SDLD22 - Transient of a system mass-arises with 8 degrees of freedom with viscous shock absorber

Summary:

The mechanical structure considered made up of a linear one-way whole of mass-springs with viscous shock absorbers and is subjected to a transitory excitation of standard crenel.

Two modelings are developed. The first retains only the degree of freedom in axial translation of the masses, the second considers the axial translation and rotation.

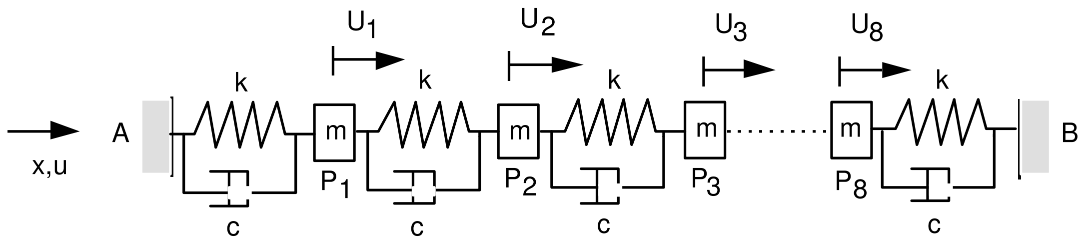
This problem makes it possible to test:

- discrete elements (masses, springs, shock absorbers) in translation-rotation,
- the definition of a force of specific excitation transitory,
- the transitory calculation of answer by modal recombination as well as the recovery with initial conditions (modeling A),
- the calculation of direct transitory response with the diagram to step of adaptive time (modeling B).

The got results (field of displacements, speeds) are in concord with the results of guide VPCS, taken for reference solution.

1 Problem of reference

1.1 Geometry



Specific masses: $m_{P_1}=m_{P_2}=m_{P_3}=\ldots\ldots=m_{P_8}=m$

Stiffnesses of connection: $k_{AP_1}=k_{P_1P_2}=k_{P_2P_3}=\ldots\ldots=k_{P_8B}=k$

Viscous damping: $c_{AP_1}=c_{P_1P_2}=c_{P_2P_3}=\ldots\ldots=c_{P_8B}=c$

1.2 Material properties

Spring of elastic translation linear $k=10^5 N/m$

Specific mass $m=10\,kg$

One-way viscous damping $c=50\,N/(m/s)$

1.3 Boundary conditions and loadings

Boundary conditions: points A and B embedded ($u=0$).

Loading: force concentrated at the point P_4 in the shape of crenel:

Not P_4	$F_{x_4}=F(t)$	$0\le t\le 1\mathrm{s}$	$F(t)=1\mathrm{N}$
		$t>1\mathrm{s}$	$F(t)=0.$
Other points P_i	$F_{x_i}=0$		

1.4 Initial conditions

For $t=0$, in any point, $u=0$ and $\dfrac{du}{dt}=0$.

2 Reference solution

The reference solution is from guide VPCS.

2.1 Method of calculating used for the reference solution

Digital integration selected to obtain this solution rests on a diagram of integration by finished differences, of the standard method β - Newmark improved, with step of time of $0.001\mathrm{s}$ [bib2].

$$\left[\frac{1}{\Delta t^2}M+\frac{1}{2\Delta t}C+\frac{1}{3}K\right]u_{n+2}=\frac{1}{3}(F_{n+2}+F_{n+1}+F_n)+\left[\frac{2}{\Delta t^2}M-\frac{1}{3}K\right]u_{n+1}+\left[\frac{1}{\Delta t^2}M+\frac{1}{2\Delta t}C-\frac{1}{3}K\right]u_n$$

The displacement of the point 4 according to time has the following pace:

