# Conditions of solid connection of body

**Summary**

One presents in this documentation a manner of modelling indeformable parts of structure, thanks to the keyword `LIAISON_SOLIDE` of `AFFE_CHAR_MECA`.

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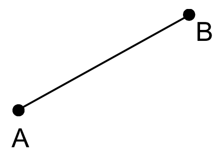
# 1 Introduction

The keyword LIAISON_SOLIDE orders AFFE_CHAR_MECA allows to model an indeformable part of a structure. The principle selected is to write relations between the degrees of freedom of the “solid” part; these relations expressing the fact that the distances between the nodes are invariable. Relations expressing the indeformability of a solid **are not linear**.

To be convinced some, let us take the example of a segment $AB$ in 2D:




Indeformability of $AB$ is written:

$$\left[\left(x_A+dx_A\right)-\left(x_B+dx_B\right)\right]^2+\left[\left(y_A+dy_A\right)-\left(y_B+dy_B\right)\right]^2=\left(x_A-x_B\right)^2+\left(y_A-y_B\right)^2$$
$$\Leftrightarrow\left(dx_B-dx_A\right)^2+2\left(x_B-x_A\right)\left(dx_B-dx_A\right)+\left(dy_B-dy_A\right)^2+2\left(y_B-y_A\right)\left(dy_B-dy_A\right)=0 \quad (1)$$

While noting $\{x_A, y_A, x_B, y_B\}$ coordinates and $\{dx_A, dy_A, dx_B, dy_B\}$ displacements of $A$ and $B$. It is seen that the expression is quadratic in $dx_A, dx_B, dy_A$ and $dy_B$.

When displacements are small, the quadratic terms are negligible and one can justify the linearization of these relations. They do not depend any more of displacement and they can be calculated (on the initial geometry) as of the execution of the order AFFE_CHAR_MECA.

On the other hand, when rotations are finished, the linearization of these relations depends on displacement and must thus be recomputed with each iteration of the algorithm of Newton. If the user thinks that rotations will not remain infinitesimal, it must announce it in the order STAT_NON_LINE (keyword EXCIT/TYPE_CHARGE=' SUIV'). The code will then recompute the linearization of the relations during calculation.

The taking into account of the “following” type of these relations is subjected to certain restrictions which are detailed in the user's documentation (U4.44.01). “To rigidify” a solid part, if the program does not allow it the use of LIAISON_SOLIDE, one is obliged to use a “hard” material (compared to the rest of the structure).

# 2 Principle of the use of the keyword

The keyword LIAISON_SOLIDE is a keyword factor répétable. With each occurrence of the keyword, the user defines a “piece of model” which it wishes to rigidify.

This “piece of model” defined by the keywords GROUP_MA, GROUP_NO, MESH and NODE, one deduces **list of the nodes** to rigidify.

Once this drawn up list, one writes the relations necessary to express that the “rigid piece” in general has nothing any more but the degrees of freedom of a solid (: three in 2D and six in 3D).

Note:

> If all the nodes of a finite element are subjected to a condition of the type LIAISON_SOLIDE, this element does not become deformed. Its state of stress will be then always null. If one wishes to reach the state of stress of a “rigid” zone, it is necessary to use the technique of “hard” material.

# 3 Which are the treated cases?

According to the degrees of freedom carried by the nodes of the list of the nodes to rigidify, one places oneself in one of the four following cases. If one does not find oneself in one of these cases, the code stops in fatal error:

- Cases 2DA and 2DB correspond to problems “plans” or axisymmetric;
- Cases 3DA and 3DB correspond to 3D problems.

**Case** $2DA$ **:**

**All** the nodes of the list of the nodes to be rigidified carry the degrees of freedom $DX$ and $DY$ and at least one nodes carries $DRZ$ .

**Case** $2DB$ **:**

All the nodes of the list of the nodes to be rigidified carry $DX$ , $DY$ but they do not carry $DRX$ , $DRY$ and $DZ$ .

**Case** $3DA$ **:**

**All** the nodes of the list of the nodes to be rigidified carry the degrees of freedom $DX$ , $DY$ and $DZ$ and at least one of the nodes carries $DRX$ , $DRY$ or $DRZ$ .

