

## SDND107 - To release and seismic excitation of a system with nonlinear viscous shock absorber of type "Zener"

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### 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].

The goal is to validate the viscous law in linear and non-linear dynamics. The following tests are carried out:

- A) in linear dynamics (operator `DYNA_NON_LINE`) in a case to release, by using an assembly of elements discrete linear as comparison for the law of behavior bases "Generalized Zener".
- B) in non-linear dynamics (operator `DYNA_NON_LINE`) with acceleration of a sinusoidal type then a zero acceleration.
- C) in transitory non-linear dynamics (operator `DYNA_VIBRA` or `DYNA_TRAN_MODAL` with a diagram in times of the type Euler) with acceleration of a sinusoidal type then a zero acceleration. It is the same study that B. the continuation is also validated.
- D, E) in transitory non-linear dynamics (operator `DYNA_VIBRA` or `DYNA_TRAN_MODAL` with two diagrams in times of the Runge-Kutta type of order 5 and order 3, to adaptive step) with acceleration of a sinusoidal type then a zero acceleration. It is the same study that B. the continuation is also validated.

This behavior is also validated with the order `STAT_NON_LINE` in `SSND101` [V6.08.101].

## 1 Problem of reference

### 1.1 Description of the device

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

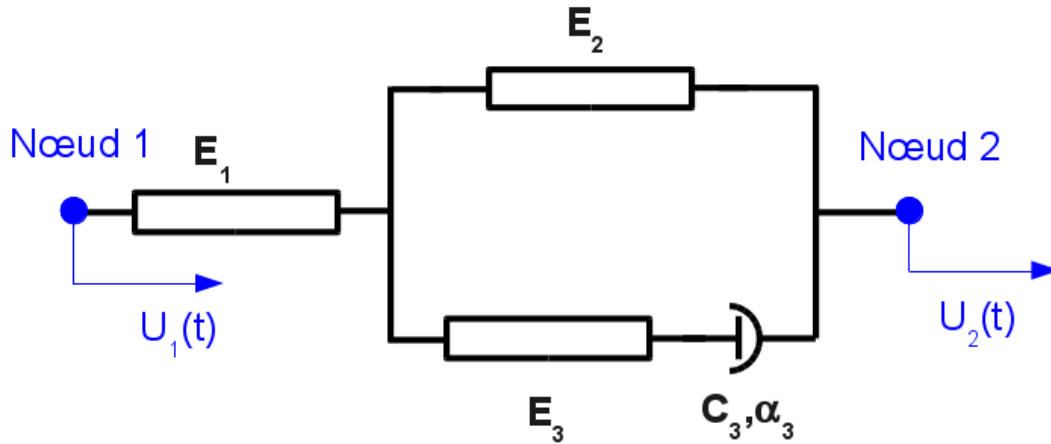


Figure 1.1-a : Rheological model of the viscous shock absorber.

Values of the various stiffnesses  $E_1$ ,  $E_2$ ,  $E_3$  and characteristics of the nonlinear viscous part  $C_3$ ,  $\alpha_3$  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

*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 compares a system of discrete (stiffnesses and linear shock absorber) assembled in series and parallel with discrete affected of the law of behavior DIS\_VISC, with  $\alpha_3=1$ , and a specific mass  $m=1.0kg$ . This comparison is carried out in transitory linear dynamics by simulating a test to release.

#### 1.2.2 Modelings B, C, D, E

This modeling is carried out in non-linear dynamics and simulates the loading due to an earthquake. Acceleration is sinusoidal for 4 periods, then a zero acceleration. The order CALC\_CHAR\_SEISME allows to define the request.

