

SSND101 – Law of behavior for viscous shock absorbers on discrete elements

Summary:

One tests the answer of the model of behavior of viscous shock absorber nonlinear `DIS_VISC`, of type "Generalized Zener", cf. [R5.03.17], formulated on discrete elements for meshes `SEG2` or `POI1`.

Although it is about a viscous law, it is the operator `STAT_NON_LINE` who is employed for the validation. One analyzes the answer of discrete elements supporting a law of nonlinear behavior viscous under a harmonic loading. Modelings are the following ones:

- A) statics into cyclic nonlinear,
- B) statics into cyclic linear and calculation of dissipation,
- C) nonlinear statics in creep,
- D) non-linear statics, by modelling a shock absorber of the type `MAXWELL`.

Modelings and discrete elements tested are in `3D` with modelings `DIS_T` and `DIS_TR` and them elementary characteristics: (`K_T_D_L`, `K_TR_D_L`, `K_T_D_N`, `K_TR_D_N`, `A_T_D_L`, `M_T_D_L`), according to the type of mesh and element.

This behavior is also validated for dynamic stresses in the CAS-test `SDND107` [V5.01.107] with the operators `DYNA_VIBRA`, `DYNA_TRAN_MODAL` and `DYNA_NON_LINE`.

1 Problem of reference

1.1 Description of the device

The viscous shock absorber is represented by the rheological model below.

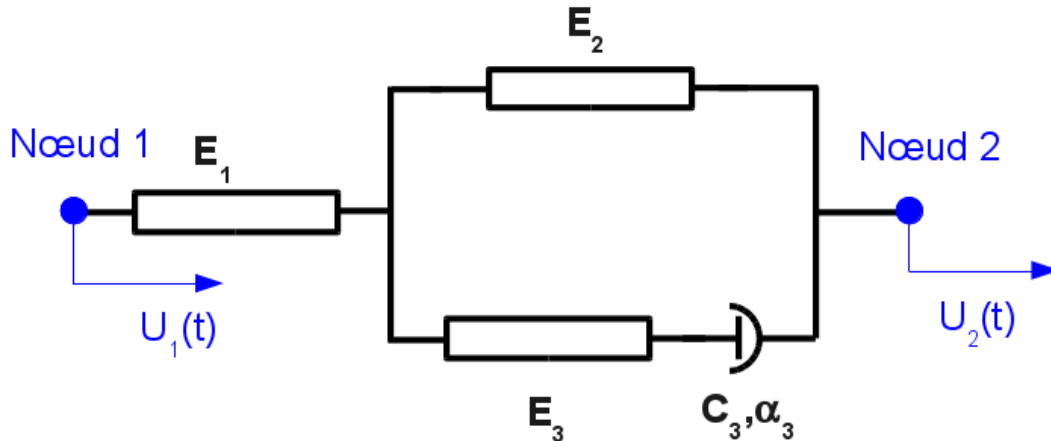


Figure 1.1-a : Rheological model of the viscous shock absorber.

Values of the various stiffnesses E_1 , E_2 , E_3 and characteristics of the nonlinear viscous part C_3 , α_3 are resulting from tests. The equations governing the behavior are [R5.03.17]:

$$\dot{F}_1 \left(\frac{1}{E_1} + \frac{1}{E_3} + \frac{E_2}{(E_1 \cdot E_3)} \right) = (\dot{U}_2 - \dot{U}_1) \left(1 + \frac{E_2}{E_3} \right) - \left\langle \left\langle \frac{F_1}{C_3} \left(1 + \frac{E_2}{E_1} \right) - \frac{E_2}{C_3} (U_2 - U_1) \right\rangle \right\rangle^{1/\alpha_3}$$

$$\text{with } \langle \langle x \rangle \rangle^a = x^a \quad \text{si } x \geq 0$$

$$\langle \langle x \rangle \rangle^a = -|x|^a \quad \text{si } x \leq 0$$

The increment of dissipation is:

$$\Delta D = C_3 \cdot \left| \frac{F_1}{C_3} \left(1 + \frac{E_2}{E_1} \right) - \frac{E_2}{C_3} (U_2 - U_1) \right|^{1+1/\alpha_3}$$

1.2 Modelings

Modelings tested are it on elements DIS_T then DIS_TR, meshes SEG2 then meshes POI1. The characteristics of stiffness of the discrete elements, which are useful for the prediction of the nonlinear algorithm, are thus of the type: K_T_D_L, K_TR_D_L, K_T_D_N, K_TR_D_N, according to the type of element.

