SDND102 - Seismic answer of a system mass-arises nonlinear multimedia

Summary

The problem consists in analyzing the answer of a mechanical structure, modelled by two systems masses - arises not deadened, subjected to a seismic loading of harmonic type, with possibility of shock.

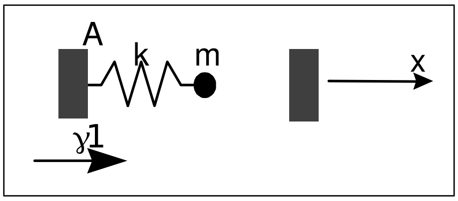
One tests the discrete element in traction and compression, the calculation of the clean modes and the static modes, the calculation of the transitory answer by nonlinear modal recombination of a structure subjected to a accélérogramme (modeling A) as well as calculation of the direct transitory seismic answer of a nonlinear structure (modeling B).
CE case test is also used to validate a calculation with explicit resolution on accelerations and shock (modelings C and D) by comparing the results respectively resulting from DYNA_NON_LINE with an implicit diagram of time, then clarifies nondissipative centered differences and, finally, clarifies dissipative TCHAMWA.

The got results are in very good agreement with the results of reference.

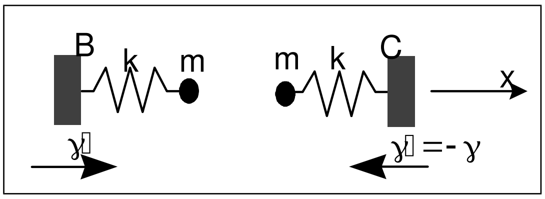
1 Problem of reference

1.1 Geometry

One compares the seismic answer of a system mass-arises with a degree of freedom which can impact a fixed wall (problem 1) with that of two systems mass-arises identical being able to clink and subjected to the same seismic request (problem 2).



Problem 1



Problem 2

1.2 Material properties

Stiffness of the springs: $k=98696\,N/m$.
Specific mass: $m=25\,kg$.

For problem 1 (impact on a rigid wall), the normal rigidity of shock is worth $K_{choc}=5{,}76\,10^{7}\,N/m$. As for problem 2 (shock of two deformable structures), it is worth $K_{choc}=2{,}88\,10^{7}\,N/m$.
In both cases, the damping of shock is null.

1.3 Boundary conditions and loadings

Boundary conditions

Only authorized displacements are the translations according to the axis x .
Points A , B and C are embedded: $dx=dy=dz=0$.

Loading

Points of anchoring A and B are subjected to an acceleration according to the direction x : $\gamma_1(t)=\sin\omega t$ with $\omega=20.\pi\,s^{-1}$ and the point C with an acceleration $\gamma_2(t)=-\sin\omega t$.

1.4 Initial conditions

In both cases, the systems mass-arises are initially at rest:
with $t=0$, $dx(0)=0$, $dx/dt(0)=0$ in any point.
For problem 1, the mass is separated from the fixed wall of the game $j=5.\,10^{-4}\,m$. As for problem 2, the masses are separated from the game $J=2\,j=10^{-3}\,m$.

2 Reference solution

2.1 Method of calculating used for the reference solution

It is a question of comparing the answer of a symmetrical system consisted two systems mass-arises identical to the answer of a system mass-arises. The two problems, exposed in detail in the reference [bib2], are requested by same the accélérogramme.

One calculates the Eigen frequencies initially f_i, associated clean vectors standardized compared to the modal mass Φ_{Ni} and static modes Ψ system (analytical values). One calculates then the generalized answer of the system multimedia by solving analytically the integral of Duhamel [bib1]. Lastly, one restores on the physical basis the relative displacement of the nodes of shock what allows us, after having calculated the field of displacements of training, to calculate the field of absolute displacements.

The function is calculated $diff$ defined as being the difference between absolute displacement of the node shocking on a mobile obstacle and that of the node shocking on a fixed obstacle. It is checked that it is quite worthless for various moments.

2.2 Results of reference

Displacements relative and absolute with the nodes of shock.

2.3 Uncertainty on the solution

Comparison between two equivalent modelings.

2.4 Bibliographical references

1) J.S. PRZEMIENIECKI: Structural Theory of matrix analysis New York, Mac Graw - Hill, 1968, p. 351-357.

2) Fe. WAECKEL: Use and validation of the developments carried out to calculate the seismic answer of multimedia structures - HP52/96.002.

