SDLD27 - System mass-arises with 8 degrees of freedom with viscous shock absorber not proportional (analyzes modal)

Summary:

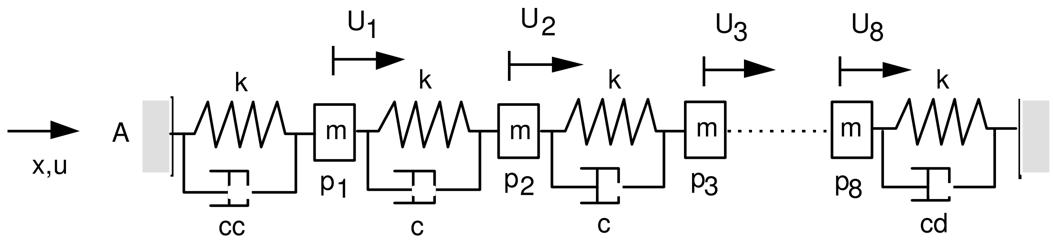
This two-dimensional problem consists in searching the frequencies, the modes of vibration and depreciation of a mechanical structure made up of masses, springs and shock absorbers viscous. This CAS-test of Mechanics of the Structures corresponds to a dynamic analysis of a discrete model having a linear behavior.

This test allows a complete validation of the options of discrete modeling of rigidity, viscous damping and mass (without finite elements) offered by the order AFFE_CARA_ELEM. Five different modelings are proposed: the modeling of the discrete elements is either in translation, or in translation/rotation and is written or in total reference mark, or in local reference mark. In addition, various features of the orders CALC_MODES (search for eigenvalues) and NORME_MODE (definition of the standard of a clean vector) are tested for this quadratic problem.

This test refers to a test VPCS, but it was modified. Indeed, the test directs the mechanical system towards an axis $3y=4x$, which makes it possible to validate the entry of the data in local reference mark. The got results are in concord with the results of reference.

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: $k_{AP1}=k_{P1P2}=k_{P2P3}=\ldots\ldots=k_{P8B}=k$

Viscous damping: $c_{P1P2}=c_{P2P3}=\ldots\ldots=c_{P7P8}=c$
$c_{AP1}=cc$
$c_{P8B}=cd$

1.2 Material properties

Spring of elastic translation linear	$k=10^5 N/m$
Specific mass	$m=10\,kg$
One-way viscous shock absorbers	$c=50\,N/(m/s)$
	$cc=250\,N/(m/s)$
	$cd=25\,N/(m/s)$

1.3 Boundary conditions and loadings

Points A and B embedded: $u=0$.

1.4 Initial conditions

Without object for the modal analysis.

2 Reference solution

2.1 Method of calculating used for the reference solution

The reference solution is that given in card SDLD27 of guide VPCS.

The problem led to search the eigenvalues and clean vectors of the following dissipative system:

$$\boldsymbol{M}\,\ddot{u}+\boldsymbol{C}\,\dot{u}+\boldsymbol{K}\,u=0$$

with $\boldsymbol{M}$ matrix of mass, $\boldsymbol{C}$ matrix of damping, $\boldsymbol{K}$ matrix of rigidity.

One associates with this dissipative problem, the conservative problem: $\boldsymbol{K}\,u+\boldsymbol{M}\,\ddot{u}=0$. In harmonic form, he is written $\boldsymbol{K}-\omega^2\boldsymbol{M}=0$.

Are $\Lambda=[\omega_v^2]$ the spectral diagonal matrix of the eigenvalues of this conservative system and $\phi=[\varphi_v]$ the corresponding matrix of the clean vectors.

φ_v are standardized such as: $\phi^T M\,\phi=Id \quad \phi^T K\,\phi=\Lambda$.

The solutions of the dissipative system are form:

$$u=u_0 e^{st} \text{ from where } (M\,s^2+C\,s+K)u_0=0 .$$

One breaks up u_0 in the base of φ_v . One has then $u_0=\phi\,q$, from where:

$$(I\,s^2+\gamma\,s+\Lambda)q=0 \text{ with } \gamma=\phi^T C\,\phi \text{ (full matrix)}$$

This problem with the eigenvalues is solved by a method of power opposite while taking for initial estimate $s_v=j\,\omega_v$.

2.2 Results of reference

8 depreciation and Eigen frequencies of the system, as well as the 1er and 8ième mode (complexes).

2.3 Uncertainty on the solution

Semi-analytical solution.