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

1.2.1 Modeling A

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

1.2.2 Modeling B

This modeling in nonlinear statics makes it possible to test, besides the law of behavior, dissipation during a stabilized cyclic loading. Dissipation is compared with a theoretical value obtained in the

typical case $\alpha_3=1.0$. For a cyclic loading with $\alpha_3 \neq 1$ the theoretical calculation of dissipation is not accessible.

1.2.3 Modeling C

This nonlinear static modeling makes it possible to test the law of behaviour during a test of type creep. Displacement is imposed and remains constant. The answer of the law of behavior as well as dissipation are compared with the theoretical values obtained in the typical case $\alpha_3=0.5$.

1.2.4 Modeling D

This modeling validates the fact that it is possible to model a shock absorber of the type Maxwell by affecting characteristic materials adapted. It is possible to make tighten the stiffnesses towards the infinite one by using the words key `UNSUR_K` at the time of the definition of material. In this typical case $K1=120.0$, $K2=0$, $K3 \rightarrow \infty$ that is to say `UNSUR_K3=0` . The modelled shock absorber is represented with the following figure.

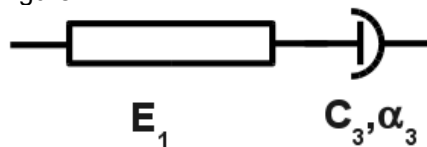


Figure 1.2.4-a : Shock absorber of the type Maxwell.

Note: One can also choose to model this shock absorber the following values $K2=0$, $K3=120.0$, $K1 \rightarrow \infty$ that is to say `UNSUR_K1=0.0` .

1.3 Properties materials

1.3.1 Modeling A

$K1=120.0$, $K2=10.0$, $K3=60.0$, $C=1.7$, `PUIS_ALPHA=0.8`

1.3.2 Modeling B

$K1=120.0$, $K2=10.0$, $K3=60.0$, $C=1.7$, `PUIS_ALPHA=1.0`

1.3.3 Modeling C

$K1=120.0$, $K2=10.0$, $K3=60.0$, $C=1.7$, `PUIS_ALPHA=0.5`

1.3.4 Modeling D

$K1=120.0$, $K2=0.0$, `UNSUR_K3=0.0` , $C=1.7$, `PUIS_ALPHA=0.50`

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 for modelings A, B and D:

$$U_0 \cdot \sin(2\pi \cdot f \cdot t) \text{ with } f=5 \text{ Hz}$$

In modeling C, displacement is imposed and remains constant: $U_0=0.1$

2 Reference solutions

2.1 Method of calculating used for the reference solutions

2.1.1 Modeling A

The equations governing the behavior are nonlinear differential equations. To validate the answer obtained with *Code_Aster* in nonlinear statics an integration by a method of Runge-Kutta is carried out with a tool external with *Code_Aster*.

The comparison is carried out on displacement and the effort, for the 4 types of discrete elements.