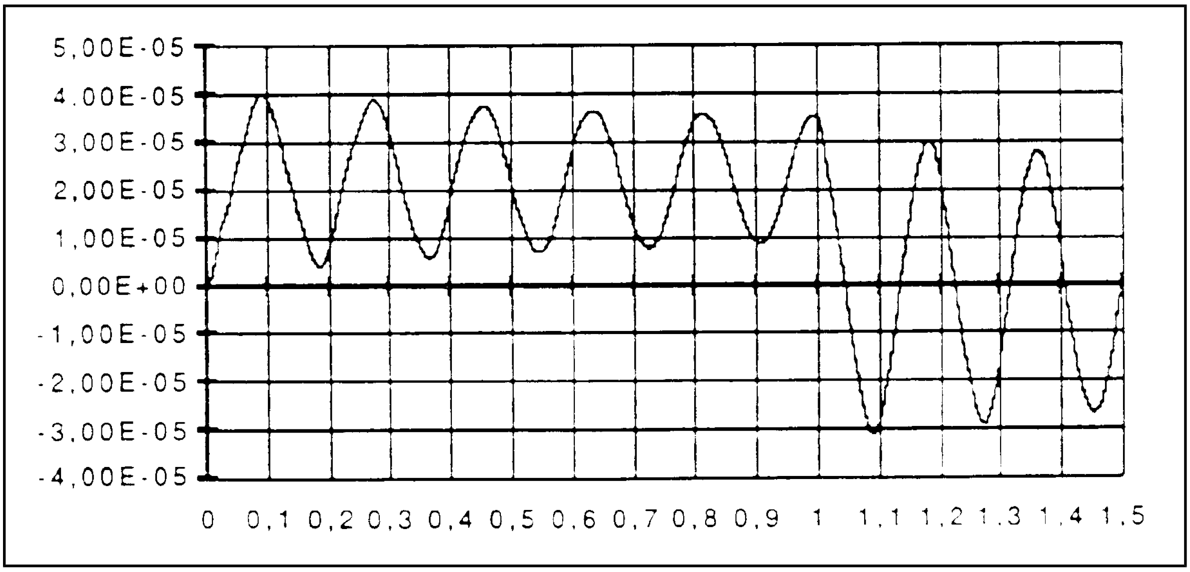


Figure 2.1-a: Point 4: displacement according to time

2.2 Results of reference

Displacement according to x point P_4.

2.3 Uncertainty on the solution

Precision of the diagram of Newmark.

2.4 Bibliographical references

[1] Card SDLD22/90 of commission VPCS.

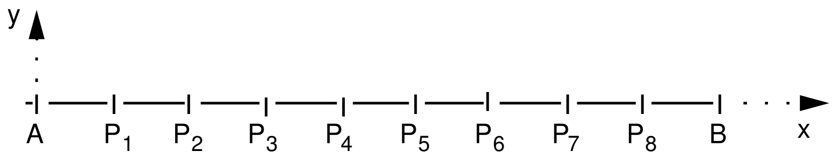
[2] NEWMARK NR. MR.: “With method of computation for structural dynamics”, proceeding ASCE J. Eng. Mech. Div E-3, July 1959, pp 67-94.

3 Modeling A

3.1 Characteristics of modeling

This modeling allows the validation of integration by modal recombination.

Discrete element of rigidity in translation



Characteristics of the elements

DISCRETE with	nodal masses	M_T_D_N	M_T_N
	matrices of rigidity	K_T_D_L	K_T_L
	matrices of damping	A_T_D_L	A_T_L

Blocking of the degrees of freedom in Y and Z of all the nodes

```
DDL_IMPO: (ALL: 'YES'    DY: 0. , DZ: 0. )
```

Boundary conditions with the extreme nodes

```
(GROUP_NO: AB  DX: 0. )
```

Names of the nodes:

Not $A=N1$ $P_1=N2$

Not $B=N10$ $P_2=N3$

....

$P_8=N9$

Modal recombination with all the modes (that is to say 8),

diagram of EULER, resumption of the first calculation with $t=0.455\,s$

pas de time used: $\Delta t=1.E-3\,s$.

3.2 Characteristics of the grid

Many nodes: 10

Many meshs and types: 9 SEG2

3.3 Sizes tested and results

Time	Reference
0.09	4.02 E-5
0.18	4.22 E-6
0.27	3.89 E-5
0.37	5.98 E-6
0.46	3.73 E-5
0.54	7.14 E-6
0.63	3.64 E-5
0.72	8.07 E-6
0.81	3.58 E-5
0.9	8.76 E-6
0.99	3.52 E-5
1.08	– 3.08 E-5
1.18	3.02 E-5
1.27	– 2.88 E-5
1.36	2.80 E-5
1.45	– 2.65 E-5

3.4 Remarks

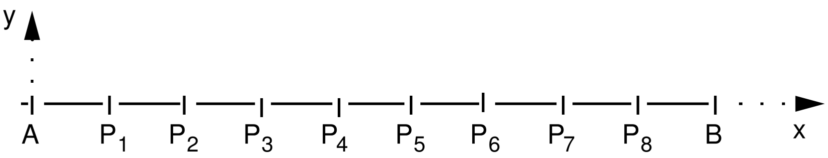
Relative minima ($t=0.18, 0.54, \ldots$) do not have a very good precision during the phase of excitation with a step $\Delta t=0.001$.