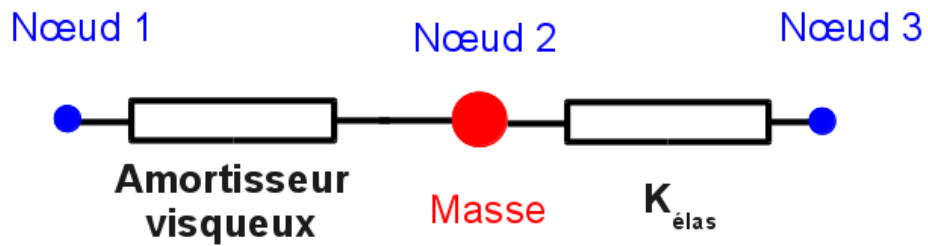


Figure 1.2.2-a : Modelled system.

Modeling B is carried out with the operator `DYNA_NON_LINE`. Modelings C, D, E are carried out with the operator `DYNA_VIBRA` (`TYPE_CALCUL='TRAN'`, `BASE_CALCUL='GENE'`) equivalent with the order `DYNA_TRAN_MODAL`, with respectively a diagram in times of the type Euler, Runge-Kutta of order 5 and Runge-Kutta of order 3.

## 1.3 Properties materials

### 1.3.1 Modeling A

The characteristics of the shock absorber are:

$$K1=120.0 \quad , \quad K2=10.0 \quad , \quad K3=60.0 \quad , \quad C=1.7 \quad , \quad PUIS\_ALPHA=1.0$$

The value of the mass is  $m=1.0\text{kg}$ .

### 1.3.2 Modeling B

The characteristics of the shock absorber are:

$$K1=120.0 \quad , \quad K2=10.0 \quad , \quad K3=60.0 \quad , \quad C=1.7 \quad , \quad PUIS\_ALPHA=0.50$$

The stiffness of the elastic spring is  $k=1.0\text{N.m}^{-1}$ , the mass is  $m=1.0\text{kg}$ .

### 1.3.3 Modeling C, D, E

The characteristics of the shock absorber are given under the key word `DIS_VISC` order `DYNA_VIBRA` or `DYNA_TRAN_MODAL`.

$$K1=120.0 \quad , \quad K2=10.0 \quad , \quad K3=60.0 \quad , \quad C=1.7 \quad , \quad PUIS\_ALPHA=0.50$$

The stiffness of the elastic spring is  $k=1.0\text{N.m}^{-1}$ , the mass is  $m=1.0\text{kg}$ .

## 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.

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

The condition in displacement is a function of time for modelings B, C, D and E:

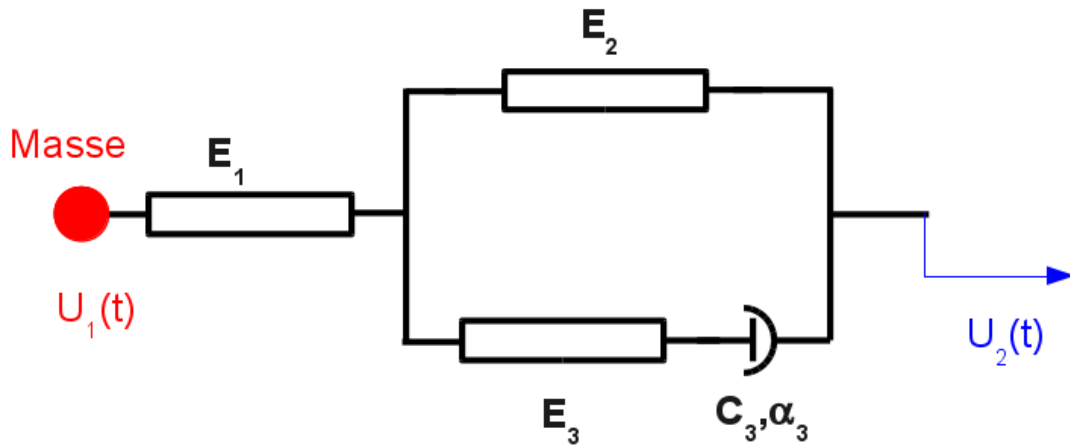
$$U_0 \cdot \sin(2\pi \cdot f \cdot t) \quad \text{with } f=5\text{Hz} \quad \text{for 4 periods, then } 0.$$

## 2 Reference solutions

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

#### 2.1.1 Modeling A

This modeling compares a system of discrete (stiffnesses and linear shock absorber, therefore  $\alpha_3=1$ ) assembled in series and discrete affected of the law of behavior `DIS_VISC`. This comparison is carried out in linear transitory dynamics by simulating a test to release.