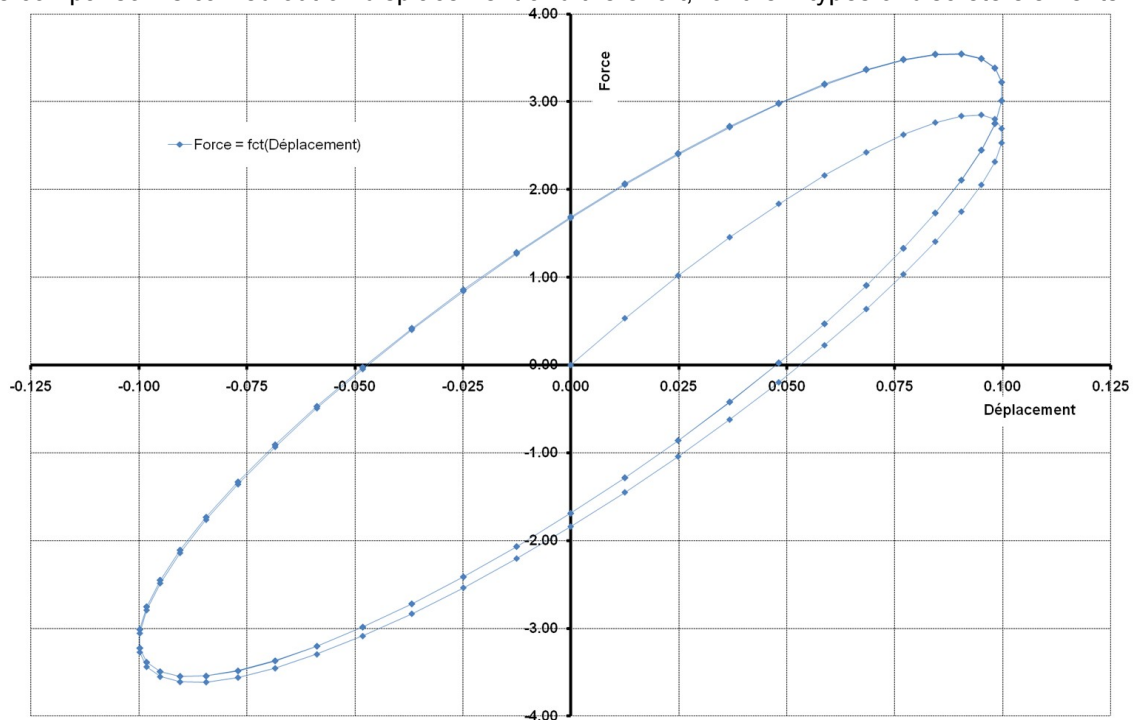


Figure 2.1.1-a : Curve Forces displacement, modeling A.

The answer given by *Code_Aster* is testée for the following values:

| Moment | Displacement U_x | Force F_x |
|----------|--------------------|------------------|
| 2,00E-02 | 5,877852523E-02 | 2,187710580E+00 |
| 4,00E-02 | 9,510565163E-02 | 2,829192223E+00 |
| 6,00E-02 | 9,510565163E-02 | 2,035749590E+00 |
| 8,00E-02 | 5,877852523E-02 | 2,402408962E-01 |
| 1,00E-01 | -1,653950414E-16 | -1,851221553E+00 |
| 1,32E-01 | -8,443279255E-02 | -3,445042947E+00 |
| 2,00E-01 | 4,196133458E-16 | 1,745702939E+00 |
| 2,32E-01 | 8,443279255E-02 | 3,409095131E+00 |
| 2,68E-01 | 8,443279255E-02 | 1,626471785E+00 |
| 3,16E-01 | -4,817536741E-02 | -2,962435650E+00 |
| 3,56E-01 | -9,822872507E-02 | -2,590008311E+00 |
| 4,12E-01 | 3,681245527E-02 | 2,724835444E+00 |
| 4,36E-01 | 9,048270525E-02 | 3,394150679E+00 |
| 5,20E-01 | -5,877852523E-02 | -3,151025904E+00 |
| 6,24E-01 | 6,845471059E-02 | 3,289283317E+00 |
| 7,16E-01 | -4,817536741E-02 | -2,962278876E+00 |
| 8,00E-01 | 1,678385621E-15 | 1,750844985E+00 |
| 8,16E-01 | 4,817536741E-02 | 2,962278875E+00 |
| 8,48E-01 | 9,980267284E-02 | 3,047135026E+00 |
| 9,40E-01 | -9,510565163E-02 | -3,326860603E+00 |
| 9,68E-01 | -8,443279255E-02 | -1,627037269E+00 |
| 1,00E+00 | -1,224606354E-16 | 1,750844985E+00 |

Table 2.1.1-a : Displacement and Efforts, modeling A.

2.1.2 Modeling B

This nonlinear static modeling makes it possible to test, besides the law of behavior, dissipation during a stabilized cyclic loading. Dissipation is compared with a theoretical value obtained in the typical case $\alpha_3 = 1.0$.

Note: For a cyclic loading with $\alpha_3 \neq 1$ the theoretical calculation of dissipation is not accessible, except for a stabilized cycle.

