SSND117 – Validation of behavior DIS_ECRO_TRAC

Summary:

One tests the answer of the nonlinear model of behavior DIS_ECRO_TRAC, formulated on discrete elements for meshs SEG2 or POI1.

The operator STAT_NON_LINE is employed for the validation. One analyzes the answer of discrete elements supporting a nonlinear law of behavior under a cyclic loading.

Modelings and discrete elements tested are in 3D with modelings DIS_T and DIS_TR on meshs POI1 and SEG2.

This behavior is also validated for dynamic stresses in the CAS-test SDND124 [V5.01.124] with the operators DYNA_VIBRA and DYNA_NON_LINE.

1 Problem of reference

1.1 Description of the device

The non-linear element is represented by the rheological model below.

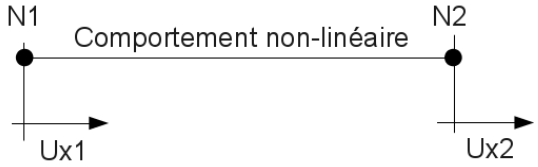

Figure 1.1-a : Model of the device.

The equations governing the behavior are in [R5.03.17].

1.2 Modelings

Modelings tested are it on elements DIS_T then DIS_TR, meshs SEG2 then meshs POI1. The characteristics of the discrete elements are of the type: K_T_D_L, K_TR_D_L, K_T_D_N, K_TR_D_N.

Note: The units of the parameters must be in agreement with the unit of the efforts, the unit lengths [R5.03.17]. For all modelings the units are homogeneous with [NR], [mm].

1.2.1 Modeling A

This modeling makes it possible to test the nonlinear static cyclic behavior of the law.

1.3 Properties materials

1.3.1 Modeling A

The only property is the non-linear function [R5.03.17].
The figure 1.3.1-a present the non-linear behavior used in the case test:

- Elastic behavior up to the point $(0.5\text{mm}, 200.0\text{N})$.
- Non-linear behavior, governs by the following equation:

$$R(p) = \frac{K_{elas} \cdot p}{\left[1+\left(\frac{k_{elas} \cdot p}{F_u - F_y}\right)^n\right]^{(1/n)}}$$

