SSNL102 - Behavior nonlinear of an assembly of angles

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

The analysis is static with an incremental nonlinear behavior model expressed by an adimensional local variable combining the two-dimensional forces and generalized displacements.

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

1 Problem of reference

1.1 Geometry

a discrete element of size null to 2 nodes.
Local coordinate system = total reference.
A stiffness matrix K_TR_D_L affected by default (partner with an element DIS_TR_L)

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

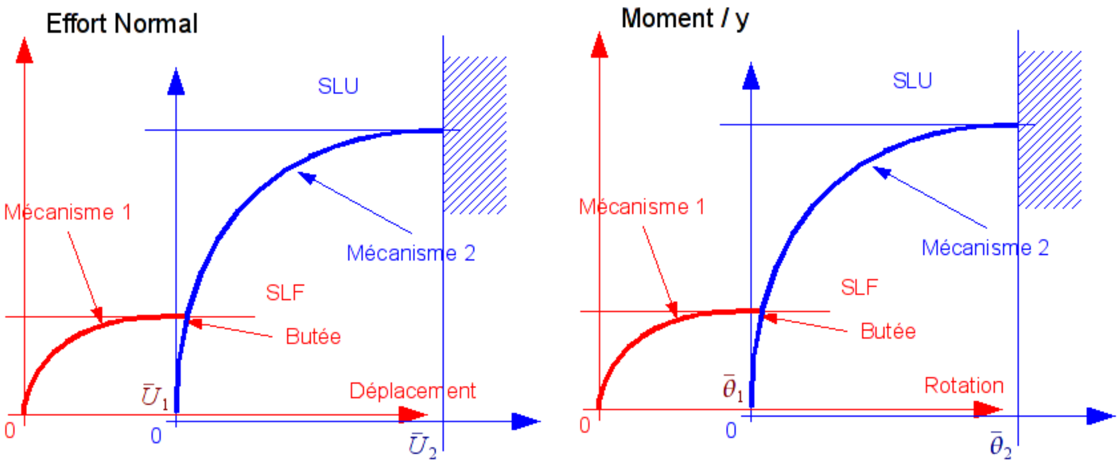
The characteristics of stiffness according to the local directions x and rotation around y are modified by a behavior model of the type ASSE_CORN introduced by a characteristic material.

1.2 Material properties

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

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

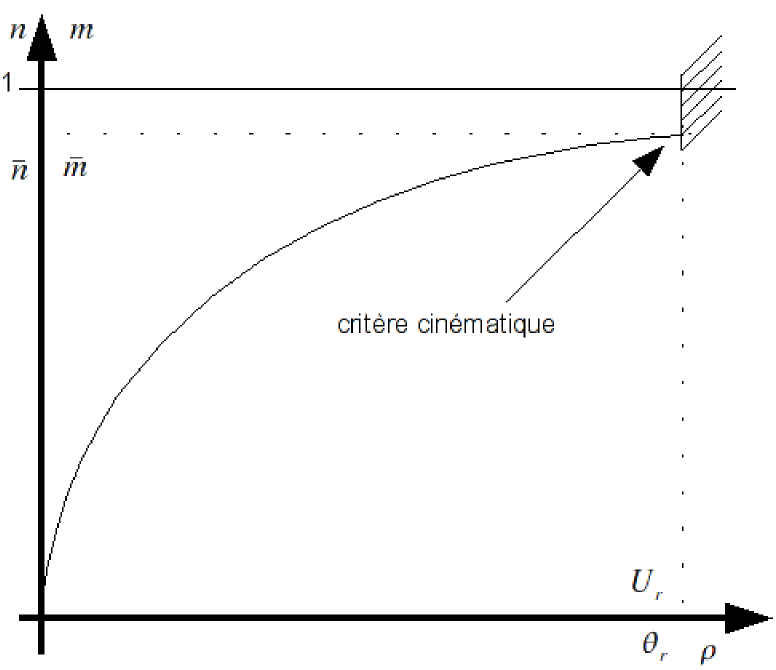
$$\bar{N}_2=50000\,N \quad \bar{M}_2=750000\,N.mm \quad \bar{U}_2=10\,mm \quad \bar{\theta}_2=0.01\ , \quad \bar{C}_2=0.95$$



1.2-a 1.2-a : Mechanisms of assembly in normal force and moment.