The answer given by *Code_Aster* is tested for the following values:

| Moment | Displacement U_x | Force F_x |
|----------|--------------------|------------------|
| 2,00E-02 | 5,877852523E-02 | 2,160195640E+00 |
| 4,00E-02 | 9,510565163E-02 | 2,849834733E+00 |
| 6,00E-02 | 9,510565163E-02 | 2,052734480E+00 |
| 8,00E-02 | 5,877852523E-02 | 2,258915314E-01 |
| 1,00E-01 | -1,653950414E-16 | -1,838798378E+00 |
| 1,32E-01 | -8,443279255E-02 | -3,611426479E+00 |
| 2,00E-01 | 4,195726882E-16 | 1,674446965E+00 |
| 2,32E-01 | 8,443279255E-02 | 3,535539017E+00 |
| 2,68E-01 | 8,443279255E-02 | 1,730277335E+00 |
| 3,16E-01 | -4,817536741E-02 | -2,984761046E+00 |
| 3,56E-01 | -9,822872507E-02 | -2,752278435E+00 |
| 4,12E-01 | 3,681245527E-02 | 2,719185079E+00 |
| 4,36E-01 | 9,048270525E-02 | 3,544941424E+00 |
| 5,20E-01 | -5,877852523E-02 | -3,201565830E+00 |
| 6,24E-01 | 6,845471059E-02 | 3,368686714E+00 |
| 7,16E-01 | -4,817536741E-02 | -2,983942123E+00 |
| 8,00E-01 | 1,678385621E-15 | 1,687931415E+00 |
| 8,16E-01 | 4,817536741E-02 | 2,983942066E+00 |
| 8,48E-01 | 9,980267284E-02 | 3,223403140E+00 |
| 9,40E-01 | -9,510565163E-02 | -3,492301297E+00 |
| 9,68E-01 | -8,443279255E-02 | -1,732887550E+00 |
| 1,00E+00 | -1,224606354E-16 | 1,687931421E+00 |

Table 2.1.2-a : Displacement and Efforts, modeling B.

The calculation of dissipation on a stabilized cycle is obtained by integrating the equations of the system in the typical case where $\alpha_3=1$.

On a stabilized cycle, for $\alpha_3=1$, the value of dissipation is:

$$\Delta D = \frac{\pi \cdot U_0^2 \cdot E_1^2 \cdot E_3^2 \cdot \omega \cdot C_3}{\omega^2 \cdot C_3^2 \cdot (E_1 + E_2 + E_3)^2 + (E_1 + E_2)^2 \cdot E_3^2} \quad [\text{éq 2.1.2-1}]$$

2.1.3 Modeling C

This nonlinear static modeling makes it possible to test the law of behaviour during a test of type creep. Displacement is imposed and remains constant: $U_0=0.1$. The answer of the law of behavior as well as dissipation are compared with the theoretical values obtained in the typical case $\alpha_3=0.5$.

Differential equations integrated in the typical case of U constant and of $\alpha_3=0.5$ the equations of the effort and dissipation according to time give:

$$F(t) = \frac{U_0 \cdot E_1 \cdot (AA_s + BB_s \cdot E_2 \cdot t)}{(E_3 + E_2 + E_1)^2 \cdot C_3^2 + BB_s \cdot (E_2 + E_1) \cdot t} \quad [\text{éq 2.1.3-1}]$$

$$D(t) = \frac{U_0^3 \cdot E_1^3 \cdot E_3^3}{2 \cdot (E_3 + E_2 + E_1)} \cdot t \cdot \frac{(2 \cdot AA_e + BB_e \cdot t)}{(AA_e + BB_e \cdot t)^2} \quad [\text{éq 2.1.3-2}]$$

$$\text{with } \begin{cases} AA_s = (E_3 + E_2) \cdot (E_1 + E_2 + E_3) \cdot C_3^2 \\ BB_s = U_0 \cdot E_1 \cdot E_3^2 \end{cases} \quad \begin{cases} AA_e = (E_3 + E_2 + E_1)^2 \cdot C_3^2 \\ BB_e = U_0 \cdot E_1 \cdot E_3^2 \cdot (E_2 + E_1) \end{cases}$$

2.1.4 Modeling D

The equations governing the behavior are nonlinear differential equations. To validate the answer obtained with *Code_Aster* in nonlinear statics an integration by a method of Runge-Kutta is carried out with an external tool with *Code_Aster*.

