

## SSND102 – kinematical Constitutive law nonlinear for discrete elements

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### Summarized:

The problem is quasi-static nonlinear in structural mechanics. It is about a model with nonlinear kinematic hardening. One analyzes the response of discrete elements supporting a nonlinear kinematical constitutive law under a cyclic loading.

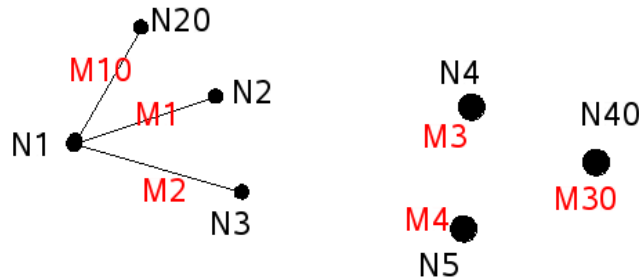
The discrete elements tested are:

- [1] 3D ( K\_T\_D\_L, K\_TR\_D\_L, K\_T\_D\_N, K\_TR\_D\_N );
- [2] 2D ( K\_T\_D\_L, K\_TR\_D\_L, K\_T\_D\_N, K\_TR\_D\_N ).

All the degrees of freedom are tested, the parameters of the loading in displacements and those of the kinematical model are different for all the degrees of freedom in order to cover various situations. The reference solutions are obtained in an analytical way or by comparison with an external application.

## 1 Problem of reference

### 1.1 Geometry



Appears 1.1.a: geometry.

	Model in 3DModèle	in 2DGROUP_MA
Nets <i>M1</i> : Node <i>N1</i> with <i>N2</i>	DIS_T2D_DIS_TDL_T	
Nets <i>M2</i> : Node <i>N1</i> with <i>N3</i>	DIS_TR2D_DIS_TRDL_TR	
Nets <i>M3</i> : Node <i>N4</i>	DIS_T2D_DIS_TDN_T	
Nets <i>M4</i> : Node <i>N5</i>	DIS_TR2D_DIS_TRDN_TR	
Nets <i>M10</i> : Node <i>N1</i> with <i>N20</i>		DIS_TDL_T0
Nets <i>M30</i> : Node <i>N40</i>		DIS_TDN_T0

### 1.2 Properties of the material

the constitutive law is written in the following generic form (for each degree of freedom):

$$\text{the elastoplastic relation: } F = K_e (U - U^{an})$$

$$\text{limiting surface: } f = |F - X| - F_y$$

$$\text{the kinematic hardening part: } X = \frac{k_x \cdot \alpha}{\left[ 1 + \left[ \frac{k_x \cdot \alpha}{F_u} \right]^n \right]^{1/n}}$$

It requires thus 5 characteristics. Their units must be in agreement with those of the study.

$K_e$  : elastic stiffness

$F_y$  : yield stress

$k_x$  : kinematical stiffness

$F_u$  : force limits kinematical

$n$  : power

### 1.3 Boundary conditions and loadings

The node is outside the field of definition with a right profile of the EXCLU type node: *N1* fixed support

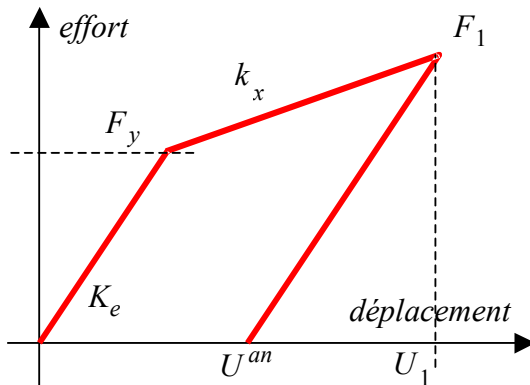
Nodes *N2 N3 N4 N5 N20 N40* : for all the degrees of freedom the signal is cyclic with imposed displacement.

## 2 Reference solution

### 2.1 Method of calculating used for the reference solution

In the general case, the complex form of the model does not make it possible to calculate a reference solution.

To validate the model, a linear kinematic hardening in the case of is placed (the power and the force limit kinematical are not given). The forces as well as dissipated energy can be calculated analytically.