The equations of the differential connection, which is of order 3, describing the analytical solution are:

$$\begin{cases} F_1 = m \ddot{U}_1 \\ \dot{F}_1 \cdot \left( \frac{1}{E_1} + \frac{1}{E_3} + \frac{E_2}{E_1 \cdot E_3} \right) = (\dot{U}_2 - \dot{U}_1) \left( 1 + \frac{E_2}{E_3} \right) - \frac{1}{C_3} \cdot \left( F_1 \cdot \left( 1 + \frac{E_2}{E_1} \right) - E_2 \cdot (U_2 - U_1) \right) \end{cases} \quad [\text{éq 2.1.1-1}]$$

The initial conditions are, with  $U_0 = 0,1 m$  :

$$\begin{aligned} \ddot{U}_1(t=0) &= 0 & \dot{U}_1(t=0) &= 0 & U_1(t=0) &= 0 \\ U_2(t) &= U_0 \cdot H(t) & \text{avec } H & \text{ la fonction de Heaviside} \end{aligned}$$

The digital integration of this differential connection, is obtained with the technique of the transforms of Laplace:

$$U_1(t) = A_s \exp(-\lambda_{sc} t) \sin(\omega_t t) - A_c \exp(-\lambda_{sc} t) \cos(\omega_t t) + A_e \exp(-\lambda_e t) + \frac{1}{10} \quad [\text{éq 2.1.1-2}]$$

$$F_1(t) = -B_s \exp(-\lambda_{sc} t) \sin(\omega_t t) + B_c \exp(-\lambda_{sc} t) \cos(\omega_t t) + B_e \exp(-\lambda_e t) \quad [\text{éq 2.1.1-3}]$$

With

$$\begin{aligned} \omega_t &= \frac{14593}{4792} \text{ s}^{-1} \\ A_s &= \frac{5516}{214807} & \lambda_{sc} &= \frac{1573}{2072} \text{ s}^{-1} & B_s &= \frac{5625}{7831} \\ A_c &= \frac{3137}{29305} & & & B_c &= \frac{9170}{11289} \\ A_e &= \frac{413}{58610} & \lambda_e &= \frac{38132}{1685} \text{ s}^{-1} & B_e &= \frac{12692}{3517} \end{aligned}$$

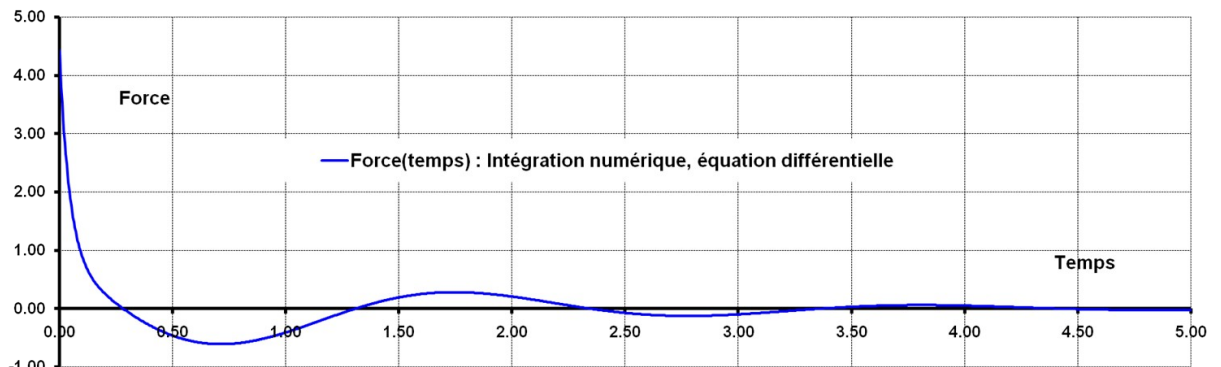


Figure 2.1.1-a : Evolution of the effort according to time, modeling A.

