# SSNL102 - Non-linear behavior of one assembly of angles

**Summary:**
One considers in this test a discrete element with 2 nodes subjected to a two-dimensional loading of traction and moment requesting the degrees of freedom in translation and rotation.

The analysis is static with a relation of nonlinear behavior incremental expressed by an adimensional internal variable combining the two-dimensional efforts and generalized displacements.

The relation of behavior understands 2 mechanisms respectively associated with 2 curves being connected between them by a concavity.

The interest of the test is to simulate in an exhaustive way the possible ways of loading in load and discharge and in particular the transition between mechanisms.

The results correspond to the digital solution in displacements of the problem with 1 unknown factor (the variable of the mechanism running) obtained by the inversion of the curve of the relation of behavior in each of the 2 mechanisms compared to an imposed force.

# 1 Problem of reference

## 1.1 Geometry

A discrete element of worthless size to 2 nodes.
Local reference mark = total reference mark.
A matrix of rigidity K_TR_D_L assigned by default (partner to an element DIS_TR_L)

$1.6\,N/mm$ in translation, $1.9\,N/mm$ in rotation.

Characteristics of rigidity according to the local directions $x$ and rotation around $y$ are modified by a relation of behavior of the type ASSE_CORN introduced by a characteristic material.

## 1.2 Material properties

Dependent on an incremental behavior ASSE_CORN including 2 mechanisms requiring each one 5 characteristic parameters (see [fig 1.2-a] and [fig 1.2-b]):

$$\bar{N}_1=10050\,N\ ,\ \bar{M}_1=150000\,N.mm\ ,\ \bar{U}_1=1\,mm\ ,\ \bar{\theta}_1=6.7\,10^{-2}\ ,\ \bar{C}_1=0.95$$

$$\bar{N}_2=50000\,N\ ,\ \bar{M}_2=750000\,N.mm\ ,\ \bar{U}_2=10\,mm\ ,\ \bar{\theta}_2=0.01\ ,\ \bar{C}_2=0.95$$

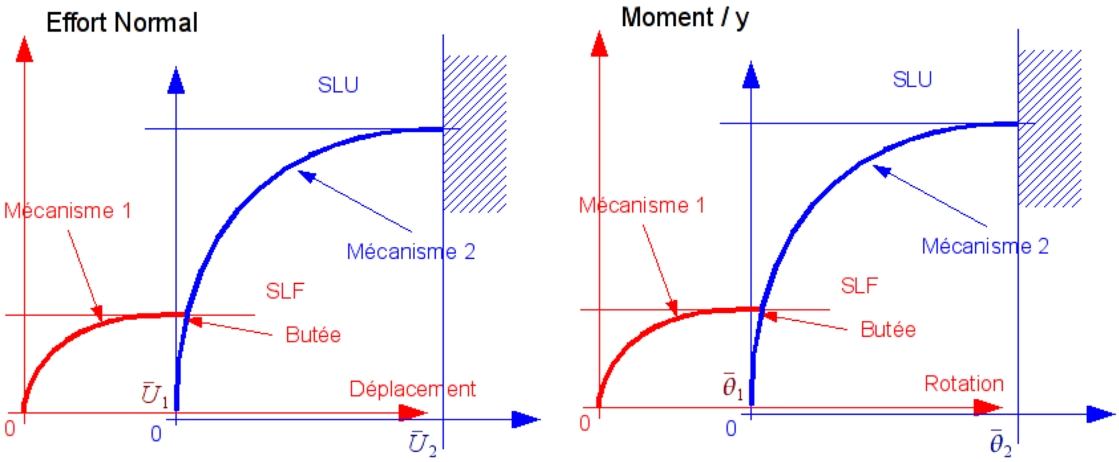
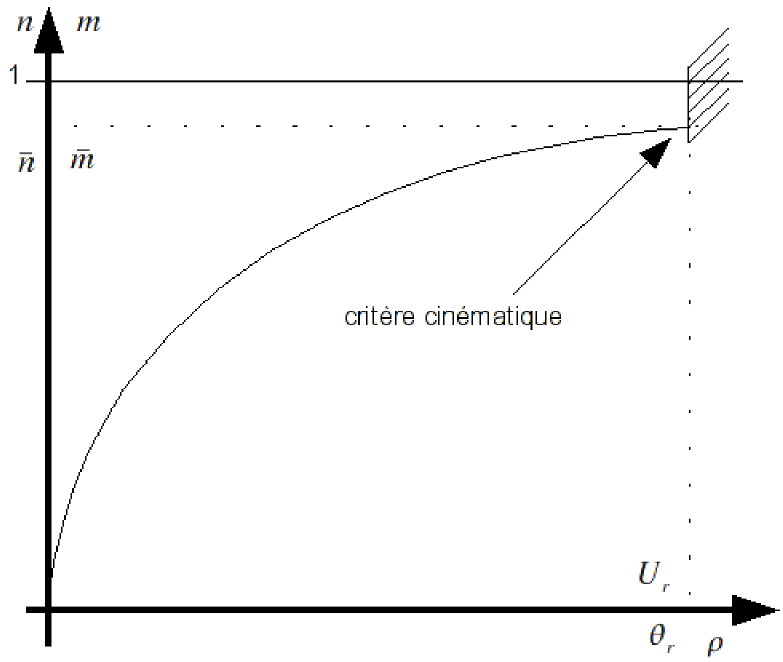