3 Modeling A

3.1 Characteristics of modeling

The systems mass-arises are modelled by discrete elements with 3 degrees of freedom `DIS_T`.

Modeling of problem 1:

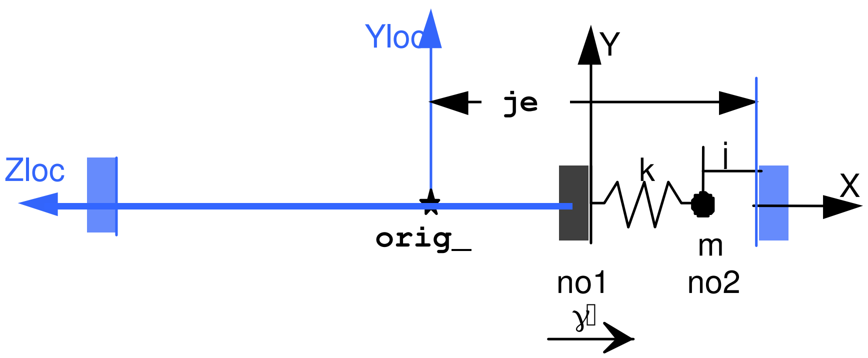


Figure 3.1-a: Modeling of a system mass-arises impacting a rigid wall

The node $no1$ is subjected to an imposed acceleration $\gamma_1(t)$. One calculates the relative displacement of the node $no2$, its displacement of training and its absolute displacement.
An obstacle of the type `PLAN_Z` (two parallel plans) is retained to simulate the impact of the system mass-arises on a rigid wall. The normal with the plan of shock is the axis Z, `NORM_OBST: (0. 0. 1.)`. Not to be constrained by the rebound of the oscillator on the symmetrical level, one pushes back very this one far (cf [Figure 3.1-a]).
From where:

[1] the origin of the obstacle `ORIG_OBST : (- 1. 0. 0.) ;`
[2] and corresponding game `game : 1.1005`

Modeling of problem 2:

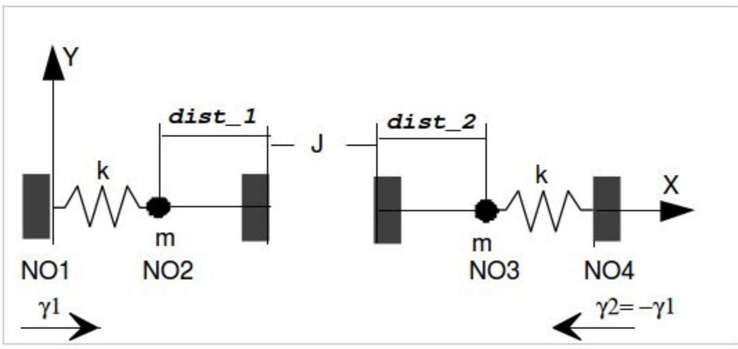


Figure 3.1-b: Modeling of two systems mass-arises which clink

The node $NO1$ is subjected to an imposed acceleration $\gamma_1(t)$, the node $NO4$ with $\gamma_2(t) = -\gamma_1(t)$. One calculates the relative displacement of the nodes $NO2$ and $NO3$, their displacement of training and their absolute displacement.

The conditions of shock between the two systems mass-arises are simulated by an obstacle of the type `BI_PLAN_Z` (obstacle plan between two mobile structures). The normal with the plan of shock is selected according to the axis Z, that is to say `NORM_OBST = (0. 0. 1.)`.
The thicknesses of matter surrounding the nodes of shock in the direction considered are specified by the operands `DIST_1` and `DIST_2`. In the treated case, one chooses `DIST_1` = `DIST_2 = 0.4495` so that at the initial moment, the two nodes of shock are separated from the game $J=2\ j=10^{-3}mm$ (cf [Figure 3.1-b]).

Temporal integration is carried out with the algorithm of Euler and a step of time of $2{,}5.10^{-4s}$. Calculations are filed all 8 pas de time.
A reduced damping is considered ξ from 7% for the whole of the calculated modes.

3.2 Characteristics of the grid

One calls `model` the grid associated with the problem made up of a system mass-arises butting against a fixed wall and `bichoc` that which is associated with problem 2.

