SDLL126 – Transitory dynamic response of a beam with 3 discs, subjected to the gyroscopic effect.

Summary:

In the case of a transitory answer, the objective is to validate the effect of the gyroscopic matrix on a beam supported on each one of its ends, on linear supports. The beam is full, of circular section and comprises three discs. All calculations are carried out at number of constant revolutions of the rotor.

There does not exist analytical reference for transitory calculation. The comparison will thus relate to the amplitudes and the phases in permanent mode, of displacements of the node of loading obtained using three different methods.

Three calculations are thus carried out:

- Calculation a: transitory calculation in physical coordinates;
- Calculation b: transitory calculation in cordonnées generalized;
- Calculation C: harmonic calculation, tree according to X ;
- Calculation D: harmonic calculation, tree according to Z .

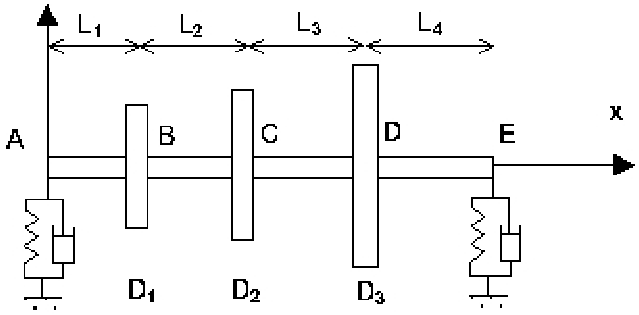
This problem thus makes it possible to in the case of test the effect of the gyroscopic matrix which was developed for a right beam and discrete elements, a transitory answer.

The gyroscopic effect can introduce an instability of the system. It is necessary to make sure that all modal depreciation is positive.

The results got by the 3 methods of calculating are coherent between them. Harmonic calculation was in addition validated using bibliographical reference. The references are based on the theory of the beams of Timoshenko.

1 Problem of reference

1.1 Geometry



Modeling:

	Mass (kg)	I_{xx} ($kg.m^2$)	$I_{yy}=I_{zz}$ ($kg.m^2$)
Disc D_1	14.580130	0.1232021	0.6463858
Disc D_2	45.945793	0.97634809	0.4977460
Disc D_3	55.134951	1.1716177	0.6023493

Length of the beam:

$L_1=AB=0.2\,m$
$L_2=BC=0.3\,m$
$L_3=CD=0.5\,m$
$L_4=DE=0.3\,m$

Circular section:

Diameter: $D=0.1\,m$

1.2 Material properties

$E=2.10^{11}\,Pa$
$\nu=0.3$
$\rho=7\,800\,kg/m^3$

1.3 Boundary conditions and loadings

Elastic supports with viscous damping in A and in E

$K_{yy}=5.10^7\,N.m^{-1}$; $K_{zz}=7.10^7\,N.m^{-1}$; $K_{yz}=K_{zy}=0$
$C_{yy}=5.10^3\,N/(m.s^{-1})$; $C_{zz}=7.10^3\,N/(m.s^{-1})$; $C_{yz}=C_{zy}=0$

Attention depreciation was multiplied by 10, compared to the harmonic calculation of test SHLL102 in order to obtain a faster attenuation of the solid modes of body with an aim of minimizing the duration of calculation. The other parameters are identical.

Unbalance of value $0.05\,m.kg$, installed on the node C (disc 2).

2 Reference solution

2.1 Method of calculating used for the reference solution

The reference solution is that obtained using Code_Aster, with a harmonic calculation. Harmonic calculation itself was validated via the results provided in the work of Michel LALANNE and Guy FERRARIS.

The comparison will thus relate to the results got via calculations A and B (calculation transitory, analysis of the results in permanent mode), and the reference defined by calculation C (harmonic calculation). The loading is of standard unbalance, the number of revolutions of the rotor being constant.
Displacements of the nodes are written in permanent mode, according to time t, in the form:

$$Y(t)=Y_{max}.\cos(\omega t+\theta_y)$$
$$Z(t)=Z_{max}.\cos(\omega t+\theta_z)$$

With:
- Y_{max} and Z_{max} the half amplitudes (in m)
- ω : number of revolutions of the rotor (in $rd.s^{-1}$)
- θ_y and θ_z, phases of the two signals.

It is rather easy, by visualizing the curves or by publishing the file result, to record the half-amplitudes of displacements according to Y and Z. For the calculation of the phases, it is first of all necessary to determine the temporal X-coordinate of a extremum of the sinusoid, and to deduce from it then only the phase. The phase corresponds to the shift compared to that of the unbalance, which one will define in the moment $t=0$, as being of zero value (force of with the unbalance colinéaire with the direction Y at the moment $t=0$).

