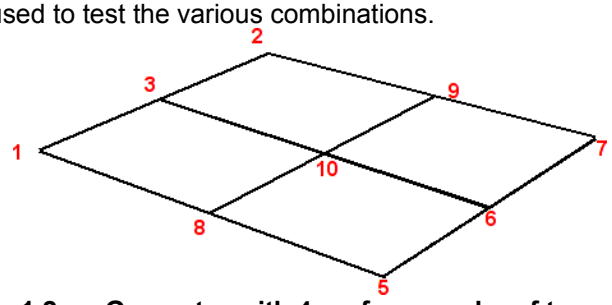

Figure 1.2-a : Geometry with 4 surface meshs of type QUAD4.

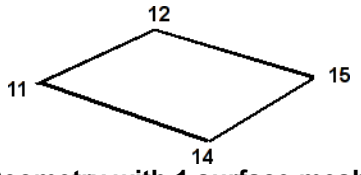

Figure 1.2-b : Geometry with 1 surface mesh of type QUAD4.

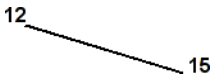

Figure 1.2-c : Geometry with 1 linear mesh of type SEG2.

Dimensions:

- The surface meshs have edges length $1.0\,m$.
- The linear mesh has a length of $1.0\,m$.

1.3 Properties of materials

Without object.

1.4 Boundary conditions and loadings

For modelings A, B, C nodes 1,3,2,8,10,9,5,6,7 are blocked in translation in the directions X , Y , Z .
A displacement not no one is imposed on nodes 12,13,16,15,14,17,19,18,20 in the directions X , Y , Z .
For modelings D, E, F nodes 1,3,2 are blocked in translation and rotation in the directions X , Y , Z .
A displacement not no one is imposed on nodes 5,6,7.

1.5 Initial conditions

Without object for a static analysis.

2 Reference solution

2.1 Method of calculating

The reference solution is obtained by a calculation carried out with *Code_Aster* by explicitly giving the relations between the degrees of freedom with the key word LIAISON_DDL order AFFE_CHAR_MECA.

The relations are following form:

- For the degrees of freedom of the nodes slaves given under the single-ended spanner word DDL.

$$DDL(N_{escl}) = \sum_i Coeff_i * DDL(N^i_{maître})$$

with I: main node of the mesh containing the node slave.

- If TYPE = OFFSETTING, the relation on the degrees of freedom of translation of the nodes slaves becomes:

$$DDL(N_{escl}) = \sum_i Coeff_i * \left(DDL(N^i_{maître}) + \overrightarrow{\omega(N^i_{maître})} \wedge \overrightarrow{N^i_{maître} N_{escl}} \right)$$

The order PROJ_CHAMP give the matrix of the coefficients:

```
matcoeff = PROJ_CHAMP (
   PROJECTION = 'NOT', METHOD = 'COLLOCATION',
   MAILLAGE_1 = e-mail, MAILLAGE_2 = e-mail,
   VIS_A_VIS = _F (GROUP_MA_2 = 'MILCUB', GROUP_MA_1 = 'LESCUBES',),
)
```

This matrix is then used in the order AFFE_CHAR_MECA key word LIAISON_PROJ in the following way:

```
CLPROJ = AFFE_CHAR_MECA (
   …,
    LIAISON_PROJ = _F (MATR_PROJECTION = matcoeff, DDL= ('DX', 'DY',
'DZ'),),
)
```

2.2 Sizes and results of reference

The sizes tested are:

- All components of displacements to all the nodes of the grid.
- All components of the constraints SIEF_ELGA at all the points of Gauss and all the under-points of the model.

2.3 Uncertainties on the solution

None. It is a comparison between two ways of giving the relations kinematics between the same degrees of freedom of the nodes slaves and Masters.

3 Modeling A

3.1 Characteristics of the grid

Type of meshs:
- voluminal meshs Masters: 8 meshs HEXA8 ;
- mesh voluminal slave: 1 mesh HEXA8.

The grids are presented to the figures 1.1-a and 1.1-b. The voluminal meshs have edges length $1.0\,m$. The mesh HEXA8 figure 1.1-b is placed in such way that nodes 30,31,33,34,36,37,38,39 are in the centre of gravity of a mesh Master HEXA8, figure 1.1-a.