The comparison is carried out on displacement and the effort.

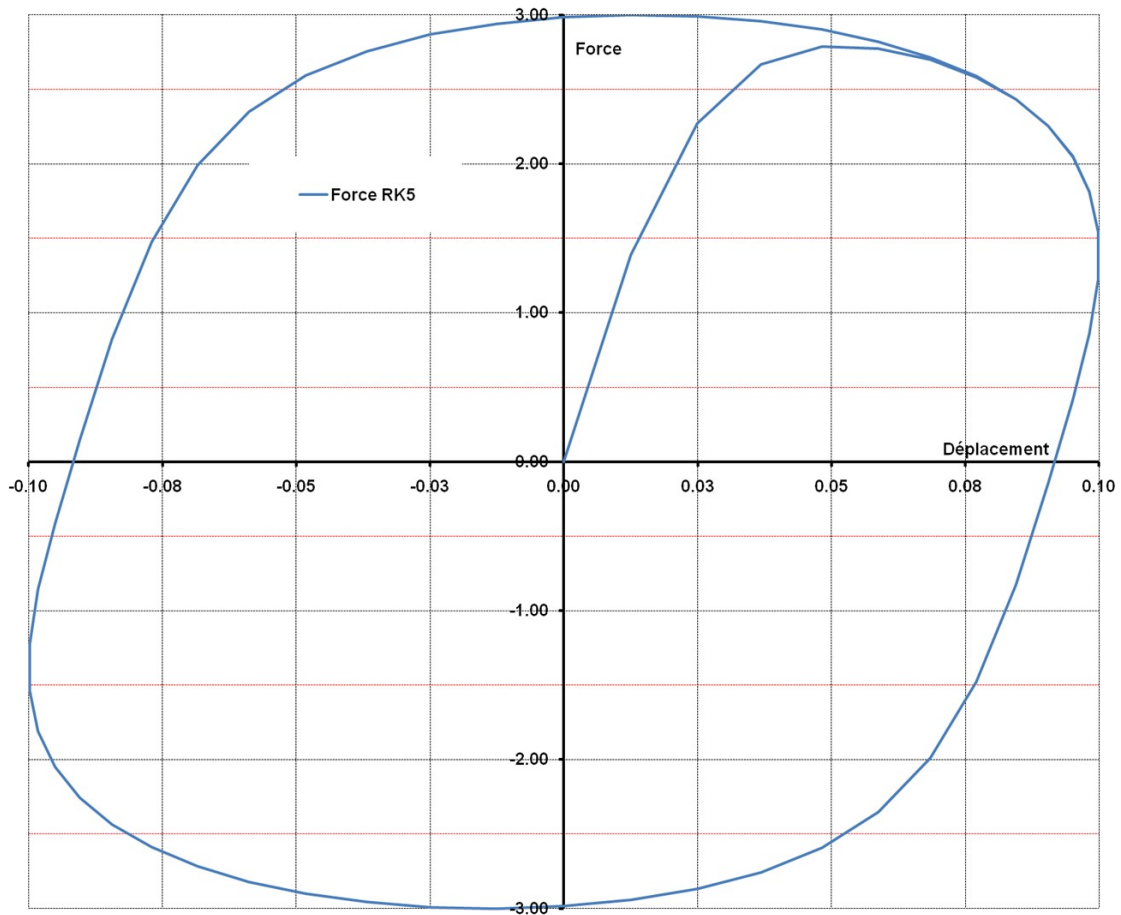


Figure 2.1.4-a : Curve Forces displacement, modeling D.