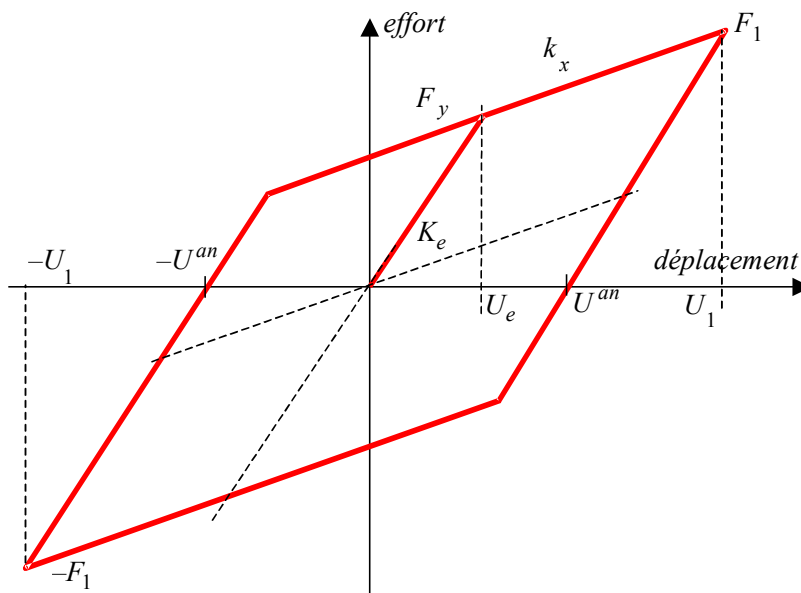
The data are:  $F_y$ ,  $K_e$ ,  $k_x$  and the amplitude of displacement:  $U_1 = 5 \cdot \frac{F_y}{K_e}$

What gives:

$$F_1 = F_y + 4 \cdot k_x \frac{F_y}{K_e}$$

$$U_{an} = 4 \cdot \frac{F_y}{K_e^2} (K_e - k_x)$$

$$\text{Dissipated energy is: } \bar{W}_1 = U_{an} \cdot \frac{(F_y + F_1)}{2}$$



Appear 2.1.a: cycle of loading.

For a cycle stabilized (going displacement of 0 with  $U_1$   $-U_1$  with  $U_e$ ) dissipated energy is  $\bar{W}_d = 4 \cdot U_{an} \cdot F_y$ .

In the general case of the model power, an external program made it possible to validate the responses in forces.

## 2.2 Results of reference

the tests are carried out on:

- 1) force with each inversion of loading;
- 2) the energy dissipated at the end of the loading.

For the two modelizations a table presents the parameters of the model as well as the values of the forces and the energy dissipated at the end of the cycle.

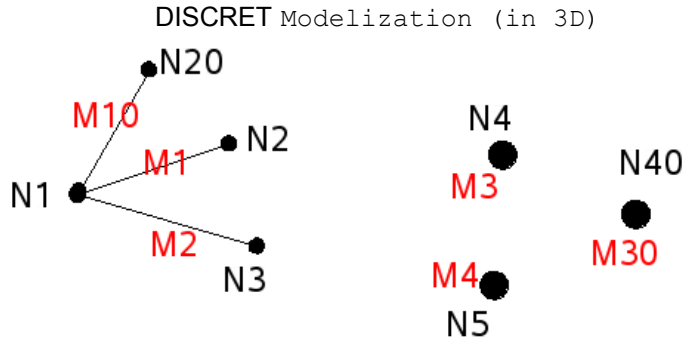
## 2.3 Uncertainty on the solution

In the case of linear kinematic hardening it has there no uncertainty, the solution is analytical, as well for the forces as for energy.

In the case of nonlinear hardening the reference solution is given by an external program.

## 3 Modelization A

### 3.1 Characteristic of the modelization



Appears 3.1.a: geometry.

#### Characteristics of the discrete elements

Nets *M1* : Node *N1* with *N2*  
 Nets *M2* : Node *N1* with *N3*  
 Nets *M3* : Node *N4*  
 Nets *M4* : Node *N5*  
 Nets *M10* : Node *N1* with *N20*  
 Nets *M30* : Node *N40*

#### Modelization in 3D

DIS\_TDL\_T  
 DIS\_TRDL\_TR  
 DIS\_TDN\_T  
 DIS\_TRDN\_TR

GROUP\_MA

DIS\_TDL\_T0

DIS\_TDN\_T0

discrete THE *DL\_T0* with the same characteristics that *DL\_T*, on the other hand its directional sense is different.