3.2 Relations between the nodes main slaves and meshs

The coefficient between the nodes slaves and Master is of $1/8$.
There are eight relations per degree of freedom which relate to the following nodes:
- node slave 33 is in relation to nodes 5,6,8,10,24,23,28,27 of the mesh Master.
- node slave 34 is in relation to nodes 6,7,10,9,27,29,23,26 of the mesh Master.
- node slave 30 is in relation to nodes 8,10,1,3,24,23,21,22 of the mesh Master.
- node slave 31 is in relation to nodes 3,2,10,9,22,25,23,26 of the mesh Master.
- node slave 36 is in relation to nodes 21,22,24,23,12,13,15,14 of the mesh Master.
- node slave 37 is in relation to nodes 22,25,23,26,13,16,14,17 of the mesh Master.
- node slave 38 is in relation to nodes 14,17,18,20,27,29,23,26 of the mesh Master.
- node slave 39 is in relation to nodes 19,18,15,14,24,23,28,27 of the mesh Master.

The first relation is form, there are seven others of them to define:

```
    _F ( NODE       = ('N33', 'N5', 'N6', 'N8', 'N10', 'N24', 'N23', 'N28',
'N27',),
       DDL        = ('DX', 'DX', 'DX', 'DX', 'DX', 'DX', 'DX', 'DX', 'DX',),
        COEF_MULT = (- 1.0, 0,125, 0,125, 0,125, 0,125, 0,125, 0,125, 0,125,
0,125,),
       COEF_IMPO = 0.0,
     )
```

3.3 Sizes tested and results

The sizes tested are:
- All components of displacements to all the nodes of the grid;
- All components of the constraints SIEF_ELGA at all the points of Gauss of the model.

Two calculations are carried out:
- with the key word LIAISON_PROJ order AFFE_CHAR_MECA ;
- with the key word LIAISON_DDL order AFFE_CHAR_MECA.

For each calculation and each field a table is created then combined in order to make the difference between the two solutions obtained. These solutions must be rigorously identical, the value to be tested is thus 0 .
The fields of displacements are normalized compared to imposed displacement, the stress fields are normalized compared to $1\mathrm{MPa}$.

The tolerance for all the fields, with all the nodes and for all the components is of $1.0\mathrm{E}-06$.

4 Modeling B

4.1 Characteristics of the grid

Type of meshs:
- voluminal meshs Masters: 8 meshs HEXA8 ;
- mesh surface slave: 1 mesh QUAD4.

The grids are presented to the figures 1.1-a and 1.1-c. The meshs voluminal and surface have edges length $1.0\,m$. The mesh QUA4 figure 1.1-c is placed in such way that nodes 30,31,33,34 are in the centre of gravity of a mesh Master HEXA8, figure 1.1-a.

4.2 Relations between the nodes main slaves and meshs

The coefficient between the nodes slaves and Master is of $1/8$.
There are four relations per degree of freedom which relate to the following nodes:
- node slave 30 is in relation to nodes 5,6,8,10,24,23,28,27 of the mesh Master.
- node slave 31 is in relation to nodes 6,7,10,9,27,29,23,26 of the mesh Master.
- node slave 33 is in relation to nodes 19,18,15,14,24,23,28,27 of the mesh Master.
- node slave 34 is in relation to nodes 14,17,18,20,27,29,23,26 of the mesh Master.

The first relation is form, there are three others of them to define:

```
      _F (NODE       = ('N30', 'N5', 'N6', 'N8', 'N10', 'N24', 'N23', 'N28',
'N27',),
        DDL        = ('DX', 'DX', 'DX', 'DX', 'DX', 'DX', 'DX', 'DX', 'DX',),
        COEF_MULT = (- 1.0, 0,125, 0,125, 0,125, 0,125, 0,125, 0,125, 0,125,
0,125,),
        COEF_IMPO = 0.0,
     )
```

4.3 Sizes tested and results

The sizes tested are:
- All components of displacements to all the nodes of the grid;
- All components of the constraints SIEF_ELGA at all the points of Gauss of the model.

Two calculations are carried out:
- with the key word LIAISON_PROJ order AFFE_CHAR_MECA ;
- with the key word LIAISON_DDL order AFFE_CHAR_MECA.

For each calculation and each field a table is created then combined in order to make the difference between the two solutions obtained. These solutions must be rigorously identical, the value to be tested is thus 0.
The fields of displacements are normalized compared to imposed displacement, the stress fields are normalized compared to $1\mathrm{MPa}$.

The tolerance for all the fields, with all the nodes and for all the components is of $1.0\mathrm{E}-06$.

5 Modeling C

5.1 Characteristics of the grid

Type of meshs:
- voluminal meshs Masters: 8 meshs HEXA8 ;
- mesh linear slave: 1 mesh SEG2.