Grid associated with the model `model:`

many nodes: 2;
many meshs and types: 1 `DIS_T.`

Grid associated with the model `bichoc:`

many nodes: 4;
many meshs and types: 2 `DIS_T.`

4 Results of modeling A

4.1 Values tested of modeling A

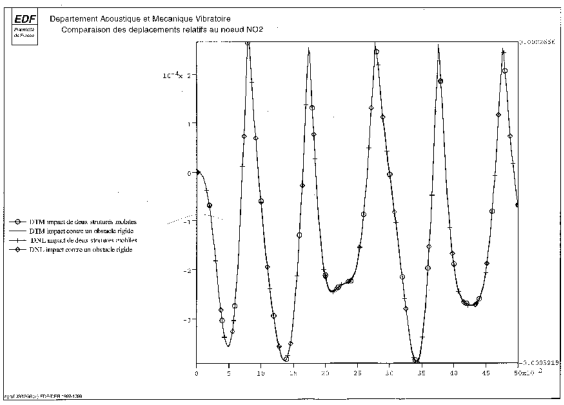
The function is calculated $diff$ defined as being the difference between absolute displacement of the node $NO2$ and that of the node $no2$. And it is checked that it is quite worthless for various moments.

Time (S)	Reference
0.1	0.0
0.3	0.0
0.5	0.0
0.7	0.0
1	0.0

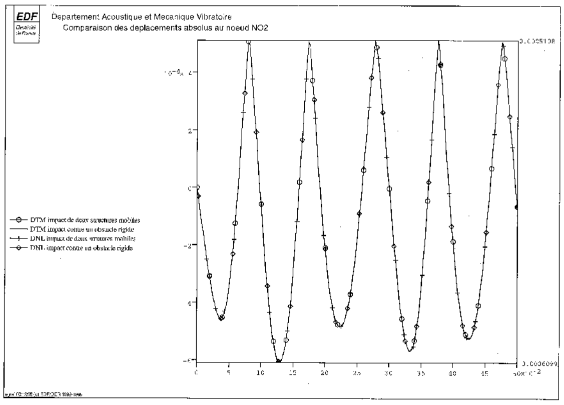
One also tests the value of the absolute displacement of the node $NO2$ for various moments.

Time (S)	Reference (problem 2)
0.05	– 3,58082E-04
0.156	– 1,22321E-04
0.25	– 1,8876E-04
0.4	– 1,89772E-04
0.5	– 6,84454E-05
0.8	– 1,11982E-04
0.9	– 1,20103E-04
1	– 1,07178E-04

One represents Ci below the pace of displacements relative and absolute with the node $NO2$:



Absolute displacements



Relative displacements

5 Modeling B

5.1 Characteristics of modeling

The systems mass-arises are modelled, as in modeling A, by a discrete element with 3 degrees of freedom DIS_T.

Modeling of problem 1:

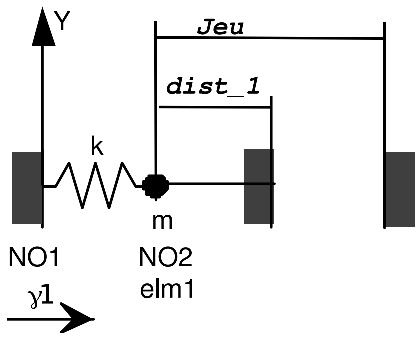


Figure 5.1-a: Modeling of a system mass-arises impacting a rigid wall

The node $NO1$ is subjected to an imposed acceleration $\gamma_1(t)$. One calculates the relative displacement of the node $NO2$, its displacement of training and its absolute displacement.
An element of the type DIST_T on a mesh POI1 is retained to simulate the impact of the beam on a rigid wall: the possible shocks between the beam and the obstacle are taken into account as being internal forces with this element. One affects to him a nonlinear behavior of standard shock (stiffness) via the law of behavior DIS_CONTACT order DEFI_MATERIAU.
The thickness of matter surrounding the node of shock in the direction considered is specified by the operand DIST_1 order DEFI_MATERIAU. In the treated case, one chooses DIST_1 $=0.4495$ and GAME $=0.45$ so that at the initial moment, the node of shock and the obstacle are separated from the game $j=5.10^{-4}mm$ (cf [Figure 5.1-a]).

The seismic loading, due to imposed displacements of the node $NO1$, is calculated by the operator CALC_CHAR_SEISME. One creates then a concept load starting from the operand VECT_ASSE order AFFE_CHAR_MECA.