CARA = "ANGL\_NAUT" , VALE = ( 90.0 , - 90.0, the 0.0)

force *N* are thus according to the axis *Z*, the force *VY* following the axis *Z* and the following *VZ* force *X*.

### 3.2 Characteristics of the mesh

Many nodes: 7, Number of meshes: 6, Elements SEG2\_: 3, Elements POI1: 3

### 3.3 Definition of the function of loading

times	values
the 0.0	0.000
30.0	1.000
90.0	-1.000
145.0	0.800
180.0	-0.450
230.0	1.150
250.0	0.500
280.0	1.450

selected steps is of 1. s .

## 3.4 Properties of discrete

the table below gives for all the requested directions the characteristics of the discrete ones.

		$F_y$ LIMY_*	$K_e$ K_T*	$F_u$ LIMU_*	$k_x$ KCIN_*	$n$ PUIS_*
DL T	dx	1000.0	3400000.0	1000.0	700000.0	2.00
DL T0	Dy	1500.0	2000000.0	800.0	900000.0	1.50
	dz	2000.0	2500000.0	800.0	700000.0	2.25
DN T	dx	1000.0	3400000.0	1000.0	700000.0	2.00
	Dy	1500.0	2000000.0	800.0	900000.0	1.50
	dz	2000.0	2500000.0	800.0	700000.0	2.25
DL TR	dx	1000.0	3400000.0	1000.0	700000.0	2.00
	Dy	1500.0	2000000.0	800.0	900000.0	1.50
	dz	2000.0	2500000.0	800.0	700000.0	2.25
	X-ray	3000.0	3000000.0	1000.0	600000.0	2.00
	ry	3500.0	2700000.0	1800.0	800000.0	1.50
	rz	2500.0	3200000.0	1400.0	850000.0	2.25
DN TR	dx	1000.0	3400000.0	1000.0	700000.0	2.00
	Dy	1500.0	2000000.0	800.0	900000.0	1.50
	dz	2000.0	2500000.0	800.0	700000.0	2.25
	X-ray	3000.0	3000000.0	1000.0	600000.0	2.00
	ry	3500.0	2700000.0	1800.0	800000.0	1.50
	rz	2500.0	3200000.0	1400.0	850000.0	2.25
DN T0	dx	1000.0	3400000.0		700000.0	
	Dy	1500.0	2000000.0		900000.0	
	dz	2000.0	2500000.0		700000.0	

## 3.5 Quantities tested and results

GROUP_MA	Urgent	Force	Force Reference	Force Code Aster	Error
DN TR	N	30.000	1635.707253	1635.707253	-8.4900e-11
DN TR	N	90.000	-1635.707253	-1635.707253	-8.4900e-11
DN TR	N	145.000	1525.492881	1525.492881	-1.8200e-10
DN TR	N	180.000	-1249.231871	-1249.231871	1.4500e-11
DN TR	N	230.000	1699.177353	1699.177353	-1.6000e-10
DN TR	N	250.000	-415.381013	-415.381013	-1.1200e-10
DN TR	N	280.000	1789.595108	1789.595108	-4.9600e-11
DN TR	VY	30.000	2224.098875	2224.098875	-4.9400e-12
DN TR	VY	90.000	-2224.098875	-2224.098875	-4.9400e-12
DN TR	VY	145.000	2190.040518	2190.040518	-1.0900e-10
DN TR	VY	180.000	-2017.290415	-2017.290415	-1.5500e-10
DN TR	VY	230.000	2239.745512	2239.745512	-6.2600e-12
DN TR	VY	250.000	-790.397664	-790.397663	-3.5800e-11
DN TR	VY	280.000	2258.782745	2258.782745	1.0400e-10
DN TR	VZ	30.000	2767.252580	2767.252580	-7.5200e-11
DN TR	VZ	90.000	-2767.252580	-2767.252580	-7.5200e-11
DN TR	VZ	145.000	2740.932239	2740.932239	1.8200e-10
DN TR	VZ	180.000	-2547.183658	-2547.183658	2.5800e-11
DN TR	VZ	230.000	2777.276300	2777.276300	-1.5700e-10
DN TR	VZ	250.000	-1243.236082	-1243.236082	-9.2100e-11
DN TR	VZ	280.000	2787.481342	2787.481342	7.7000e-11
DN TR	MFY	30.000	5022.231028	5022.231028	9.6800e-11
DN TR	MFY	90.000	-5022.231028	-5022.231028	9.6800e-11
DN TR	MFY	145.000	4911.499221	4911.499221	8.9600e-11
DN TR	MFY	180.000	-4443.221450	-4443.221450	-4.3200e-12
DN TR	MFY	230.000	5075.752629	5075.752629	3.5200e-12
DN TR	MFY	250.000	-2025.828992	-2025.828992	-8.7200e-11
DN TR	MFY	280.000	5143.339483	5143.339483	-4.7600e-11
DN TR	MFZ	30.000	3773.863680	3773.863680	4.0200e-11
DN TR	MFZ	90.000	-3773.863680	-3773.863680	4.0200e-11
DN TR	MFZ	145.000	3686.099695	3686.099695	-2.8500e-11
DN TR	MFZ	180.000	-3236.583886	-3236.583886	1.3700e-10
DN TR	MFZ	230.000	3810.233618	3810.233618	6.2600e-11
DN TR	MFZ	250.000	-1262.367026	-1262.367026	5.6200e-11
DN TR	MFZ	280.000	3849.201624	3849.201624	-1.8600e-12