with $K_{elas} = \frac{200.0\,N}{0.5\,mm} = 400\ N/mm$

$F_y = 200.0\,N$

$F_u = 450.0\,N$

$n = 1.5$

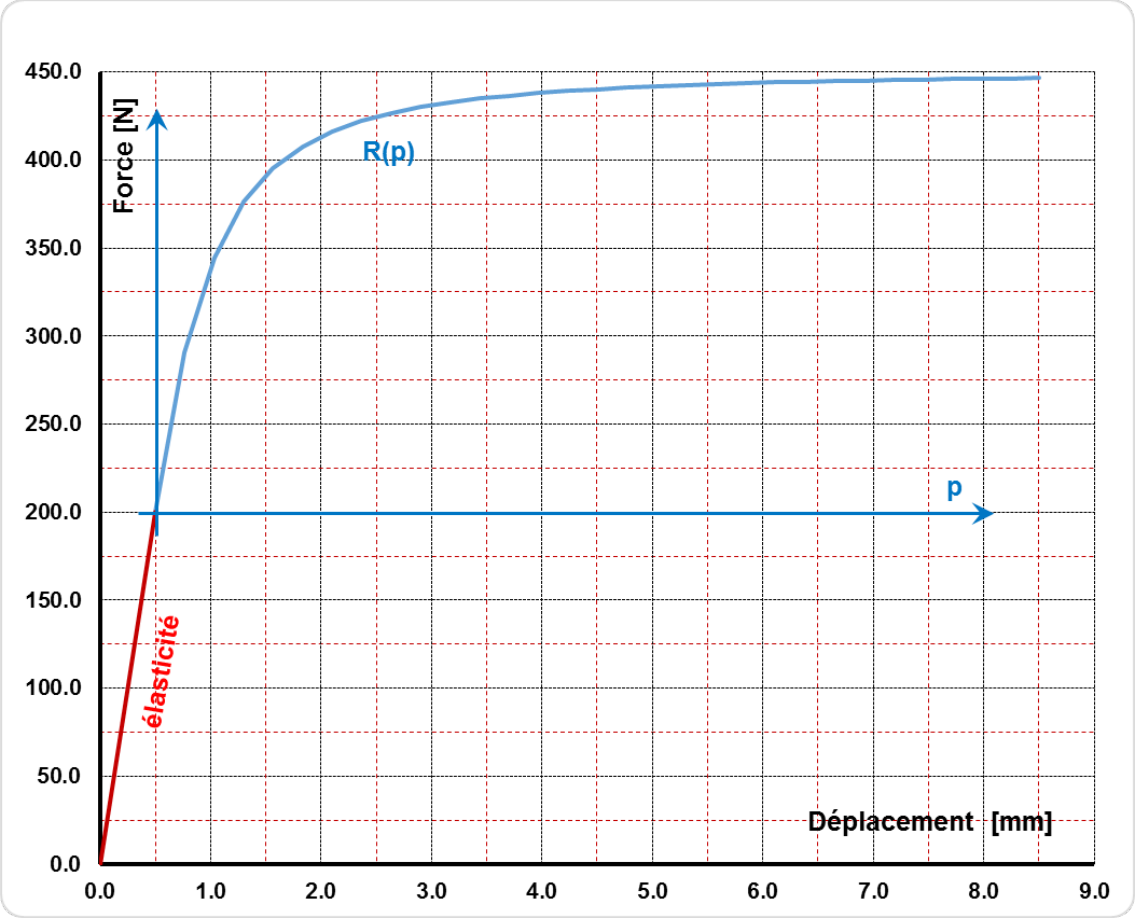

Figure 1.3.1-a **: Non-linear behavior**

1.4 Boundary conditions and loadings

When the discrete one is one SEG2, one of the nodes is blocked, on the other a condition of displacement is imposed. When the discrete one is one POI1 the condition of displacement is imposed on this node.

The condition in displacement is a function of time:

$U_0.\sin(2\pi.f.t)$ with $f=1\,Hz$ and U_0=2.0mm

2 Reference solutions

2.1 Method of calculating used for the reference solutions

2.1.1 Modeling A

The equation of the non-linear behavior is known as well as the loading in displacement, the solution is calculated in an analytical way.

The answer in effort of the law of behavior is:

INST	DX [mm]	Force [NR]
0.0E+00	0,000000000E+00	0,000000000E+00
5.0E-02	6,180339888E-01	2,447916682E+02
1.0E-01	1,175570505E+00	3,635571124E+02
1.5E-01	1,618033989E+00	3,980839557E+02
2.0E-01	1,902113033E+00	4,101477045E+02
2.5E-01	2,000000000E+00	4,132978462E+02
3.0E-01	1,902113033E+00	3,741385062E+02
3.5E-01	1,618033989E+00	2,605068886E+02
4.0E-01	1,175570505E+00	8,352149498E+01
4.5E-01	6,180339888E-01	-1,394931114E+02
5.0E-01	1,110223025E-15	-3,867067069E+02
5.5E-01	-6,180339888E-01	-4,254065302E+02
6.0E-01	-1,175570505E+00	-4,322037428E+02
6.5E-01	-1,618033989E+00	-4,356703944E+02
7.0E-01	-1,902113033E+00	-4,373491138E+02
7.5E-01	-2,000000000E+00	-4,378540507E+02
8.0E-01	-1,902113033E+00	-3,986934353E+02
8.5E-01	-1,618033989E+00	-2,850618178E+02
9.0E-01	-1,175570505E+00	-1,080764241E+02
9.5E-01	-6,180339888E-01	1,149381822E+02
1.0E+00	3,108624469E-15	3,621517777E+02
1.0E+00	6,180339888E-01	4,397241501E+02
1.1E+00	1,175570505E+00	4,415313517E+02
1.1E+00	1,618033989E+00	4,426215323E+02
1.2E+00	1,902113033E+00	4,432047994E+02
1.2E+00	2,000000000E+00	4,433883866E+02
1.3E+00	1,902113033E+00	4,042276150E+02
1.3E+00	1,618033989E+00	2,905959975E+02
1.4E+00	1,175570505E+00	1,136106038E+02
1.4E+00	6,180339888E-01	-1,094040026E+02
1.5E+00	7,771561172E-16	-3,566175981E+02

The internal variables of the law of behavior are also calculated and will be tested.