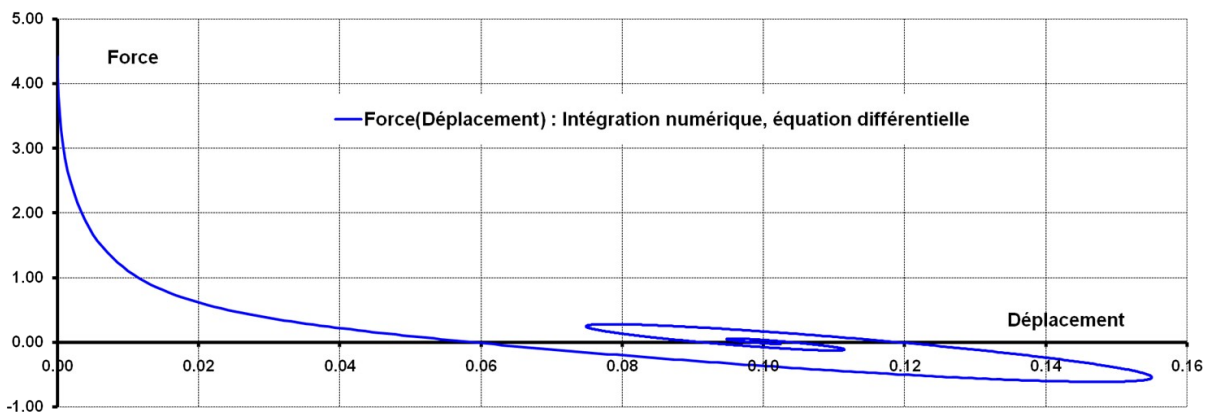


Figure 2.1.1-b : Evolution of the effort according to displacement  $U_1$ , modeling A.

## 2.1.2 Modelings B, C, D, E

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

The comparisons are carried out on displacement and the effort.

## 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 differential connection, with the technique of the transforms of Laplace. There is no uncertainty, the solution is analytical.

### 2.2.2 Modelings B, C, D, E

*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

Modeling tested is DIS\_T on meshes SEG2. The characteristics of stiffness of discrete are of the type K\_T\_D\_L.

### 3.2 Characteristics of the grid

Many nodes: 6, many meshes: 5, elements SEG2 : 2.

### 3.3 Boundary conditions and loadings

The test models a test to release, the condition in displacement is imposed on  $U_0=0.1m$ .

### 3.4 Discretization in time

The step of time, within the framework of the diagram of Newmark of average acceleration, and the time interval of analysis are:

$$\Delta t = 4,010^{-3} \text{ s and } t \in [0 \text{ s}, 5 \text{ s}]$$

### 3.5 Sizes tested and results

The sizes tested are the displacement of the mass and the effort of recall of the mass. The expressions of the solutions are given by the equations 2.1.1-2 and 2.1.1-3.

The tests are carried out on the extremum of the sizes. The tolerances are those by default.

Moment	Displacement	Force
0.71200	0.14743848131052892	-0.61203598667620518
0.87600	0.15500886072840997	-0.54027070148989931
1.74400	0.07830664477251346	0.27967212825227283
1.90400	0.07486355560127801	0.24824092018131852
2.77600	0.10992022804400776	-0.12779697017453923
2.93600	0.11148618864103731	-0.11337010953074489
3.80800	0.09546355597615262	0.05839710629684153
3.96800	0.09475135206710744	0.05177536407974284
4.84000	0.10207447608212881	-0.02668464914494027