GROUP_MA	Urgent	Force	Force Reference	Force Code Aster	Error
DN T	N	30.000	1635.707253	1635.707253	-8.4900e-11
DN T	N	90.000	-1635.707253	-1635.707253	-8.4900e-11
DN T	N	145.000	1525.492881	1525.492881	-1.8200e-10
DN T	N	180.000	-1249.231871	-1249.231871	1.4500e-11
DN T	N	230.000	1699.177353	1699.177353	-1.6000e-10
DN T	N	250.000	-415.381013	-415.381013	-1.1200e-10
DN T	N	280.000	1789.595108	1789.595108	-4.9600e-11
DN T	VY	30.000	2224.098875	2224.098875	-4.9400e-12
DN T	VY	90.000	-2224.098875	-2224.098875	-4.9400e-12
DN T	VY	145.000	2190.040518	2190.040518	-1.0900e-10
DN T	VY	180.000	-2017.290415	-2017.290415	-1.5500e-10
DN T	VY	230.000	2239.745512	2239.745512	-6.2600e-12
DN T	VY	250.000	-790.397664	-790.397663	-3.5800e-11

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DN T	VY	280.000	2258.782745	2258.782745	1.0400e-10
DN T	VZ	30.000	2767.252580	2767.252580	-7.5200e-11
DN T	VZ	90.000	-2767.252580	-2767.252580	-7.5200e-11
DN T	VZ	145.000	2740.932239	2740.932239	1.8200e-10
DN T	VZ	180.000	-2547.183658	-2547.183658	2.5800e-11
DN T	VZ	230.000	2777.276300	2777.276300	-1.5700e-10
DN T	VZ	250.000	-1243.236082	-1243.236082	-9.2100e-11
DN T	VZ	280.000	2787.481342	2787.481342	7.7000e-11