	Name of the variable	
V1	FORCE	Thrust load in the local reference mark
V2	DEPLX	Axial displacement in the local reference mark
V3	DISSTHER	Dissipation
V4	DEPLANEX	Unelastic displacement
V5	DEPLCUMX	Cumulated unelastic displacement

Internal variables of the law of behavior:

INST	V1	V2	V3	V4	V5
0.0E+00	0,000000000E+00	0,000000000E+00	0,000000000E+00	0,000000000E+00	0,000000000E+00
5.0E-02	2,447916682E+02	6,180339888E-01	1,405971753E+00	6,054818205E-03	1,180121159E-01
1.0E-01	3,635571124E+02	1,175570505E+00	8,686106364E+01	2,666777237E-01	6,755486318E-01
1.5E-01	3,980839557E+02	1,618033989E+00	2,234786626E+02	6,228240995E-01	1,118012116E+00
2.0E-01	4,101477045E+02	1,902113033E+00	3,262110703E+02	8,767437714E-01	1,402091160E+00
2.5E-01	4,132978462E+02	2,000000000E+00	3,632742706E+02	9,667553845E-01	1,499978127E+00
3.0E-01	3,741385062E+02	1,902113033E+00	3,632789750E+02	9,667667671E-01	1,499990444E+00
3.5E-01	2,605068886E+02	1,618033989E+00	3,632789750E+02	9,667667671E-01	1,499990444E+00
4.0E-01	8,352149498E+01	1,175570505E+00	3,632789750E+02	9,667667671E-01	1,499990444E+00
4.5E-01	-1,394931114E+02	6,180339888E-01	3,632789750E+02	9,667667671E-01	1,499990444E+00
5.0E-01	-3,867067069E+02	1,137978600E-15	3,632789750E+02	9,667667671E-01	1,499990444E+00
5.5E-01	-4,254065302E+02	-6,180339888E-01	5,822409187E+02	4,454823368E-01	2,051520473E+00
6.0E-01	-4,322037428E+02	-1,175570505E+00	8,141946142E+02	-9,506114752E-02	2,609056989E+00
6.5E-01	-4,356703944E+02	-1,618033989E+00	1,002480475E+03	-5,288580027E-01	3,051520473E+00
7.0E-01	-4,373491138E+02	-1,902113033E+00	1,124660128E+03	-8,087402481E-01	3,335599517E+00
7.5E-01	-4,378540507E+02	-2,000000000E+00	1,166943511E+03	-9,053648734E-01	3,433486484E+00
8.0E-01	-3,986934353E+02	-1,902113033E+00	1,166949891E+03	-9,053794443E-01	3,433501239E+00
8.5E-01	-2,850618178E+02	-1,618033989E+00	1,166949891E+03	-9,053794443E-01	3,433501239E+00
9.0E-01	-1,080764241E+02	-1,175570505E+00	1,166949891E+03	-9,053794443E-01	3,433501239E+00
9.5E-01	1,149381822E+02	-6,180339888E-01	1,166949891E+03	-9,053794443E-01	3,433501239E+00
1.0E+00	3,621517777E+02	3,164135620E-15	1,166949891E+03	-9,053794443E-01	3,433501239E+00
1.0E+00	4,397241501E+02	6,180339888E-01	1,353061170E+03	-4,812763864E-01	3,862268636E+00
1.1E+00	4,415313517E+02	1,175570505E+00	1,596763084E+03	7,174212534E-02	4,419805151E+00
1.1E+00	4,426215323E+02	1,618033989E+00	1,791170002E+03	5,114801581E-01	4,862268636E+00
1.2E+00	4,432047994E+02	1,902113033E+00	1,916348431E+03	7,941010341E-01	5,146347679E+00
1.2E+00	4,433883866E+02	2,000000000E+00	1,959538004E+03	8,915290336E-01	5,244234647E+00
1.3E+00	4,042276150E+02	1,902113033E+00	1,959544637E+03	8,915439951E-01	5,244249677E+00
1.3E+00	2,905959975E+02	1,618033989E+00	1,959544637E+03	8,915439951E-01	5,244249677E+00
1.4E+00	1,136106038E+02	1,175570505E+00	1,959544637E+03	8,915439951E-01	5,244249677E+00
1.4E+00	-1,094040026E+02	6,180339888E-01	1,959544637E+03	8,915439951E-01	5,244249677E+00
1.5E+00	-3,566175981E+02	8,604228441E-16	1,959544637E+03	8,915439951E-01	5,244249677E+00