The answer given by *Code_Aster* is tested for the following values:

| Moment | Displacement U_x | Force F_x |
|-----------|----------------------|----------------------|
| 4.000E-03 | 1.2533323356430E-02 | 1.3901305564654E+00 |
| 4.800E-02 | 9.9802672842827E-02 | 1.5399690347096E+00 |
| 1.000E-01 | -1.6539504141266E-16 | -2.9840799981192E+00 |
| 1.360E-01 | -9.0482705246602E-02 | -2.2555706075403E+00 |
| 2.040E-01 | 1.2533323356431E-02 | 2.9999350282465E+00 |
| 2.480E-01 | 9.9802672842827E-02 | 1.5401915597398E+00 |
| 3.040E-01 | -1.2533323356431E-02 | -2.9999350282852E+00 |
| 3.480E-01 | -9.9802672842827E-02 | -1.5401915597074E+00 |
| 4.040E-01 | 1.2533323356431E-02 | 2.9999350282970E+00 |
| 5.000E-01 | -1.0045133128078E-15 | -2.9840798812719E+00 |
| 5.600E-01 | -9.5105651629515E-02 | -4.1551773591104E-01 |
| 6.000E-01 | 1.3475548801822E-15 | 2.9840798812750E+00 |
| 6.400E-01 | 9.5105651629516E-02 | 2.0490126532863E+00 |
| 7.040E-01 | -1.2533323356432E-02 | -2.9999350283063E+00 |
| 7.480E-01 | -9.9802672842827E-02 | -1.5401915596821E+00 |
| 8.040E-01 | 1.2533323356432E-02 | 2.9999350283073E+00 |
| 8.480E-01 | 9.9802672842827E-02 | 1.5401915596806E+00 |
| 9.040E-01 | -1.2533323356432E-02 | -2.9999350283079E+00 |
| 9.480E-01 | -9.9802672842827E-02 | -1.5401915596795E+00 |
| 1.000E+00 | -1.2240642527361E-16 | 2.9840798812793E+00 |

Table 2.1.4-a : Displacement and Efforts, modeling D.

2.2 Uncertainty on the solution

2.2.1 Modeling A

For the answer in effort, displacement:

The reference solution is obtained by digital integration of a nonlinear differential connection.

2.2.2 Modeling B

For the answer in effort, displacement:

The reference solution is obtained by digital integration of a differential connection, with a method of the Runge-Kutta type of order 5.

For dissipation:

No uncertainty, the solution is analytical.

2.2.3 Modeling C

For the answer in effort, displacement:

No uncertainty, the solution is analytical.

For dissipation:

No uncertainty, the solution is analytical.

2.2.4 Modeling D

For the answer in effort, displacement:

The reference solution is obtained by digital integration of a differential connection.

3 Modeling A

3.1 Characteristics of modeling

Modelings tested are `DIS_T` and `DIS_TR` on meshes 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 meshes: 4, elements `SEG2` : 2, elements `POI1` : 2.

3.3 Boundary conditions and loadings

The condition in displacement is a function of time:

$$U_0 \cdot \sin(2\pi \cdot f \cdot t) \text{ with } f = 5 \text{ Hz} ; U_0 = 0.1 \text{ m}$$

3.4 Discretization in time

The step of time and the time interval of analysis are:

$$\Delta t = 4,010^{-3} \text{ s and } t \in [0 \text{ s}, 1 \text{ s}]$$

3.5 Sizes tested and results

The sizes tested are displacement, and the efforts. The values are those presented to the table 2.1.1-a.

The tolerances are those by default.

4 Modeling B

4.1 Characteristics of modeling

Modelings tested are DIS_T and DIS_TR on meshes 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.

4.2 Characteristics of the grid

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

4.3 Boundary conditions and loadings

The condition in displacement is a function of time:

$$U_0 \cdot \sin(2\pi \cdot f \cdot t) \text{ with } f = 5 \text{ Hz}; U_0 = 0.1 \text{ m}$$

4.4 Discretization in time

The step of time and the time interval of analysis are:

$$\Delta t = 4,0 \cdot 10^{-3} \text{ s and } t \in [0 \text{ s}, 1 \text{ s}]$$

4.5 Sizes tested and results

The sizes tested are:

- displacement, and efforts. The values are those presented to the table 2.1.2-a.
- dissipation on a stabilized cycle, is given by the equation 2.1.2-1.