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

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



$$n = Nx / \bar{N}$$

$$m = My / \bar{M}$$

$$U_r = U / \bar{U}$$

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

Appear 1.2-b : Behavior model 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

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

1.4 Initial conditions

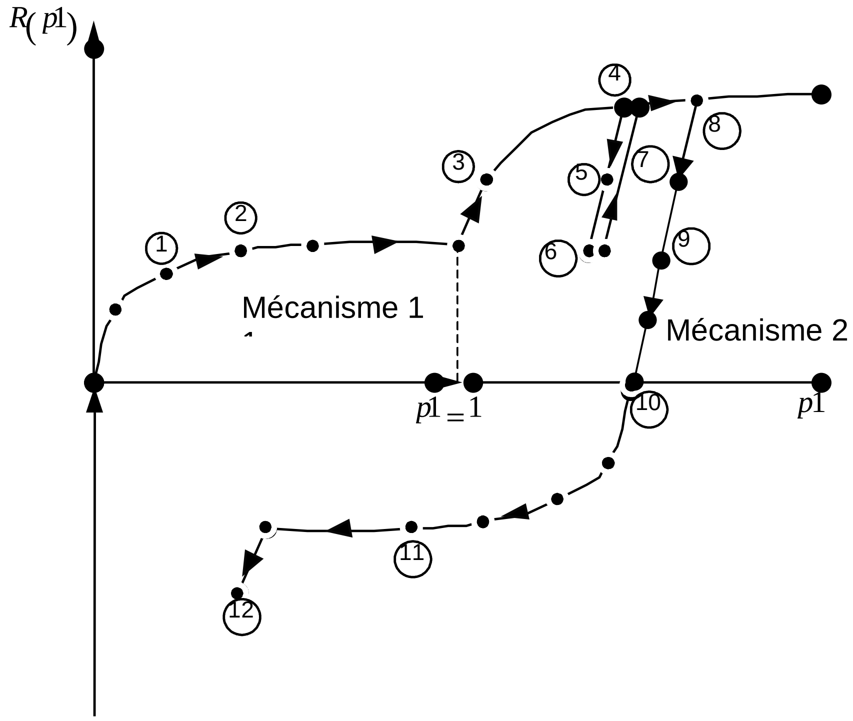
Displacements, forces and local variables null.

2 Reference solution

2.1 Method of calculating used for the reference solution

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

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



2.2 Results reference

Finding the correspondence variable-criterion of the curve limits behavior model.

2.3 Uncertainty on the numerical

solution Solution of the inversion of a nonlinear relation. There is an unknown at the same time: the local variable of the mechanism. The other values result some. The computation is direct for the 1st mechanism, incremental for the second (discussion in the synthesis in [§5]).

2.4 Bibliographical references

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

3 Modelization A

3.1 Characteristic of the modelization

an element DIS_TR_L with 2 nodes of size null (idem 1.1).
One the node is outside the field of definition with a right profile of the EXCLU type node: $N2$ all is blocked.
One the node is outside the field of definition with a right profile of the EXCLU type node: $N3$ one imposes F_x by step of $1\,000\ N$ and M_y by step of $3\,000\ N.mm$ with the card 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 mesh

1 SEG2.
2 nodes.

3.3 Quantities tested and results

Identification	Reference	% difference
Displacement UX, Node $N3$, Order 2 Displacement DRY, Node $N3$, Order 2	9.468E-02 1.275E-03	(direct Computation and exact)
Displacement UX, Node $N3$, Order 8 Displacement DRY, Node $N3$, Order 8	3.7366 1.3754E-02	incremental Computation exact
Displacement UX, Node $N3$, Order 12	2.6799	incremental Computation
Displacement DRY, Node $N3$, exact Order	12	5.3598E-04
Local variable 1, Node $N3$, Order 2	9.6574E-02	exact direct Computation
Local variable 1, Node $N3$, Order 3	1.07417	exact incremental Computation
Local variable 1, Node $N3$, Order 11	9.6574E-02	exact incremental Computation
Local variable 1, Node $N3$, Order 12	1.07417	exact incremental Computation

3.4 Notices

the reference solution is the numerical solution ofa problem with an unknown 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 (the current local variable), solution of the inversion of the curve of the constitutive law: 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 result as a numerical solution "exact".