2.2 Uncertainty on the solution

2.2.1 Modeling A

No, the reference solution is exact.

3 Modeling A

3.1 Characteristics of modeling

Modelings tested are DIS_T and DIS_TR on meshs and points. The characteristics of stiffness of discrete are thus of the type: K_T_D_L, K_TR_D_L, K_T_D_N, K_TR_D_N.

3.2 Characteristics of the grid

Many nodes: 6, many meshs: 4, elements SEG2 : 2, elements POI1 : 2.

3.3 Boundary conditions and loadings

The condition in displacement is the function of time:

3.4 Sizes tested and results

The sizes tested are displacement, the effort, the internal variables.
The tolerances are those by default.

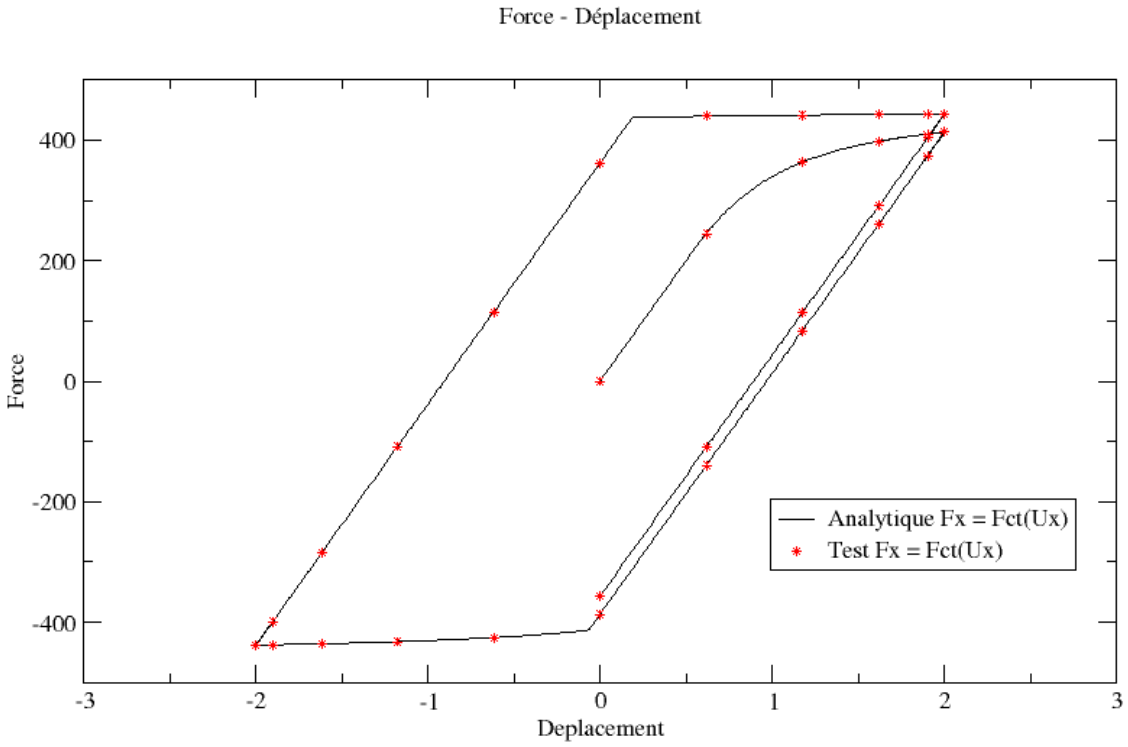

Figure 3.4-a **: Comparison of the answer force-displacement.**

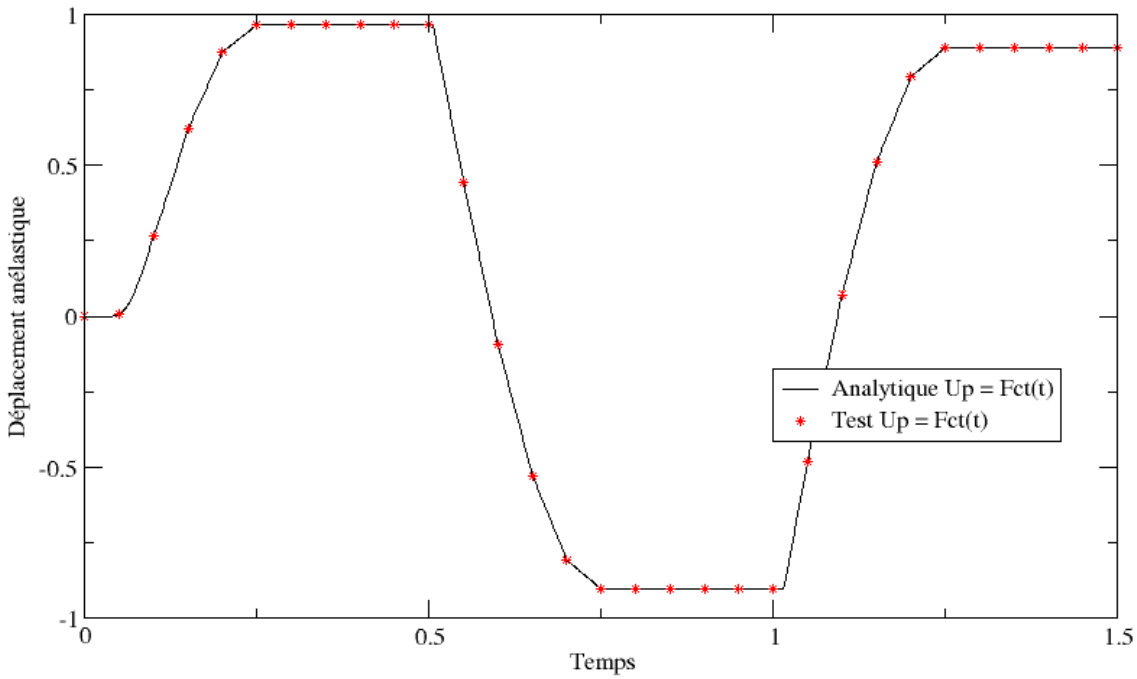

Figure 3.4-b **: Comparison of unelastic displacement vs time.**