After digital application, dissipation on a stabilized cycle is:

$$D_{cycle} = 0.53097854397953936 \text{ J}$$

The cycle considered for the calculation of dissipation is the last of simulation, between the moments $(1.0 - 1.0/f) \text{ sec}$ and 1.0 sec . Actually this cycle is not completely stabilized, but for reasons of time CPU, one will consider it stabilized. That involves a light difference between the theoretical value and the computed value.

| | Value Reference | Precision | Computed value |
|-------------|---------------------|-----------|----------------|
| Dissipation | 0.53097854397953936 | 3,00E-003 | 0.5295830097 |

5 Modeling C

5.1 Characteristics of modeling

Modeling tested is DIS_T on a mesh SEG2. The characteristic of stiffness of discrete is of the type K_T_D_L.

5.2 Characteristics of the grid

Many nodes: 2, many meshes: 1, Elements SEG2 : 1.

5.3 Boundary conditions and loadings

The condition in displacement is imposed on $U_0=0.1 m$.

5.4 Discretization in time

The step of time and the time interval of analysis are:

$$\Delta t = 4,0 \cdot 10^{-3} \text{ s and } t \in [0 \text{ s}, 1 \text{ s}]$$

5.5 Sizes tested and results

The sizes tested are the effort and dissipation for a one duration loading of 1 sec. Equations 2.1.3-1 and 2.1.3-2 are evaluated in the case tests. The tolerances are those by default.

| Moment | Force | Dissipation |
|--------|-----------------|-----------------|
| 0,080 | 1,582279190E+00 | 1,686873697E-01 |
| 0,120 | 1,392001789E+00 | 1,717556743E-01 |
| 0,200 | 1,220373612E+00 | 1,736354073E-01 |
| 0,280 | 1,140716683E+00 | 1,742217215E-01 |
| 0,400 | 1,078322512E+00 | 1,745542834E-01 |
| 0,600 | 1,028128094E+00 | 1,747410406E-01 |
| 0,680 | 1,016097791E+00 | 1,747751013E-01 |
| 1,000 | 9,868740067E-01 | 1,748406080E-01 |

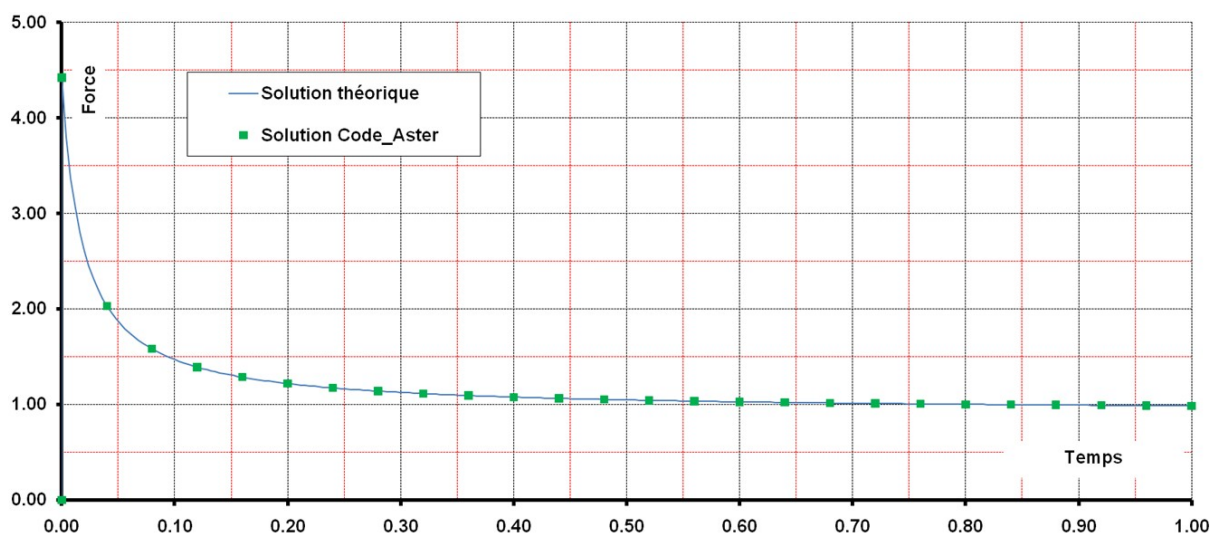


Figure 5.5-a : Curves of creep theoretical and calculated by Code_Aster.