## 4 Modelings B, C, D, E

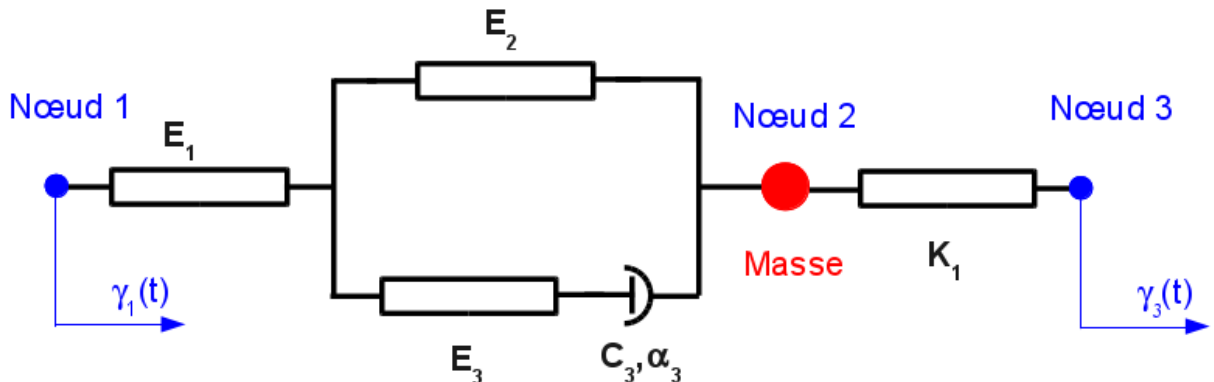
### 4.1 Boundary conditions and loadings

The condition in acceleration is a function of time:

$$A_0 \cdot \sin(2\pi \cdot f \cdot t) \text{ with } f=5 \text{ Hz}; A_0=1.0 \text{ m/s}^2 \text{ for 4 periods is } t \in [0, 0.8\text{sec}]$$

then

$$0 \text{ for } t \in [0.8\text{sec}, 3.2\text{sec}]$$



In the order `DYNA_NON_LINE` the diagram in time is: for modeling B of the type `NEWMARK` (average acceleration).

In the order `DYNA_VIBRA` the diagram in time is: for modeling C of the type `EULER`, for modeling D of the type `RK54`, for modeling E of the type `RK32`.

### 4.2 Sizes tested and results

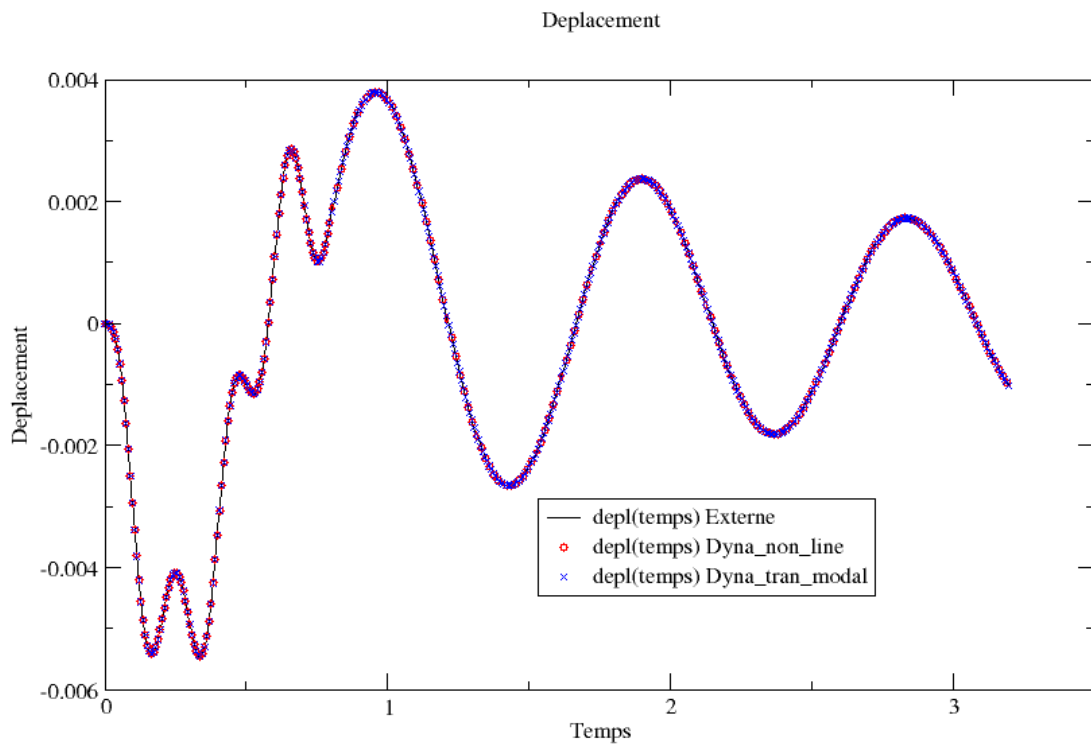
The sizes tested are displacement and the efforts.