4 Modeling B

4.1 Characteristics of modeling

This modeling allows, in addition to a new use of the modal recombination, the validation of direct integration with adaptive step.

Discrete element of rigidity in translation and rotation



Characteristics of the elements:

`DISCRETE:`	with nodal masses	`M_TR_D_N`	`M_TR_N`
	and matrices of rigidity	`K_TR_D_L`	`K_TR_L`
	and matrices of damping	`A_TR_D_L`	`A_TR_L`

Boundary conditions and directions blocked:

in all the nodes	`DDL_IMPO:`	`(ALL: 'YES' DY: 0. , DZ: 0. )`
		`(ALL: 'YES' DRX: 0. DRY MARTINI: 0 DRZ: 0)`
with the nodes ends		`(GROUP_NO: AB  DX: 0. )`

Diagrams of integration tested in this version:

- Integration by modal recombination with the diagram of Euler.
- Integration by direct integration with the algorithm `ADAPT_ORDRE2`maximum , pas de time $10^{-3}s$.
- Integration by modal recombination with the diagram `RUNGE_KUTTA_32`, with a tolerance of relative error of $10^{-3}s$ and a maximum step of time of $10^{-3}s$.
- Integration by modal recombination with the diagram `RUNGE_KUTTA_54`, with a tolerance of relative error of $10^{-3}s$ and a maximum step of time of $10^{-3}s$.

4.2 Characteristics of the grid

Many nodes: 10

Many meshs and types: 9 `SEG2`

4.3 Sizes tested and results

Transient by modal recombination with algorithm EULER

Time	Reference
0.09	4.02 E-5
0.18	4.22 E-6
0.27	3.89 E-5
0.37	5.98 E-6
0.46	3.73 E-5
0.54	7.14 E-6
0.63	3.64 E-5
0.72	8.07 E-6
0.81	3.58 E-5
0.9	8.76 E-6
0.99	3.52 E-5
1.08	– 3.08 E-5
1.18	3.02 E-5
1.27	– 2.88 E-5
1.36	2.80 E-5
1.45	– 2.65 E-5

Transient by direct integration with the algorithm `ADAPT_ORDRE2`

Time	Reference
0.09	4.02 E-5
0.18	4.22 E-6
0.27	3.89 E-5
0.37	5.98 E-6
0.46	3.73 E-5
0.54	7.14 E-6
0.63	3.64 E-5
0.72	8.07 E-6
0.81	3.58 E-5
0.9	8.76 E-6
0.99	3.52 E-5
1.08	– 3.08 E-5
1.18	3.02 E-5
1.27	– 2.88 E-5
1.36	2.80 E-5
1.45	– 2.65 E-5

Transient by modal recombination with the algorithm `RUNGE_KUTTA_32`

Time	Reference
0.09	4.02 E-5
0.18	4.22 E-6
0.27	3.89 E-5
0.37	5.98 E-6
0.46	3.73 E-5
0.54	7.14 E-6
0.63	3.64 E-5
0.72	8.07 E-6
0.81	3.58 E-5
0.9	8.76 E-6
0.99	3.52 E-5
1.08	– 3.08 E-5
1.18	3.02 E-5
1.27	– 2.88 E-5
1.36	2.80 E-5
1.45	– 2.65 E-5

Transient by modal recombination with the algorithm `RUNGE_KUTTA_54`

Time	Reference
0.09	4.02 E-5
0.18	4.22 E-6
0.27	3.89 E-5
0.37	5.98 E-6
0.46	3.73 E-5
0.54	7.14 E-6
0.63	3.64 E-5
0.72	8.07 E-6
0.81	3.58 E-5
0.9	8.76 E-6
0.99	3.52 E-5
1.08	– 3.08 E-5
1.18	3.02 E-5
1.27	– 2.88 E-5
1.36	2.80 E-5
1.45	– 2.65 E-5

4.4 Remarks

Modelings A and B lead to the same results.

Relative minima ($t=0.18, 0.54, \ldots$) do not have a very good precision during the phase of excitation with a step $\Delta t=0.001$.

5 Summary of the results

This test is to be supplemented while using:

- a step of time $\Delta t = 1.E-4$,
- other diagrams of integration.