GROUP_MA	Urgent	Force	Force Reference	Force Code_Aster	Error
DL TR	N	30.000	1635.707253	1635.707253	-8.4900e-11
DL TR	N	90.000	-1635.707253	-1635.707253	-8.4900e-11
DL TR	N	145.000	1525.492881	1525.492881	-1.8200e-10
DL TR	N	180.000	-1249.231871	-1249.231871	1.4500e-11
DL TR	N	230.000	1699.177353	1699.177353	-1.6000e-10
DL TR	N	250.000	-415.381013	-415.381013	-1.1200e-10
DL TR	N	280.000	1789.595108	1789.595108	-4.9600e-11
DL TR	VY	30.000	2224.098875	2224.098875	-4.9400e-12
DL TR	VY	90.000	-2224.098875	-2224.098875	-4.9400e-12
DL TR	VY	145.000	2190.040518	2190.040518	-1.0900e-10
DL TR	VY	180.000	-2017.290415	-2017.290415	-1.5500e-10
DL TR	VY	230.000	2239.745512	2239.745512	-6.2600e-12
DL TR	VY	250.000	-790.397664	-790.397663	-3.5800e-11
DL TR	VY	280.000	2258.782745	2258.782745	1.0400e-10
DL TR	VZ	30.000	2767.252580	2767.252580	-7.5200e-11
DL TR	VZ	90.000	-2767.252580	-2767.252580	-7.5200e-11
DL TR	VZ	145.000	2740.932239	2740.932239	1.8200e-10
DL TR	VZ	180.000	-2547.183658	-2547.183658	2.5800e-11
DL TR	VZ	230.000	2777.276300	2777.276300	-1.5700e-10
DL TR	VZ	250.000	-1243.236082	-1243.236082	-9.2100e-11
DL TR	VZ	280.000	2787.481342	2787.481342	7.7000e-11
DL TR	MFY	30.000	5022.231028	5022.231028	9.6800e-11
DL TR	MFY	90.000	-5022.231028	-5022.231028	9.6800e-11
DL TR	MFY	145.000	4911.499221	4911.499221	8.9600e-11
DL TR	MFY	180.000	-4443.221450	-4443.221450	-4.3200e-12
DL TR	MFY	230.000	5075.752629	5075.752629	3.5200e-12
DL TR	MFY	250.000	-2025.828992	-2025.828992	-8.7200e-11
DL TR	MFY	280.000	5143.339483	5143.339483	-4.7600e-11
DL TR	MFZ	30.000	3773.863680	3773.863680	4.0200e-11
DL TR	MFZ	90.000	-3773.863680	-3773.863680	4.0200e-11
DL TR	MFZ	145.000	3686.099695	3686.099695	-2.8500e-11
DL TR	MFZ	180.000	-3236.583886	-3236.583886	1.3700e-10
DL TR	MFZ	230.000	3810.233618	3810.233618	6.2600e-11
DL TR	MFZ	250.000	-1262.367026	-1262.367026	5.6200e-11
DL TR	MFZ	280.000	3849.201624	3849.201624	-1.8600e-12

GROUP_MA	Urgent	Force	Force Reference	Force Code_Aster	Error
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DL_T	N	90.000	-1635.707253	-1635.707253	-8.4900e-11
DL_T	N	145.000	1525.492881	1525.492881	-1.8200e-10
DL_T	N	180.000	-1249.231871	-1249.231871	1.4500e-11
DL_T	N	230.000	1699.177353	1699.177353	-1.6000e-10

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DL T	N	250.000	-415.381013	-415.381013	-1.1200e-10
DL T	N	280.000	1789.595108	1789.595108	-4.9600e-11
DL T	VY	30.000	2224.098875	2224.098875	-4.9400e-12
DL T	VY	90.000	-2224.098875	-2224.098875	-4.9400e-12
DL T	VY	145.000	2190.040518	2190.040518	-1.0900e-10
DL T	VY	180.000	-2017.290415	-2017.290415	-1.5500e-10
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DL T	VZ	230.000	2777.276300	2777.276300	-1.5700e-10
DL T	VZ	250.000	-1243.236082	-1243.236082	-9.2100e-11
DL T	VZ	280.000	2787.481342	2787.481342	7.7000e-11

GROUP_MA	Urgent	force	Force Reference	Force Code_Aster	Error
DL T0	N	30.000	1635.707253	1635.707253	-8.4900e-11
DL T0	N	90.000	-1635.707253	-1635.707253	-8.4900e-11
DL T0	N	145.000	1525.492881	1525.492881	-1.8200e-10
DL T0	N	180.000	-1249.231871	-1249.231871	1.4500e-11
DL T0	N	230.000	1699.177353	1699.177353	-1.6000e-10
DL T0	N	250.000	-415.381013	-415.381013	-1.1200e-10
DL T0	N	280.000	1789.595108	1789.595108	-4.9600e-11
DL T0	VY	30.000	2224.098875	2224.098875	-4.9400e-12
DL T0	VY	90.000	-2224.098875	-2224.098875	-4.9400e-12
DL T0	VY	145.000	2190.040518	2190.040518	-1.0900e-10
DL T0	VY	180.000	-2017.290415	-2017.290415	-1.5500e-10
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DL T0	VY	280.000	2258.782745	2258.782745	1.0400e-10
DL T0	VZ	30.000	2767.252580	2767.252580	-7.5200e-11
DL T0	VZ	90.000	-2767.252580	-2767.252580	-7.5200e-11
DL T0	VZ	145.000	2740.932239	2740.932239	1.8200e-10
DL T0	VZ	180.000	-2547.183658	-2547.183658	2.5800e-11
DL T0	VZ	230.000	2777.276300	2777.276300	-1.5700e-10
DL T0	VZ	250.000	-1243.236082	-1243.236082	-9.2100e-11
DL T0	VZ	280.000	2787.481342	2787.481342	7.7000e-11