The functions displacement and force are extracted from the results and are withdrawn from the functions displacement and force obtained by a method of integration of the external problem with *Code\_Aster*. These new functions are normalized by the maximum value either of displacements or of the efforts. The size tested is the maximum change.

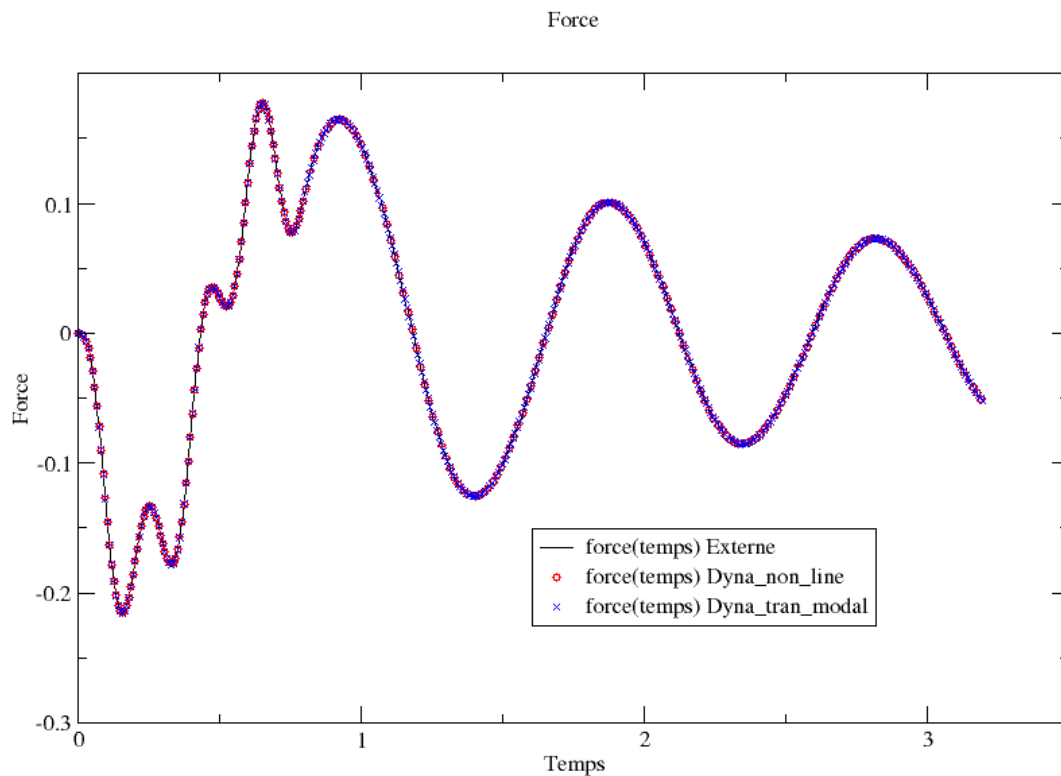
What gives for displacement:

$$\text{Grandeur testée} = \frac{\text{Max}[Depl_{Externe}(Temps)] - Depl_{Code\_Aster}(Temps)}{\text{Max}[Depl_{Externe}(Temps)]}$$

The tolerances are those by default.