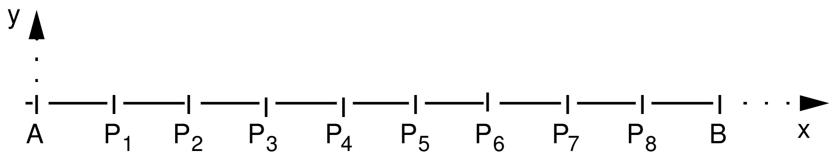
2.4 Bibliographical references

- J. PIRANDA - Note of use of the software of modal analysis MODAN - Version 0.2 (1990) Laboratory of Mechanics Applied - University of Frank - County - Besancon (France)
- Guide VPCS. Complement Groups Dynamic. September 94

3 Modeling A

3.1 Characteristics of modeling

Discrete element of rigidity in translation DIS_T



Characteristics of the elements

DISCRETE:

with nodal masses			
in all the nodes	M_T_D_N	in absolute reference mark	$(m=10.)$
matrices of rigidity			
in all the meshs	M_T_D_L	in absolute reference mark	$(K_x=1.10^5)$
matrices of damping			
internal meshs	A_T_D_L	in absolute reference mark	$(C_x=50.)$
initial mesh	A_T_D_L	in absolute reference mark	$(C_x=250.)$
final mesh	A_T_D_L	in absolute reference mark	$(C_x=25.)$

Limiting conditions:

DDL_IMPO:	(ALL: 'YES' DY: 0. , DZ: 0.)
with the nodes ends	(NODE: (WITH B) DX: 0.)

Names of the nodes: $A, P_{1,} P_{2,} \ldots., P_{8,} B$

3.2 Characteristics of the grid

Many nodes:	10
Many meshs and types:	9 SEG2 and 8 POI1

3.3 Sizes tested and results

Frequency	Reference
Order of the clean mode 1	5.53
Order of the clean mode 2	10.90
Order of the clean mode 3	15.93
Order of the clean mode 4	20.45
Order of the clean mode 5	24.34
Order of the clean mode 6	27.49
Order of the clean mode 7	29.84
Order of the clean mode 8	31.29

Damping	Reference
Order of the clean mode 1	1.521e-2
Order of the clean mode 2	2.877e-2
Order of the clean mode 3	3.960e-2
Order of the clean mode 4	4.709e-2
Order of the clean mode 5	5.098e-2
Order of the clean mode 6	5.183e-2
Order of the clean mode 7	5.115e-2
Order of the clean mode 8	5.036e-2

Nature of the clean mode	Not	Clean mode Reference in 10^{-3} Real part Imaginary part
Translation 1 (Dy) Φ_1	P1	4.07, – 4.56
	P2	7.97, – 8.28
	P3	10.9, – 11.0
	P4	12.5, – 12.5
	P5	12.5, – 12.4
	P6	11.1, – 10.9
	P7	8.24, – 8.04
	P8	4.41, – 4.25
Translation 8 (Dy) Φ_8	P1	2.23, – 1.14
	P2	– 3.71, 2.98
	P3	4.75, – 4.41
	P4	– 5.25, 5.27
	P5	5.14, – 5.43
	P6	– 4.44, 4.88
	P7	3.23, – 3.69
	P8	– 1.66, 2.01

Own standard mode with the unit modal mass: $\phi_i^t \boldsymbol{C}\, \phi_i + 2\lambda_i \phi_i^t \boldsymbol{M}\, \phi_i = 1$

λ : is the eigenvalue associated with damping and the Eigen frequency.

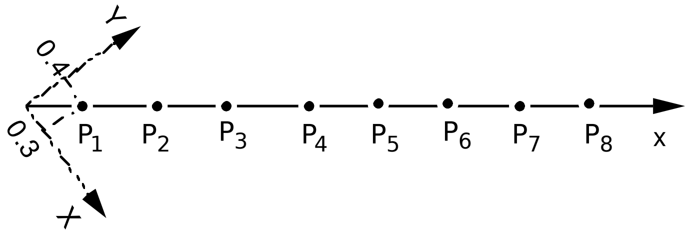
3.4 Contents of the file results

8 depreciation and Eigen frequencies, as well as the associated clean vectors.