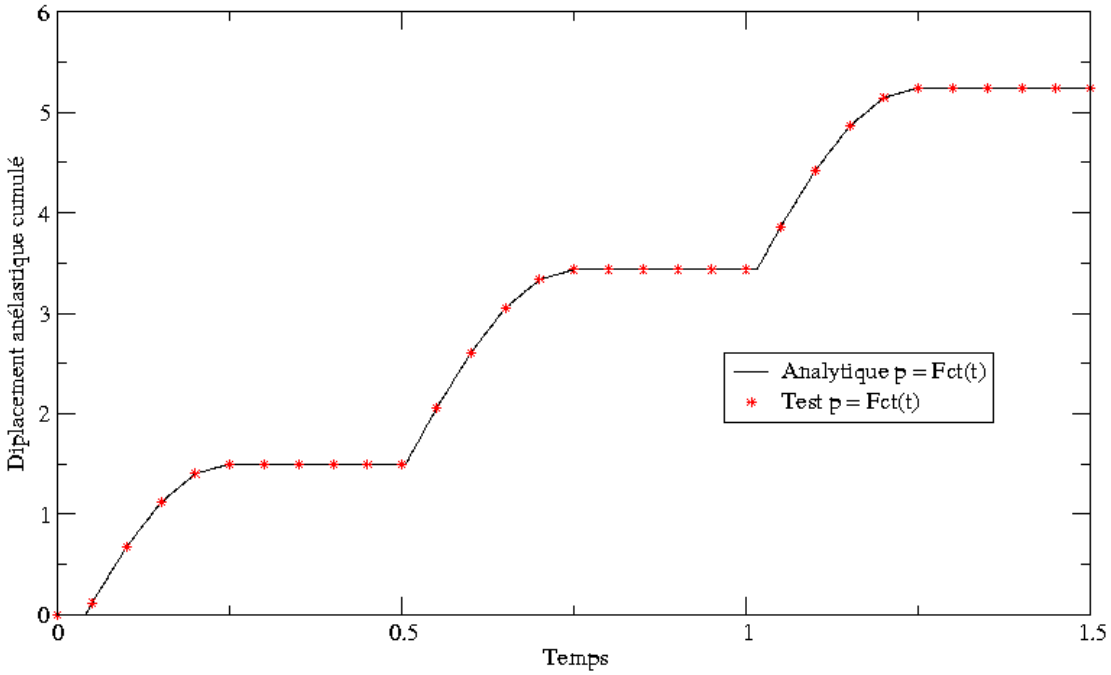

Figure 3.4-c **: Comparison of unelastic displacement cumulated vs time.**

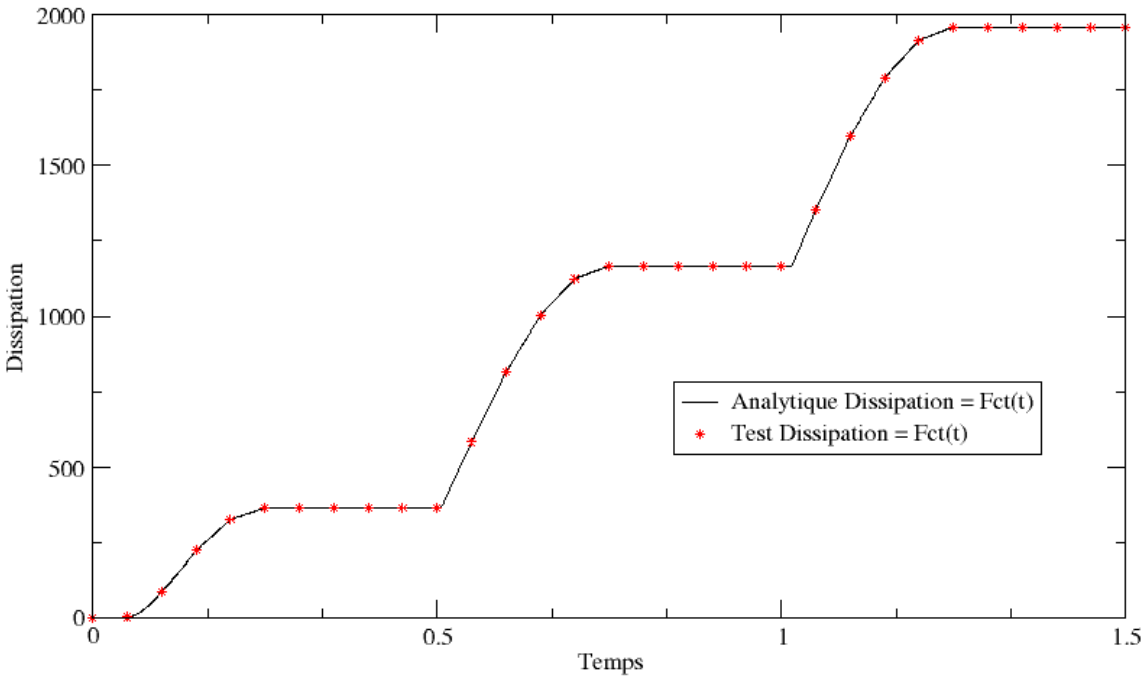

Figure 3.4-d **: comparison of dissipation vs time.**

4 Summary of the results

These tests make it possible to check the good performance of the discrete elements with the behavior DIS_ECRO_TRAC within the framework of a use with the order STAT_NON_LINE.