One thus raises t_{ymax} (X-coordinate in time of a extremum of following displacement Y)

One has then: $$Y(t=t_{ymax})=Y_{max}.\cos(\omega.t_{ymax}+\theta_y)=Y_{max}$$

$$\cos(\omega.t_{ymax}+\theta_y)=1$$

$$\omega.t_{ymax}+\theta_y=2k\pi$$

from where: $$\theta_y=2k\pi-\omega.t_{ymax}=Ent(\omega.t_{ymax})-\omega.t_{ymax}$$

One operates the same treatment for following displacement Z.

Code_Aster provides directly, in harmonic calculation the phases and the amplitudes of displacements to the nodes.

2.2 Results of reference

Amplitude of radial displacements (according to Y and Z) node of loading (disc 2) in permanent mode.

Phase compared to the loading of radial displacements of the node of loading (disc 2) in permanent mode.

2.3 Uncertainty on the solution

Lower than 1% .

2.4 Bibliographical references

Michel LALANNE and Guy FERRARIS, Rotordynamics, Prediction in Engineering, JOHN WILEY AND SOUNDS (1990).

3 Modeling A

3.1 Characteristics of modeling

Modeling : 130 Elements équi-distribute beam POU_D_T in the direction x

3.2 Characteristics of the grid

Grid: Many nodes: 131
Many meshs and types: 130 SEG2

3.3 Sizes tested and results

In permanent mode, displacements according to the radial directions of the node C (disc 2) are sinusoids whose amplitude and phase are identical to those found using calculation B.
Since the characteristics of the stages are not axisymmetric, the trajectories of the nodes are ellipses and not circles.

N	Y_{max}	t_{ymax}	θ_y	Z_{max}	t_{zmax}	θ_z
tr/min	m	s	$deg.$	m	s	$deg.$
15000	5,668 E-04	4.99790	-171.0	6.945E-04	4.99890	99

N.B. : to reduce the computing time transient on physical basis, one chose in the test of the base of validation a step of too coarse time ($0,1\,ms$) to obtain a good precision over the moment compared to the rotational frequency of the system ($250\,Hz$). The phase is in particular very vague. Precision of TEST_RESU is thus not optimal compared to the study which was led with a step of time of $0,03\,ms$.

4 Modeling B

4.1 Characteristics of modeling

Modeling : 130 Elements équi-distribute beam POU_D_T in the direction x

4.2 Characteristics of the grid

Grid: Many nodes: 131
Many meshs and types: 130 SEG2

4.3 Sizes tested and results

Results in permanent mode for the displacement of the node C give for calculation B the following results:

N	Y_{max}	t_{ymax}	θ_y	Z_{max}	t_{zmax}	θ_z
tr/min	m	s	$deg.$	m	s	$deg.$
15000	5,718 E-04	4.99790	-171.0	7.01E-04	4.99890	99

5 Modeling C

The comparison relates to the results with those of calculations With and B.

5.1 Characteristics of modeling

Modeling : 130 Elements équi-distribute beam `POU_D_T` in the direction x

5.2 Characteristics of the grid

Grid: Many nodes: 131
Many meshs and types: 130 `SEG2`

5.3 Sizes tested and results

	Calculation A	Calculation B	Calculation C	Variation in % (between A and C)	Variation in % (between B and C)
Y_{max} (in m)	5,668 E-04	5,722 E-04	5,721 E-04	0.93%	0.02%
θ_y (in $deg.$)	-171.0	-171.0	-172.08	3.03%	3.03%
Z_{max} (in m)	6,945 E-04	7,017 E-04	7,023 E-04	1.11%	0.09%
θ_z (in $deg.$)	99	99	96.09	3.03%	3.03%

6 Modeling D

The comparison relates to the results with those of calculations C.

6.1 Characteristics of modeling

Modeling : 130 Elements équi-distribute beam POU_D_T in the direction z

6.2 Characteristics of the grid

Grid: Many nodes: 131
Many meshs and types: 130 SEG2

6.3 Sizes tested and results

	Calculation D (modulo $[2\pi]$)	Calculation C (modulo $[2\pi]$)	Variation in %
Y_{max} (in m)	5.7214 E-04	5.7210 E-04	0.0069%
θ_y (in $deg.$)	-173.91	-172.08	1.0600%
X_{max} (in m)	7.0235 E-04	7.0230 E-04	0.0071%
θ_x (in $deg.$)	97.92	96.09	1.9000%

7 Summary of the results

One notes a good establishment of the gyroscopic effect for the element of beam. The results of transitory calculation in permanent mode (with or without modal synthesis) result in finding those of harmonic calculation.