**Figure 1.2-a : Mechanisms of assembly in normal effort and moment.**

$$R(p)=\sqrt{n^2+m^2}$$

$$\dot{p}\cdot\begin{pmatrix} n \\ m \end{pmatrix}=R(p)\cdot\begin{pmatrix} \dot{U}_r \\ \dot{\theta}_r \end{pmatrix}$$




$n = Nx/\bar{N}$

$m = My/\bar{M}$

$U_r = U/\bar{U}$

$\theta = \theta/\bar{\theta}$

**Figure 1.2-b : Relation of behaviour of assembly**

with

$$\dot{p} = \sqrt{\dot{U}_r^2+\dot{\theta}_r^2}$$

$$p = R^{-1}(p')=h(p')=\frac{1-c}{c^2}\cdot\frac{p^{2\prime}}{1-p'}$$

## 1.3 Boundary conditions and loadings

Embedding in one of the 2 nodes.
Force imposed in the direction $x$ by unit of $1\ 000\ N$ and Moment imposed around the axis $z$ by unit of $3\ 000\ N$. The whole on the second node, by increments of load.

## 1.4 Initial conditions

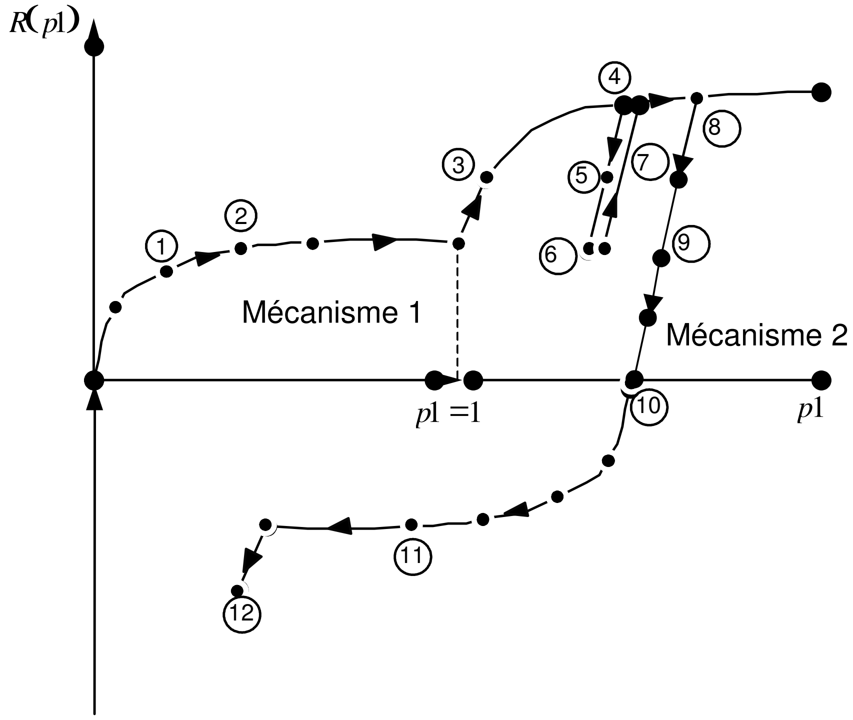
Internal displacements, efforts and variables worthless.