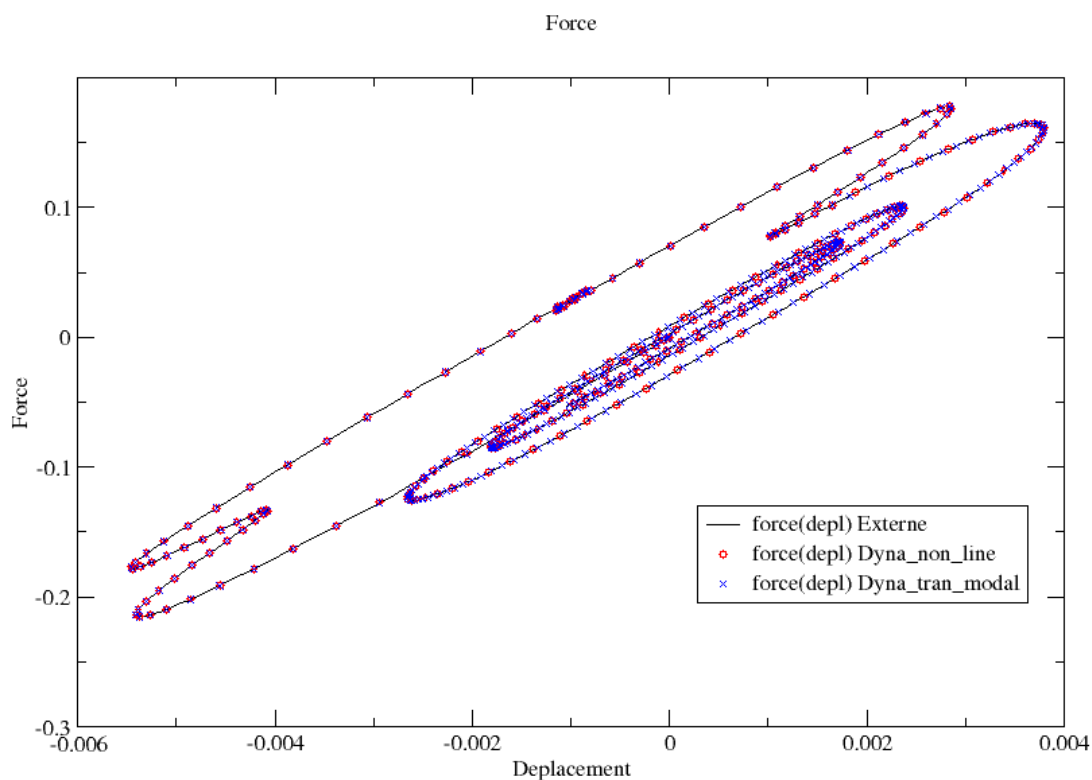


**Figure 4.2-a : Answers (displacement according to time) calculated by an external method and by Code\_Aster with the commandes `DYNA_NON_LINE` and `DYNA_VIBRA`.**



**Figure 4.2-b : Answers (force according to time), calculated by an external method and by Code\_Aster frontEC orders `DYNA_NON_LINE` and `DYNA_VIBRA`.**





**Figure 4.2-c : Answers (Force according to displacement), calculated by an external method and by Code\_Aster with S orders `DYNA_NON_LINE` and `DYNA_VIBRA`.**

## 5 Summary of the results

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Modelings A and B check the good performance of the discrete elements with the order DYNANONLINE.

Modelings C, D, E check the good performance of the law DIS\_VISC with the orders DYNAVIBRA / DYNATRAN\_MODAL.

In the order DYNANONLINE the diagram in time is (modélisation B) : NEWMARK (average acceleration).