The grids are presented to the figures 1.1-a and 1.1-d. The voluminal meshs have edges length $1.0\,m$, the linear mesh is length $1.0\,m$. The mesh SEG2 figure 1.1-d is placed in such way that nodes 30.31 are in the centre of gravity of a mesh Master HEXA8, figure 1.1-a.

5.2 Relations between the nodes main slaves and meshs

The coefficient between the nodes slaves and Master is of $1/8$.
There are two relations per degree of freedom which relate to the following nodes:
- node slave 30 is in relation to nodes 6,7,10,9,27,29,23,26 of the mesh Master;
- node slave 31 is in relation to nodes 14,17,18,20,27,29,23,26 of the mesh Master.

The first relation is form, there is another of them to define:

```
      _F (NODE      = ('N30', 'N6', 'N7', 'N10', 'N9', 'N27', 'N29', 'N23',
'N26',),
        DDL       = ('DX', 'DX', 'DX', 'DX', 'DX', 'DX', 'DX', 'DX', 'DX',),
        COEF_MULT = (- 1.0, 0,125, 0,125, 0,125, 0,125, 0,125, 0,125, 0,125,
0,125,),
        COEF_IMPO = 0.0,
     )
```

5.3 Sizes tested and results

The sizes tested are:
- All components of displacements to all the nodes of the grid;
- All components of the constraints SIEF_ELGA at all the points of Gauss of the model.

Two calculations are carried out:
- with the key word LIAISON_PROJ order AFFE_CHAR_MECA ;
- with the key word LIAISON_DDL order AFFE_CHAR_MECA.

For each calculation and each field a table is created then combined in order to make the difference between the two solutions obtained. These solutions must be rigorously identical, the value to be tested is thus 0 .
The fields of displacements are normalized compared to imposed displacement, the stress fields are normalized compared to $1\mathrm{MPa}$.

The tolerance for all the fields, with all the nodes and for all the components is of $1.0\mathrm{E}-06$.

6 Modeling D

6.1 Characteristics of the grid

Type of meshs:
- surface meshs Masters: 4 meshs QUAD4 ;
- mesh surface slave: 1 mesh QUAD4.

The grids are presented to the figures 1.2-a and 1.2-b. The surface meshs have edges length $1.0\,m$. The mesh QUA4 figure 1.2-b is placed in such way that nodes 11,12,14,15 are in the centre of gravity of a mesh Master QUA4, figure 1.2-a.

6.2 Relations between the nodes main slaves and meshs

The coefficient between the nodes slaves and Master is of $1/4$.
There are four relations per degree of freedom which relate to the following nodes:
- node slave 11 is in relation to nodes 1,3,8,10 of the mesh Master.
- node slave 12 is in relation to nodes 3,2,10,9 of the mesh Master.
- node slave 14 is in relation to nodes 8,10,5,6 of the mesh Master.
- node slave 15 is in relation to nodes 10,9,6,7 of the mesh Master.

The first relation is form, there are three others of them to define:

```
_F (NODE      = ('N11', 'N1', 'N3', 'N8', 'N10'),
    DDL       = ('DX', 'DX', 'DX', 'DX', 'DX',),
    COEF_MULT = (- 1.0, 0.25, 0.25, 0.25, 0.25,),
    COEF_IMPO = 0.0,
)
```

6.3 Sizes tested and results

The sizes tested are:
- All components of displacements to all the nodes of the grid;
- All components of the constraints SIEF_ELGA at all the points of Gauss and all the under-points of the model.

Four calculations are carried out with relations on the degrees of translation then of translation and rotation:
- with the key word LIAISON_PROJ order AFFE_CHAR_MECA ;
- with the key word LIAISON_DDL order AFFE_CHAR_MECA.

For each calculation and each field a table is created then combined in order to make the difference between the two solutions obtained. These solutions must be rigorously identical, the value to be tested is thus 0.
The fields of displacements are normalized compared to imposed displacement, the stress fields are normalized compared to $1\mathrm{MPa}$.

The tolerance for all the fields, with all the nodes and for all the components is of $1.0\mathrm{E}-06$.

7 Modeling E

7.1 Characteristics of the grid

Type of meshs:
- surface meshs Masters: 4 meshs QUAD4 ;
- mesh surface slave: 1 mesh QUAD4.

The grids are presented to the figures 1.2-a and 1.2-b. The surface meshs have edges length $1.0\,m$. The mesh QUA4 figure 1.2-b is placed in such way that the projection of nodes 11,12,14,15 are in the centre of gravity of a mesh Master QUA4, figure 1.2-a. Nodes 11,12,14,15 are shifted of $0.05\,m$ compared to the meshs Masters, the objective is to check the good performance of TYPE = OFFSETTING.