4 Modeling B

4.1 Characteristics of modeling

Discrete element of rigidity in translation `DIS_T`



Characteristics of the elements

`ORIENTATION:`	in all the nodes	with an angle	$\alpha=53.130102°$
`DISCRETE:`			
with nodal masses			
in all the nodes	`M_T_D_N`	in absolute reference mark	$(m=10.)$
matrices of rigidity			
in all the meshs	`K_T_D_L`	in local reference mark	$(K_x=1.10^5)$
with the nodes ends	`K_T_D_N`	in local reference mark	$(K_x=1.10^5)$
matrices of damping			
internal meshs	`A_T_D_L`	in local reference mark	$(C_x=50.)$
initial mesh	`A_T_D_N`	in local reference mark	$(C_x=250.)$
final mesh	`A_T_D_N`	in local reference mark	$(C_x=25.)$

Limiting conditions:

`DDL_IMPO:` `(ALL: 'YES' DZ: 0. )`
`LIAISON_DDL:` (such as $3\mathrm{Dy}=4\mathrm{Dx}$ in all the nodes)

Names of the nodes: $P_{1,} P_{2,} \ldots, P_8$

4.2 Characteristics of the grid

Many nodes:	8
Many meshs and types:	7 `SEG2`

Points P_1 and P_8 are connected to a fixed fictitious point by nodal springs (`K_T_D_N`, `A_T_D_N`) what makes it possible not to model the nodes A and B .

4.3 Sizes tested and results

Frequency	Reference
Order of the clean mode 1	5.53
Order of the clean mode 2	10.90
Order of the clean mode 3	15.93
Order of the clean mode 4	20.45
Order of the clean mode 5	24.34
Order of the clean mode 6	27.49
Order of the clean mode 7	29.84
Order of the clean mode 8	31.29

Damping	Reference
Order of the clean mode 1	1.521e-2
Order of the clean mode 2	2.877e-2
Order of the clean mode 3	3.960e-2
Order of the clean mode 4	4.709e-2
Order of the clean mode 5	5.098e-2
Order of the clean mode 6	5.183e-2
Order of the clean mode 7	5.115e-2
Order of the clean mode 8	5.036e-2

Nature of the clean mode	Not	Clean mode Reference in 10^{-3} Real part Imaginary part
Translation 1 (Dy) Φ_1	P1	– 2,442, 2,736
	P2	– 4,782, 4,968
	P3	– 6.54 , 6.6
	P4	– 7.5 , 7.5
	P5	– 7.5 , 7.44
	P6	– 6.66 , 6.54
	P7	– 4,944, 4,824
	P8	– 2,646, 2.55
Translation 8 (Dy) Φ_8	P1	– 1,338, 0,684
	P2	– 2,226, 1,788
	P3	– 2.85 , 2,646
	P4	– 3.15 , 3,162
	P5	– 3,084, 3,258
	P6	– 2,664, 2,928
	P7	– 1,938, 2,214
	P8	– 0,996, 1,206

Own standard mode with the unit modal mass: $\phi_i^t \boldsymbol{C}\, \phi_i + 2\lambda_i \phi_i^t \boldsymbol{M}\, \phi_i = 1$

λ : is the eigenvalue associated with damping and the Eigen frequency.

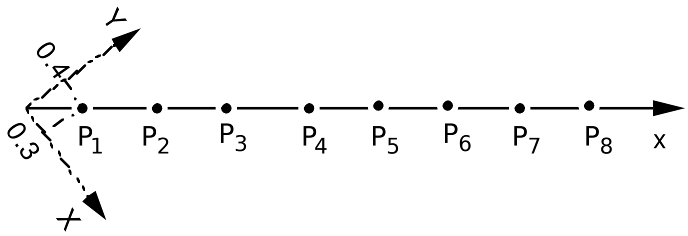
4.4 Contents of the file results

8 depreciation and Eigen frequencies, as well as the associated clean vectors.

5 Modeling C

5.1 Characteristics of modeling

Discrete element of rigidity in translation `DIS_T`



Characteristics of the elements

`ORIENTATION:`	in all the nodes	with an angle $\alpha=53.130102°$	
`DISCRETE:`			
with nodal masses			
in all the nodes	`M_T_N`	in absolute reference mark	$(m=10.)$
matrices of rigidity			
in all the meshs	`K_T_L`	in local reference mark	$(K_x=1.10^5)$
with the nodes ends	`K_T_N`	in local reference mark	$(K_x=1.10^5)$
matrices of damping			
in all the meshs	`A_T_L`	in local reference mark	$(C_x=50.)$
with the initial node	`A_T_N`	in local reference mark	$(C_x=250.)$
with the final node	`A_T_N`	in local reference mark	$(C_x=25.)$

Limiting conditions:

`DDL_IMPO:` (ALL: 'YES' DZ: 0.)
`LIAISON_DDL:` (such as $3Dy=4Dx$ in all the nodes)

Names of the nodes: $P_{1,} P_{2,} ...., P_8$

5.2 Characteristics of the grid

Many nodes: 8
Many meshs and types: 7 `SEG2`

Points P_1 and P_8 are connected to a fixed fictitious node by nodal springs (`K_T_N`, `A_T_N`).