# 2 Reference solution

## 2.1 Method of calculating used for the reference solution

One reproduces on an element a course of loading (growing and in discharge) in each of the 2 mechanisms of assembly of the bidirectional relation of behavior (effort according to the direction $x$ and moment around the axis $y$ ). This one expresses the displacements reduced compared to the reduced efforts. The mechanisms and the law of behaviour of assembly are described on the figures [Figure 1.2-a] and [Figure 1.2-b].

The way of load expressed in $\left(p_{1,} R\left(p_1\right)\right)$ comprise 12 stages thus definite:




## 2.2 Results of reference

To find the correspondence variable-criterion of the curve limits relation of behavior.

## 2.3 Uncertainty on the solution

Digital solution of the inversion of a non-linear relation. There is an unknown factor at the same time: the variable interns mechanism. The other values result some. Calculation is direct for the 1st mechanism, incremental for the second (discussion in the synthesis in [§5]).

## 2.4 Bibliographical references

P. PENSERINI: “Modeling of the assemblies bolted in the webmasts”. Note HM-77/93/287

# 3 Modeling A

## 3.1 Characteristics of modeling

An element DIS_TR_L with 2 nodes of worthless size (idem 1.1).
A node $N2$ : all is blocked.
A node $N3$ : one imposes $F_x$ by step of $1\ 000\ N$ and $M_y$ by step of $3\ 000\ N.mm$ with the map of time:

| $t$ | 0. | 1. | 2. | 3. | 4. | 6. | 8. | 10. | 11. | 12. |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0. | 6. | 7 | 17. | 40. | 20. | 42 | 0. | -6. | -17. |

## 3.2 Characteristics of the grid

1 SEG2.
2 nodes.

## 3.3 Sizes tested and results

| Identification | Reference | % difference |
|---|---|---|
| Displacement $UX$, Node $N3$, Order 2<br>Displacement $DRY$, Node $N3$, Order 2 | 9.468E-02<br>1.275E-03 | (Direct Calculation and exact) |
| Displacement $UX$, Node $N3$, Order 8<br>Displacement $DRY$, Node $N3$, Order 8 | 3.7366<br>1.3754E-02 | Incremental calculation exact |
| Displacement $UX$, Node $N3$, Order 12 | 2.6799 | Incremental calculation |
| Displacement $DRY$, Node $N3$, Order 12 | 5.3598E-04 | exact |
| Variable interns 1, Node $N3$, Order 2 | 9.6574E-02 | Exact direct calculation |
| Variable interns 1, Node $N3$, Order 3 | 1.07417 | Exact incremental calculation |
| Variable interns 1, Node $N3$, Order 11 | 9.6574E-02 | Exact incremental calculation |
| Variable interns 1, Node $N3$, Order 12 | 1.07417 | Exact incremental calculation |

## 3.4 Notice

The reference solution is the digital solution of a problem to an unknown factor determined by *Code_Aster*.

# 4 Summary of the results

The interest of the test is to represent the exhaustiveness of the possible ways of loadings with multiple factors of change of incline: load-discharge, transition from mechanism.

On the other hand, the dimension of the problem makes it possible to have only one unknown factor (the current internal variable), solution of the inversion of the curve of the law of behavior: direct solution for the 1st mechanism and incremental for the second.

The reduction of the problem makes it possible (if one converges) to trust *Aster* like “slide rule” and to regard the result as a digital solution “exact”.