7.2 Relations between the nodes main slaves and meshs

The coefficient between the nodes slaves and Master is of $1/4$.
There are four relations per degree of freedom which relate to the following nodes:
- node slave 11 is in relation to nodes 1,3,8,10 of the mesh Master.
- node slave 12 is in relation to nodes 3,2,10,9 of the mesh Master.
- node slave 14 is in relation to nodes 8,10,5,6 of the mesh Master.
- node slave 15 is in relation to nodes 10,9,6,7 of the mesh Master.

The first relation is form, there are three others of them to define:

```
_F (NODE      = ('N11', 'N1', 'N3', 'N8', 'N10'),
    DDL       = ('DX', 'DX', 'DX', 'DX', 'DX',),
    COEF_MULT = (- 1.0, 0.25, 0.25, 0.25, 0.25,),
    COEF_IMPO = 0.0,
)
```

7.3 Sizes tested and results

The sizes tested are:
- All components of displacements to all the nodes of the grid;
- All components of the constraints SIEF_ELGA at all the points of Gauss and all the under-points of the model.

Six calculations are carried out with relations on the degrees of translation, of translation and rotation, translation with the option TYPE = OFFSETTING :
- with the key word LIAISON_PROJ order AFFE_CHAR_MECA ;
- with the key word LIAISON_DDL order AFFE_CHAR_MECA.

For each calculation and each field a table is created then combined in order to make the difference between the two solutions obtained. These solutions must be rigorously identical, the value to be tested is thus 0.
The fields of displacements are normalized compared to imposed displacement, the stress fields are normalized compared to $1\mathrm{MPa}$.

The tolerance for all the fields, with all the nodes and for all the components is of $1.0\mathrm{E}-06$.

8 Modeling F

8.1 Characteristics of the grid

Type of meshs:
- surface meshs Masters: 4 meshs QUAD4 ;
- mesh linear slave: 1 mesh SEG2.

The grids are presented to the figures 1.2-a and 1.2-c. The surface meshs have edges length $1.0\,m$, the mesh SEG2 with a length of $1.0\,m$. The mesh SEG2 figure 1.2-c is placed in such way that the projection of nodes 12.15 are in the centre of gravity of a mesh Master QUA4, figure 1.2-a. Nodes 12.15 are shifted of $0.05\,m$ compared to the meshs Masters, the objective is to check the good performance of TYPE = OFFSETTING.

8.2 Relations between the nodes main slaves and meshs

The coefficient between the nodes slaves and Master is of $1/4$.
There are two relations per degree of freedom which relate to the following nodes:
- node slave 12 is in relation to nodes 3,2,10,9 of the mesh Master.
- node slave 15 is in relation to nodes 10,9,6,7 of the mesh Master.

The first relation is form, there is another of them to define:

```
_F (NODE      = ('N12', 'N3', 'N2', 'N10', 'N9'),
    DDL       = ('DX', 'DX', 'DX', 'DX', 'DX',),
    COEF_MULT = (- 1.0, 0.25, 0.25, 0.25, 0.25,),
    COEF_IMPO = 0.0,
)
```

8.3 Sizes tested and results

The sizes tested are:
- All components of displacements to all the nodes of the grid.
- All components of the constraints SIEF_ELGA at all the points of Gauss and all the under-points of the model.

Six calculations are carried out with relations on the degrees of translation, of translation and rotation, translation with TYPE = OFFSETTING :
- with the key word LIAISON_PROJ order AFFE_CHAR_MECA ;
- with the key word LIAISON_DDL order AFFE_CHAR_MECA.

For each calculation and each field a table is created then combined in order to make the difference between the two solutions obtained. These solutions must be rigorously identical, the value to be tested is thus 0.
The fields of displacements are normalized compared to imposed displacement, the stress fields are normalized compared to $1\mathrm{MPa}$.

The tolerance for all the fields, with all the nodes and for all the components is of $1.0\mathrm{E}-06$.

9 Summary of the results

The comparison enters the calculations carried out with relations on the degrees of translation, of translation and rotation, translation with TYPE=' EXCENTREMENT' with the key word factor LIAISON_PROJ order AFFE_CHAR_MECA and the calculations carried out by explicitly giving the relations between the degrees of freedom (key word factor LIAISON_DDL order AFFE_CHAR_MECA) watch the good performance of the order:

- The comparisons carried out on the field of displacements to all the nodes and on all the components show that one gets identical results;
- The comparisons carried out on the stress field at all the points of Gauss, all the under-points and for all the components show that one gets identical results.