5.3 Sizes tested and results

Frequency	Reference
Order of the clean mode 1	5.53
Order of the clean mode 2	10.90
Order of the clean mode 3	15.93
Order of the clean mode 4	20.45
Order of the clean mode 5	24.34
Order of the clean mode 6	27.49
Order of the clean mode 7	29.84
Order of the clean mode 8	31.29

Damping	Reference
Order of the clean mode 1	1.521e-2
Order of the clean mode 2	2.877e-2
Order of the clean mode 3	3.960e-2
Order of the clean mode 4	4.709e-2
Order of the clean mode 5	5.098e-2
Order of the clean mode 6	5.183e-2
Order of the clean mode 7	5.115e-2
Order of the clean mode 8	5.036e-2

Nature of the clean mode	Not	Clean mode Reference in 10^{-3} Real part Imaginary part
Translation 1 (Dy) Φ_1	P1	– 2,442, 2,736
	P2	– 4,782, 4,968
	P3	– 6.54 , 6.6
	P4	– 7.5 , 7.5
	P5	– 7.5 , 7.44
	P6	– 6.66 , 6.54
	P7	– 4,944, 4,824
	P8	– 2,646, 2.55
Translation 8 (Dy) Φ_8	P1	– 1,338, 0,684
	P2	– 2,226, 1,788
	P3	– 2.85 , 2,646
	P4	– 3.15 , 3,162
	P5	– 3,084, 3,258
	P6	– 2,664, 2,928
	P7	– 1,938, 2,214
	P8	– 0,996, 1,206

Own standard mode with the unit modal mass: $\phi_i^t \boldsymbol{C} \, \phi_i + 2 \lambda_i \phi_i^t \boldsymbol{M} \, \phi_i = 1$

λ is the eigenvalue associated with damping and the Eigen frequency.

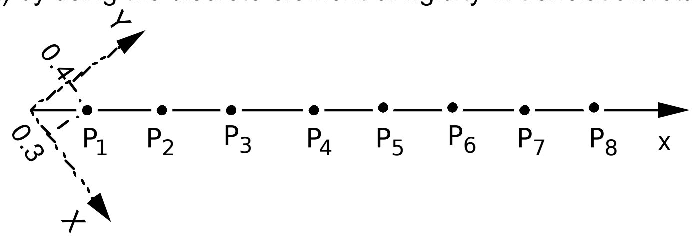
5.4 Contents of the file results

8 depreciation and Eigen frequencies, as well as the associated clean vectors.

6 Modeling D

6.1 Characteristics of modeling

Transposition of the test of reference to the case of the degrees of freedom of rotation (from torsion + inertia comes out) by using the discrete element of rigidity in translation/rotation.



Characteristics of the elements

`ORIENTATION:`	in all the nodes	with an angle $\alpha=53.130102°$	
`DISCRETE:`			
with nodal masses			
in all the nodes	`M_TR_D_N`	in local reference mark	$(m=10.)$
matrices of rigidity			
in all the meshs	`K_TR_D_L`	in local reference mark	$(KR_x=1.10^5)$
with the nodes ends	`K_TR_D_N`	in local reference mark	$(KR_x=1.10^5)$
matrices of damping			
in all the meshs	`A_TR_D_L`	in local reference mark	$(CR_x=50.)$
with the initial node	`A_TR_D_N`	in local reference mark	$(CR_x=250.)$
with the final node	`A_TR_D_N`	in local reference mark	$(CR_x=25.)$

Limiting conditions:

`DDL_IMPO:` `(ALL: 'YES' DX: 0. , DY: 0. , DZ: 0. , DRZ: 0. )`
`LIAISON_DDL:` (such as $3DRy=4DRx$ in all the nodes)

Names of the nodes: $P_{1,} P_{2,} ...., P_8$

6.2 Characteristics of the grid

Many nodes: 8
Many meshs and types: 7 `SEG2`

Nodes P_1 and P_8 are connected to a fixed fictitious node by nodal springs (`K_TR_N`, `A_TR_N`).