One uses the implicit diagram of integration of NEWMARK of DYNA_NON_LINE with keyword SCHEMA_TEMPS (FORMULATION=' DEPLACEMENT') with a step of time of $10^{-3}s$ and the parameters by default.

Modeling of problem 2:

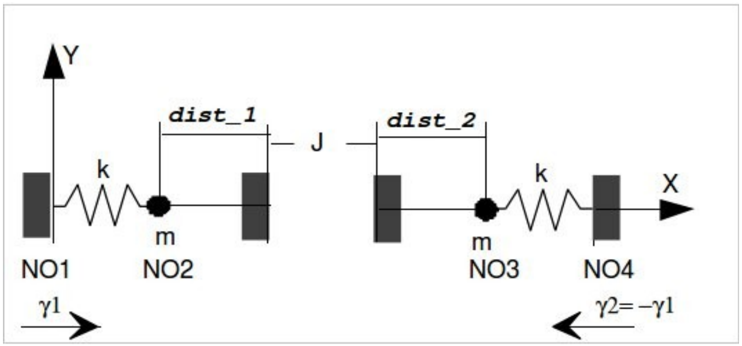


Figure 5.1-b: Modeling of two systems mass-arises which clink

The node $NO1$ is subjected to an imposed acceleration $\gamma_1(t)$, the node $NO4$ with $\gamma_2(t)=-\gamma_1(t)$. Displacements relative and absolutes of the nodes are calculated $NO2$ and $NO3$, their displacement of training and their absolute displacement.

The possible shocks between the two beams are taken into account as being internal forces with an element with two nodes. One assigns to this element a nonlinear behavior of standard shock (stiffness) via the keyword RIGI_NOR law of behavior DIS_CONTACT order DEFI_MATERIAU. The normal direction of contact is the local axis x discrete element with two nodes.

The thicknesses of matter surrounding the nodes of shock in the direction considered are specified by the operands DIST_1 and DIST_2 order DEFI_MATERIAU. In the treated case, one chooses DIST_1 = DIST_2 $=0.4495$ so that at the initial moment, the two nodes of shock are separated from the game $J=2.\ j=10^{-3}m$ (cf [Figure 5.1-a]).

The seismic loading, due to imposed displacements of anchorings (node $NO1$ and $NO4$, is calculated by the operator CALC_CHAR_SEISME. A concept is created load starting from the operand VECT_ASSE order AFFE_CHAR_MECA.

Temporal integration is carried out with the algorithm of Newmark and a step of time of $10^{-3}s$.
Calculations are filed all 8 pas de time.
A reduced damping is considered ξ from 7% for the whole of the calculated modes (keyword AMOR_MODAL of the operator DYNA_NON_LINE).

5.2 Characteristics of the grid

Grid associated with the model bichoc consists of 4 nodes and 3 meshs of the type DIS_T.

6 Results of modeling B

6.1 Values tested of modeling B

The function is calculated $diff$ defined as being the difference between absolute displacement of the node $NO2$ and that of the node $no2$. And it is checked that it is quite worthless for various moments.

Time (S)	Reference
0.1	0.0
0.2	0.0
0.3	0.0
0.4	0.0
0.5	0.0

One also tests the maximum value of the force of impact to the node $NO2$.

Type of impact	Reference
against a rigid wall	6,29287E+02
between two mobile structures	6,29287E+02

One also tests the values of the absolute fields to the node $NO2$ and at the moment $t=0.01$.

Field	Reference	Type	Tolerance
DEPL_ABSOLU	-1,488877E-004	NON_REGRESSION	1,00E-010
VITE_ABSOLU	-1,287591E-002	NON_REGRESSION	1,00E-010
ACCE_ABSOLU	5,877853E-001	NON_REGRESSION	1,00E-010

The functionality is also tested OBSERVATION . L be absolute fields with the node $NO2$ and at the moment $t=0.01$ must be identical to the preceding fields:

Field	Reference	Type	Tolerance
DEPL_ABSOLU	-1,488877E-004	NON_REGRESSION	1,00E-010
VITE_ABSOLU	-1,287591E-002	NON_REGRESSION	1,00E-010
ACCE_ABSOLU	5,877853E-001	NON_REGRESSION	1,00E-010

One tests finally the option SUIVI_DDL by visually comparing the values obtained with those extracted the table fromOBSERVATION generated. These checks relate to displacement and speed (fields DEPL and QUICKLY) with the node $NO2$ at the moment $t=0.1$. One tests also the option MIN of SUIVI_DDL on the group of meshs RESSORT1 at the same moment. This moment was selected so that the minimal value of the fields of displacement and speed on this group of mesh is obtained with the node $NO2$.
For displacement one thus finds the value: $-3.99791\mathrm{E}-05\,m$ and for speed the value: $-1.51040\mathrm{E}-02\,m/s$.