6 Modeling D

6.1 Characteristics of modeling

Modeling tested is DIS_T on a mesh SEG2. The characteristic of stiffness of discrete is of the type K_T_D_L.

6.2 Characteristics of the grid

Many nodes: 2, many meshes: 1, elements SEG2 : 1.

6.3 Boundary conditions and loadings

The condition in displacement is a function of time:

$$U_0 \cdot \sin(2\pi \cdot f \cdot t) \text{ with } f = 5 \text{ Hz}; U_0 = 0.1 \text{ m}$$

The step of time and the time interval of analysis are:

$$\Delta t = 4,0 \cdot 10^{-3} \text{ s and } t \in [0 \text{ s}, 5 \text{ s}]$$

6.4 Sizes tested and results

The sizes tested are displacement, and the efforts. The values are those presented to the table 2.1.1-a.

The tolerances are those by default.

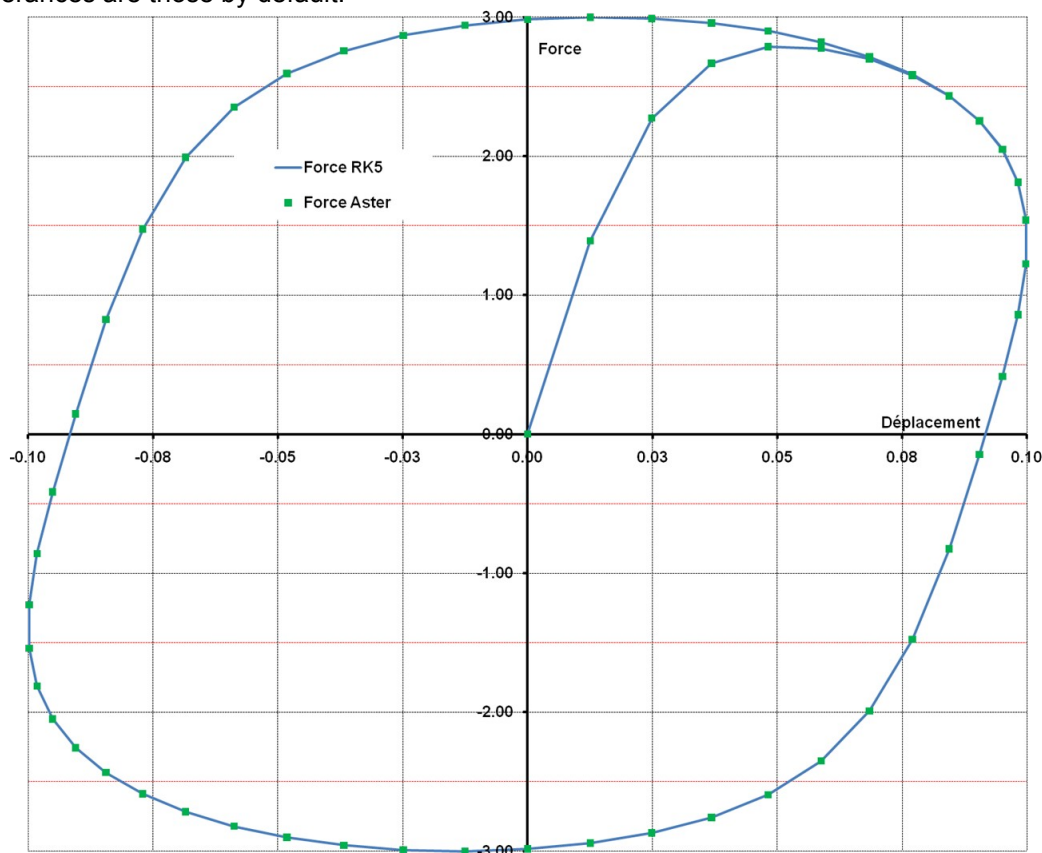


Figure 6.4-a : Answer Force-displacement, calculated by a method RK5 and by Code_Aster.

7 Summary of the results

These tests make it possible to check the good performance of the discrete elements 2D and 3D with the behavior `DIS_VISC` within the framework of a use with the order `STAT_NON_LINE`.