6.3 Contents of the file results

Results got with:

```
CALC_FREQ: (LIST_FREQ: (6. , 10. , 15. , 19. , 24. , 29. , 29. , 31.))
CALC_MODE: (NMAX_MODE: 75)
```

6.4 Sizes tested and results

Frequency	**Reference**
Order of the clean mode 1	5.53
Order of the clean mode 2	10.90
Order of the clean mode 3	15.93
Order of the clean mode 4	20.45
Order of the clean mode 5	24.34
Order of the clean mode 6	27.49
Order of the clean mode 7	29.84
Order of the clean mode 8	31.29

Damping	**Reference**
Order of the clean mode 1	1.521e-2
Order of the clean mode 2	2.877e-2
Order of the clean mode 3	3.960e-2
Order of the clean mode 4	4.709e-2
Order of the clean mode 5	5.098e-2
Order of the clean mode 6	5.183e-2
Order of the clean mode 7	5.115e-2
Order of the clean mode 8	5.036e-2

Nature of the clean mode	**Not**	**Clean mode Reference in 10^{-3} Real part Imaginary part**
Rotation 1 (DRx) Φ_1	P1	– 2,442, 2,736
	P2	– 4,782, 4,968
	P3	– 6.54 , 6.6
	P4	– 7.5 , 7.5
	P5	– 7.5 , 7.44
	P6	– 6.66 , 6.54
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	P8	– 2,646, 2.55
Rotation 8 (DRx) Φ_8	P1	– 1,338, 0,684
	P2	– 2,226, 1,788
	P3	– 2.85 , 2,646
	P4	– 3.15 , 3,162
	P5	– 3,084, 3,258
	P6	– 2,664, 2,928
	P7	– 1,938, 2,214
	P8	– 0,996, 1,206

Own standard mode with the unit modal mass: $\phi_i^t \boldsymbol{C} \, \phi_i + 2\lambda_i \phi_i^t \boldsymbol{M} \, \phi_i = 1$

λ is the eigenvalue associated with damping and the Eigen frequency.

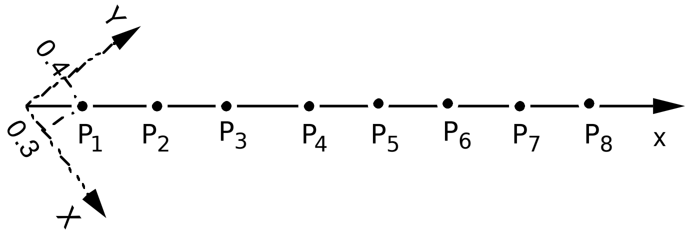
6.5 Contents of the file results

8 depreciation and Eigen frequencies, as well as the associated clean vectors.

7 Modeling E

7.1 Characteristics of modeling

Transposition of the test of reference to the case of the degrees of freedom of rotation (from torsion + inertia comes out) by using the discrete element of rigidity in translation/rotation: DIS_TR



Characteristics of the elements

ORIENTATION:	in all the nodes	with an angle $\alpha=53.130102°$	
DISCRETE:			
with nodal masses			
in all the nodes	M_TR_N	in local reference mark	$(I_{xx}=10.)$
matrices of rigidity			
in all the meshs	K_TR_L	in local reference mark	$(KR_x=1.10^5)$
with the nodes ends	K_TR_N	in local reference mark	$(KR_x=1.10^5)$
matrices of damping			
in all the meshs	A_TR_L	in local reference mark	$(CR_x=50.)$
with the initial node	A_TR_N	in local reference mark	$(CR_x=250.)$
with the final node	A_TR_N	in local reference mark	$(CR_x=25.)$

Limiting conditions:

DDL_IMPO: (ALL: 'YES' DX: 0. , DY: 0. , DZ: 0. , DRZ: 0.)
LIAISON_DDL: (such as $3DRy=4DRx$ in all the nodes)

Names of the nodes: $P_{1,} P_{2,} \ldots, P_8$

7.2 Characteristics of the grid

Many nodes: 8
Many meshs and types: 7 SEG2

Nodes P_1 and P_8 are connected to a fixed fictitious node by nodal springs (K_TR_N, A_TR_N).

7.3 Sizes tested and results

Frequency	Reference
Order of the clean mode 1	5.53
Order of the clean mode 2	10.90
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Order of the clean mode 4	20.45
Order of the clean mode 5	24.34
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Order of the clean mode 8	31.29

Damping	Reference
Order of the clean mode 1	1.521e-2
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Own standard mode with the unit modal mass: $\phi_i^t \boldsymbol{C}\,\phi_i + 2\lambda_i \phi_i^t \boldsymbol{M}\,\phi_i = 1$

λ : is the eigenvalue associated with damping and the Eigen frequency.

7.4 Contents of the file results

8 depreciation and Eigen frequencies, as well as the associated clean vectors.

8 Summary of the results

For all the options of modeling of the discrete elements of rigidity, of mass and damping offered by AFFE_CARA_ELEM the solutions obtained are those of the reference solution (frequencies and clean modes).