7 Modeling C

7.1 Characteristics of modeling

Modeling C is before a whole test of DYNA_NON_LINE with keyword SCHEMA_TEMPS (FORMULATION=' ACCELERATION'), of which the results are compared with DYNA_NON_LINE with keyword SCHEMA_TEMPS (FORMULATION=' DEPLACEMENT').
The systems mass-arises are modelled, as in modeling A, by a discrete element with 3 degrees of freedom DIS_T. Only modeling with a degree of freedom is tested.

Modeling of the problem:

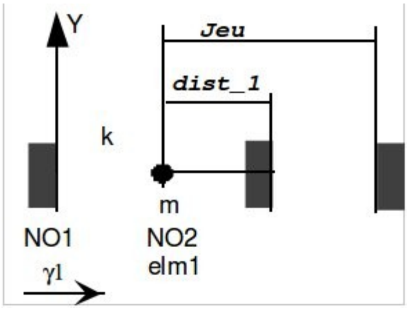


Figure 7.1-a: Modeling of a system mass-arises impacting a rigid wall

The node $NO1$ is subjected to an imposed acceleration $\gamma_1(t)$. One calculates the relative displacement of the node $NO2$, its displacement of training and its absolute displacement.
An element of the type DIST_T on a mesh POI1 is retained to simulate the impact of the beam on a rigid wall: the possible shocks between the beam and the obstacle are taken into account as being internal forces with this element. One affects to him a nonlinear behavior of standard shock (stiffness) via the law of behavior DIS_CONTACT order DEFI_MATERIAU.
The thickness of matter surrounding the node of shock in the direction considered is specified by the operand DIST_1 order DEFI_MATERIAU. In the treated case, one chooses DIST_1 $=0.4495$ and GAME $=0.45$ so that at the initial moment, the node of shock and the obstacle are separated from the game $j=5.10^{-4} mm$ (cf [Figure 5.1-a]).

The seismic loading, due to imposed displacements of the node $NO1$, is calculated by the operator CALC_CHAR_SEISME. One creates then a concept load starting from the operand VECT_ASSE order AFFE_CHAR_MECA.

One uses the diagram of integration of explicit NEWMARK of type DIFFERENCES CENTREES with a step in time of $10^{-3} s$. Calculation by DYNA_NON_LINE with keyword SCHEMA_TEMPS (FORMULATION=' ACCELERATION') is carried out in modal space, non-linearity being due to the shock and thus resident local.

7.2 Characteristics of the grid

The grid associated with the model consists of 2 nodes, of a mesh SEG2 of type DIS_T and of a specific mesh POI1 of type DIS_T.