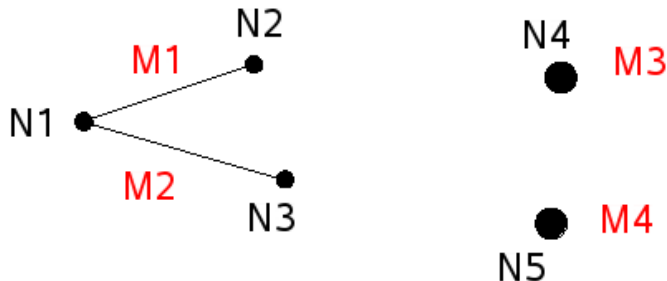
GROUP_MA	Urgent	Force	Force Reference	Force Code_Aster	Error
DN T0	N	30.000	1823.529412	1823.529412	3.5500e-11
DN T0	N	90.000	-1823.529412	-1823.529412	3.5500e-11
DN T0	N	145.000	1823.529412	1823.529412	3.5500e-11
DN T0	VY	30.000	4200.000000	4200.000000	2.1700e-16
DN T0	VY	90.000	-4200.000000	-4200.000000	-4.3300e-16
DN T0	VY	145.000	4200.000000	4200.000000	-2.1700e-16
DN T0	VZ	30.000	4240.000000	4240.000000	0.0000e+00
DN T0	VZ	90.000	-4240.000000	-4240.000000	-2.1500e-16
DN T0	VZ	145.000	4240.000000	4240.000000	2.1500e-16

GROUP_MA	Direction	Energy Reference	Energy Code Aster	Error
DN TR	DX	9.083900	9.083899	-1.1600e-07
DN TR	DY	35.563390	35.563387	-9.4500 10 <sup>-8</sup>
DN TR	DZ	51.155440	51.155445	9.2600 10 <sup>-8</sup>
DN TR	X-ray	96.706530	96.706529	-1.5000 10 <sup>-8</sup>
DN TR	RY	144.155340	144.155339	-4.8400 10 <sup>-9</sup>
DN TR	RZ	61.549450	61.549446	-5.8100 10 <sup>-8</sup>
DN T	DX	9.083900	9.083899	-1.1600e-07
DN T	DY	35.563390	35.563387	-9.4500 10 <sup>-8</sup>
DN T	DZ	51.155440	51.155445	9.2600 10 <sup>-8</sup>
DL TR	DX	9.083900	9.083899	-1.1600e-07
DL TR	DY	35.563390	35.563387	-9.4500 10 <sup>-8</sup>
DL TR	DZ	51.155440	51.155445	9.2600 10 <sup>-8</sup>
DL TR	X-ray	96.706530	96.706529	-1.5000 10 <sup>-8</sup>
DL TR	RY	144.155340	144.155339	-4.8400e-09
DL TR	RZ	61.549450	61.549446	-5.8100 10 <sup>-8</sup>
DL T	DX	9.083900	9.083899	-1.1600e-07
DL T	DY	35.563390	35.563387	-9.4500 10 <sup>-8</sup>
DL T	DZ	51.155440	51.155445	9.2600 10 <sup>-8</sup>
DL T0	DX	9.083900	9.083899	-1.1600e-07
DL T0	DY	35.563390	35.563387	-9.4500 10 <sup>-8</sup>
DL T0	DZ	51.155440	51.155445	9.2600 10 <sup>-8</sup>
DN T0	DX	5.055974	5.055974	-5.5200e-12
DN T0	DY	14.602500	14.602500	0.0000
DN T0	DZ	25.620480	25.620480	1.3900e-16

## 4 Modelization B

### 4.1 Characteristic of the modelization

Modelization 2D\_DISCRET



Appear 5.1.a: geometry.