**Case** $3DB$ **:**

All the nodes of the list of the nodes to be rigidified carry $DX$ , $DY$ , $DZ$ and there does not exist node of the list of the nodes to be rigidified carrying degrees of freedom of rotation $DRX$ , $DRY$ , $DRZ$ .
Only cases $2DB$ and $3DB$ can be currently treated into nonlinear (`TYPE_CHARGE=' SUIV'`).

# 4 Treatment of cases 2DA and 3DA

In these two cases, one could find a node of the list of the nodes to be rigidified which carried **all** degrees of freedom of the solid. That is to say $A$ this node, then:

- In 2D: $DX$ , $DY$ , $DRZ$ ;
- In 3D: $DX$ , $DY$ , $DZ$ , $DRX$ , $DRY$ , $DRZ$

That is to say a node $M$ list of the nodes to be rigidified unspecified. In theory of small displacements, the movement of a solid body is expressed by:

$$\boldsymbol{U}_M=\boldsymbol{U}_A+\boldsymbol{\theta}\wedge\mathbf{AM} \text{ where } \begin{Bmatrix} \boldsymbol{U}_A \text{ est le déplacement de A} \\ \boldsymbol{\theta} \text{ est le vecteur rotation du solide} \end{Bmatrix} \quad (2)$$

## 4.1 Case 2DA

The linear relations are written:

$$\forall M\neq A:\begin{Bmatrix} DX(M)-DX(A)+y\,DRZ(A)=0 \\ DY(M)-DY(A)-x\,DRZ(A)=0 \end{Bmatrix} \quad avec\ \boldsymbol{AM}=\begin{pmatrix} x \\ y \end{pmatrix}$$
$$+\text{si } M \text{ porte DRZ}: DRZ(M)-DRZ(A)=0 \quad (3)$$

## 4.2 Case 3DA

$$\forall M\neq A:\begin{Bmatrix} DX(M)-DX(A)-DRY(A).z+DRZ(A).y=0 \\ DY(M)-DY(A)-DRZ(A).x+DRX(A).z=0 \\ DZ(M)-DZ(A)-DRX(A).y+DRY(A).x=0 \end{Bmatrix}$$

$$+\text{si } M \text{ porte } DRX\,,DRY\,,\text{DRZ}:\begin{Bmatrix} DRX(M)-DRX(A)=0 \\ DRY(M)-DRY(A)=0 \\ DRZ(M)-DRZ(A)=0 \end{Bmatrix}$$

# 5 Treatment of cases 2DB and 3DB

One distinguishes four cases for the cloud from the "solidified" nodes:

- Voluminal: there exist at least 4 noncoplanar nodes (except for an epsilon);
- Plan: there exist at least 3 not aligned nodes (except for an epsilon);
- Segment: there exist at least 2 not confused nodes (except for an epsilon);
- Specific: all the nodes are geometrically confused (except for an epsilon)

The routine which determines the case also turns over the 1,2,3 or 4 nodes which make it possible "to define" the solid. The relations kinematics which one writes depend (rather slightly) on the case.

Let us take the example of the case "Plan" in 3D.

One has three nodes $A$, $B$, $C$ not aligned. It is written that the square of the three distances $AB$, $AC$ and $BC$ remain constant at the time of the movement. These three relations are non-linear. They are quadratic and one can easily derive them to obtain the tangent linearized problem.

For each node ( $M$ ) different from $A$, $B$, $C$, the barycentric coordinates are calculated $\alpha$, $\beta$ and $\gamma$ such as:

$$M=\alpha A+\beta B+\gamma C \quad (4)$$

Then, the three linear relations are written:

$$U(M)=\alpha U(A)+\beta U(B)+\gamma U(C) \quad (5)$$

On the whole, if the cloud comprises $n\geq 3$ nodes, one writes:

- Three quadratic relations (easily linéarisables);
- $3(n-3)$ linear relations.

The cloud had $3n$ degrees of freedom. One wrote $3n-6$ independent relations. There remain to him six degrees of freedom, which corresponds to the number of possible movements for a solid 3D.

Note:

- For the case "segment" in 3D, for example, one writes $3n-5$ relations, which wants to say that the solid has only five possible movements, which is normal because the rotation of the solid around the right-hand side is unspecified;
- Each solid generates only few non-linear relations (to the maximum six).