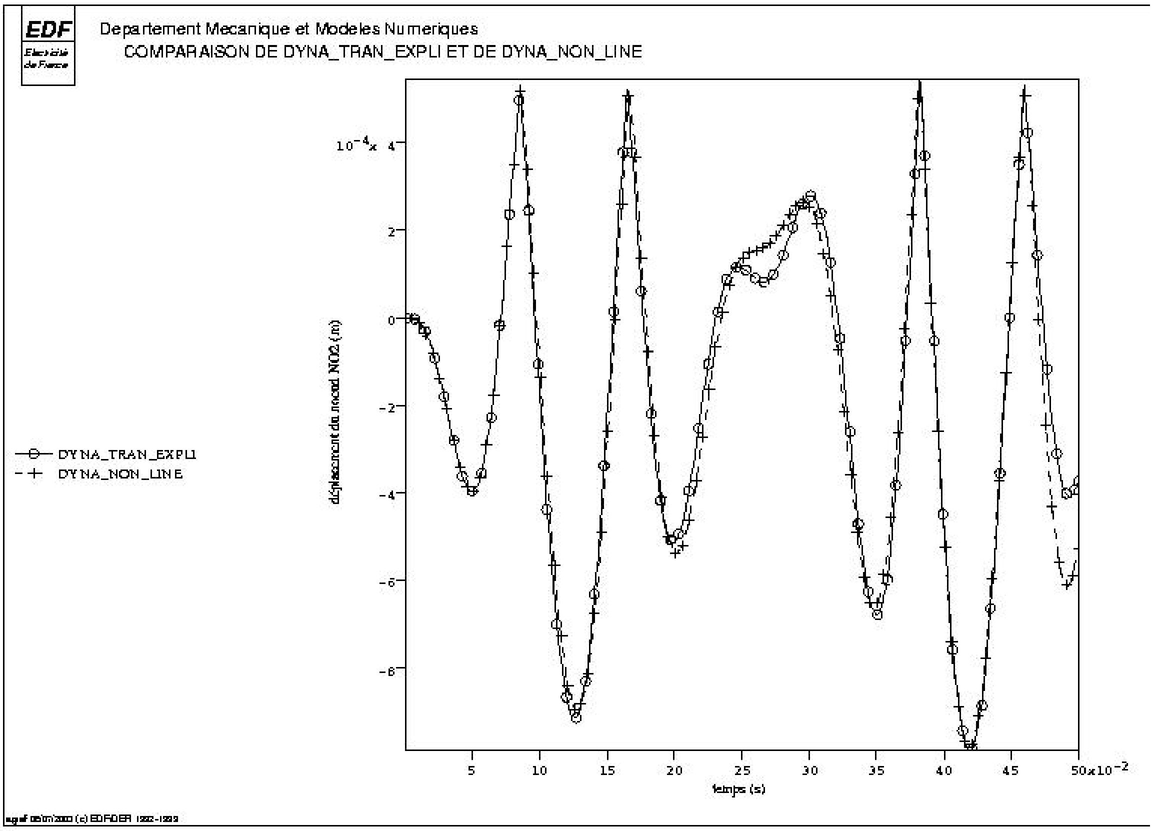
8 Results of modeling C

8.1 Values tested of modeling C

Calculation is non-linear because of shock and one does not have analytical solution. One thus tests calculation on values of not-regression on displacement according to x node $NO2$.

Time (S)	Reference
0.1	– 15,6520E-3
0.2	– 51,4832E-3
0.3	28,1291E-3
0.4	– 44,9343E-3
0.5	– 37,7508E-3

One compares absolute displacements resulting from `DYNA_NON_LINE` with keyword `SCHEMA_TEMPS (FORMULATION=' ACCELERATION')` with those given by `DYNA_NON_LINE` with keyword `SCHEMA_TEMPS (FORMULATION=' DEPLACEMENT')`.



9 Modeling D

9.1 Characteristics of modeling

Modeling D is an alternative of modeling C where one will replace the diagram in nondissipative time of the differences centered by the dissipative explicit diagram of TCHAMWA (with the parameter PHI = 1.05). Unlike modeling C, one solves here on physical basis and not on modal basis (the keyword PROJ_MODAL of DYNA_NON_LINE is not thus present any more in modeling D).

10 Results of modeling D

10.1 Values tested of modeling D

Calculation is non-linear because of shock and one does not have analytical solution. Compared with modeling C the values obtained are different because the diagram in time introduces a digital dissipation. One tests calculation on values of not-regression on displacement according to x node $NO2$.

Time (S)	Reference	*Tolerance*
0.1	– 15,6911E-3	0,10%
0.2	– 49,4505E-3	0,10%
0.3	30,2638E-3	0,10%
0.4	– 38,0509E-3	0,10%
0.5	– 39,2295E-3	0,10%

The fact of changing diagram into time and of introducing an additional dissipation, modifies some of the instantaneous values tested of about a 10%.

11 Summary of the results

Results got with *Code_Aster* are in conformity with those expected (error lower than the thousandths). On this example, direct nonlinear calculation is much more expensive in computing times, of a factor 20, that on modal basis.

Modeling C shows that one obtains many similar results with a method of temporal integration explicit with keyword SCHEMA_TEMPS (FORMULATION=' ACCELERATION')) and implicit (DYNA_NON_LINE with keyword SCHEMA_TEMPS (FORMULATION=' ACCELERATION')).

Modeling D proves that one gets also results close with a method of dissipative explicit temporal integration to TCHAMWA (the variation being due to this added digital damping).