#### Characteristics of the discrete elements

Nets  $M1$  : Node  $N1$  with  $N2$   
Nets  $M2$  : Node  $N1$  with  $N3$   
Nets  $M3$  : Node  $N4$   
Nets  $M4$  : Node  $N5$

Modelization 2D GROUP\_MA  
2D\_DIS\_TDL\_T  
2D\_DIS\_TRDL\_TR  
2D\_DIS\_TDN\_T  
2D\_DIS\_TRDN\_TR

### 4.2 Characteristic of the mesh

Many nodes: 5, Number of meshes: 4, Element SEG2 : 2, Element POI1 : 2

### 4.3 Properties of discrete

the table below gives for all the requested directions the characteristics of the discrete ones.

		$F_y$	$K_e$	$F_u$	$k_x$	$n$
DL_T	dx	1000.0	3400000.0	1000.0	700000.0	2.00
	Dy	1500.0	2000000.0	800.0	900000.0	1.50
DN_T	dx	1000.0	3400000.0	1000.0	700000.0	2.00
	Dy	1500.0	2000000.0	800.0	900000.0	1.50
DL_TR	dx	1000.0	3400000.0	1000.0	700000.0	2.00
	Dy	1500.0	2000000.0	800.0	900000.0	1.50
	rZ	2500.0	3200000.0	1400.0	850000.0	2.25
DN_TR	dx	1000.0	3400000.0	1000.0	700000.0	2.00
	Dy	1500.0	2000000.0	800.0	900000.0	1.50
	rZ	2500.0	3200000.0	1400.0	850000.0	2.25

## 4.4 Quantities tested and results

GROUP_MA	Urgent	Force	Force Reference	Force Code_Aster	Error
DN TR	N	30.000	1635.707253	1635.707253	-8.4900e-11
DN TR	N	90.000	-1635.707253	-1635.707253	-8.4900e-11
DN TR	N	145.000	1525.492881	1525.492881	-1.8200e-10
DN TR	N	180.000	-1249.231871	-1249.231871	1.4500e-11
DN TR	N	230.000	1699.177353	1699.177353	-1.6000e-10
DN TR	N	250.000	-415.381013	-415.381013	-1.1200e-10
DN TR	N	280.000	1789.595108	1789.595108	-4.9600e-11
DN TR	VY	30.000	2224.098875	2224.098875	-4.9400e-12
DN TR	VY	90.000	-2224.098875	-2224.098875	-4.9400e-12
DN TR	VY	145.000	2190.040518	2190.040518	-1.0900e-10
DN TR	VY	180.000	-2017.290415	-2017.290415	-1.5500e-10
DN TR	VY	230.000	2239.745512	2239.745512	-6.2600e-12
DN TR	VY	250.000	-790.397664	-790.397663	-3.5800e-11
DN TR	VY	280.000	2258.782745	2258.782745	1.0400e-10
DN TR	MFZ	30.000	3773.863680	3773.863680	4.0200e-11
DN TR	MFZ	90.000	-3773.863680	-3773.863680	4.0200e-11
DN TR	MFZ	145.000	3686.099695	3686.099695	-2.8500e-11
DN TR	MFZ	180.000	-3236.583886	-3236.583886	1.3700e-10
DN TR	MFZ	230.000	3810.233618	3810.233618	6.2600e-11
DN TR	MFZ	250.000	-1262.367026	-1262.367026	5.6200e-11
DN TR	MFZ	280.000	3849.201624	3849.201624	-1.8600e-12

GROUP_MA	Urgent	Force	Force Reference	Force Code_Aster	Error
DN T	N	30.000	1635.707253	1635.707253	-8.4900e-11
DN T	N	90.000	-1635.707253	-1635.707253	-8.4900e-11
DN T	N	145.000	1525.492881	1525.492881	-1.8200e-10
DN T	N	180.000	-1249.231871	-1249.231871	1.4500e-11
DN T	N	230.000	1699.177353	1699.177353	-1.6000e-10
DN T	N	250.000	-415.381013	-415.381013	-1.1200e-10
DN T	N	280.000	1789.595108	1789.595108	-4.9600e-11
DN T	VY	30.000	2224.098875	2224.098875	-4.9400e-12
DN T	VY	90.000	-2224.098875	-2224.098875	-4.9400e-12
DN T	VY	145.000	2190.040518	2190.040518	-1.0900e-10
DN T	VY	180.000	-2017.290415	-2017.290415	-1.5500e-10
DN T	VY	230.000	2239.745512	2239.745512	-6.2600e-12
DN T	VY	250.000	-790.397664	-790.397663	-3.5800e-11
DN T	VY	280.000	2258.782745	2258.782745	1.0400e-10

GROUP_MA	Urgent	Force	Force Reference	Force Code_Aster	Error
DL TR	N	30.000	1635.707253	1635.707253	-8.4900e-11
DL TR	N	90.000	-1635.707253	-1635.707253	-8.4900e-11
DL TR	N	145.000	1525.492881	1525.492881	-1.8200e-10
DL TR	N	180.000	-1249.231871	-1249.231871	1.4500e-11
DL TR	N	230.000	1699.177353	1699.177353	-1.6000e-10
DL TR	N	250.000	-415.381013	-415.381013	-1.1200e-10
DL TR	N	280.000	1789.595108	1789.595108	-4.9600e-11
DL TR	VY	30.000	2224.098875	2224.098875	-4.9400e-12
DL TR	VY	90.000	-2224.098875	-2224.098875	-4.9400e-12

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

DL TR	VY	145.000	2190.040518	2190.040518	-1.0900e-10
DL TR	VY	180.000	-2017.290415	-2017.290415	-1.5500e-10
DL TR	VY	230.000	2239.745512	2239.745512	-6.2600e-12
DL TR	VY	250.000	-790.397664	-790.397663	-3.5800e-11
DL TR	VY	280.000	2258.782745	2258.782745	1.0400e-10
DL TR	MFZ	30.000	3773.863680	3773.863680	4.0200e-11
DL TR	MFZ	90.000	-3773.863680	-3773.863680	4.0200e-11
DL TR	MFZ	145.000	3686.099695	3686.099695	-2.8500e-11
DL TR	MFZ	180.000	-3236.583886	-3236.583886	1.3700e-10
DL TR	MFZ	230.000	3810.233618	3810.233618	6.2600e-11
DL TR	MFZ	250.000	-1262.367026	-1262.367026	5.6200e-11
DL TR	MFZ	280.000	3849.201624	3849.201624	-1.8600e-12

GROUP_MA	Urgent	Force	Force Reference	Force Code Aster	Error
DL T	N	30.000	1635.707253	1635.707253	-8.4900e-11
DL T	N	90.000	-1635.707253	-1635.707253	-8.4900e-11
DL T	N	145.000	1525.492881	1525.492881	-1.8200e-10
DL T	N	180.000	-1249.231871	-1249.231871	1.4500e-11
DL T	N	230.000	1699.177353	1699.177353	-1.6000e-10
DL T	N	250.000	-415.381013	-415.381013	-1.1200e-10
DL T	N	280.000	1789.595108	1789.595108	-4.9600e-11
DL T	VY	30.000	2224.098875	2224.098875	-4.9400e-12
DL T	VY	90.000	-2224.098875	-2224.098875	-4.9400e-12
DL T	VY	145.000	2190.040518	2190.040518	-1.0900e-10
DL T	VY	180.000	-2017.290415	-2017.290415	-1.5500e-10
DL T	VY	230.000	2239.745512	2239.745512	-6.2600e-12
DL T	VY	250.000	-790.397664	-790.397663	-3.5800e-11
DL T	VY	280.000	2258.782745	2258.782745	1.0400e-10

GROUP_MA	Direction	Energy Reference	Energy Code Aster	Error
DN TR	DX	12.862800	12.862836	2.8000 10 <sup>-6</sup>
DN TR	DY	49.538500	49.538536	7.3200e-07
DN TR	RZ	84.921900	84.921949	5.8100e-07
DN T	DX	12.862800	12.862836	2.8000 10 <sup>-6</sup>
DN T	DY	49.538500	49.538536	7.3200e-07
DL TR	DX	12.862800	12.862836	2.8000 10 <sup>-6</sup>
DL TR	DY	49.538500	49.538536	7.3200e-07
DL TR	RZ	84.921900	84.921949	5.8100e-07
DL T	DX	12.862800	12.862836	2.8000 10 <sup>-6</sup>
DL T	DY	49.538500	49.538536	7.3200e-07

## 5 Summary of the results

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These tests make it possible to check the correct operation of the discrete elements 2D and 3D with the behavior `DIS_ECRO_CINE` and the use of `STAT_NON_LINE`.