SDLL126 – Response transient dynamics of a beam with 3 discs, subjected to the gyroscopic effect.

Abstract:

In the case of a transient response, the purpose is to validate the effect of the gyroscopic matrix on a beam supported on each one of its ends, on linear bearings. The beam is full, of circular section and comprises three discs. All computations are carried out at constant rotational speed of the rotor.

It does not exist of analytical reference for transient computation. The comparison will thus carry on the amplitudes and the phases in permanent mode, of displacements of the node of loading obtained using three different methods.

Three computations are thus carried out:

- Computation a: transient computation in physical coordinates;
- Computation b: transient computation in cordonnées generalized;
- Computation C: harmonic computation, shaft according to X ;
- Computation D: harmonic computation, shaft according to Z .

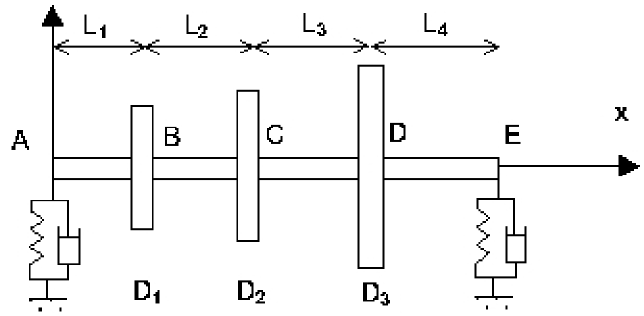
This problem thus makes it possible in the case of to test the effect of the gyroscopic matrix which was developed for a straight beam and discrete elements, a transient response.

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

The results got by the 3 methods of calculating are coherent between them. The computation harmonic 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



Modelization:

	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	1.176177	0.6023493

Length of 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 Elastic

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

1.3 material properties Boundary conditions and

loadings Bearings 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 computation of test SHLL102 in order to obtain a faster attenuation of the modes of solid bodies with an aim of minimizing the period of computation. 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 computation. The computation harmonic 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 computations A and B (transient computation, analysis of results in permanent mode), and the reference defined by computation C (harmonic computation). The loading is of standard unbalance, the rotational speed 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 the Z_{max} half amplitudes (in m)
ω : the rotational speed 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 results file, to record the half-amplitudes of displacements according to Y and Z. For the computation 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 time $t=0$, as being of value zero (force of with the unbalance colinéaire with the direction Y at time $t=0$).

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 processing for following displacement Z.

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

2.2 Results of reference

Amplitude of radial displacements (according to Y and Z) of the 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 Modelization A

3.1 Characteristic of the modelization

Modelization : 130 Elements équi-distribute Mesh: beam POU_D_T in x

3.2 the direction Characteristics of

the mesh Many nodes: 131
Number of meshes and types: 130 SEG2

3.3 Quantities 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 computation B.
Since the characteristics of the bearings 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 transient computation time on physical base, one chose in the test of the base of validation time step too coarse ($0,1\,ms$) to obtain a good accuracy over time compared to the rotational frequency of the system ($250\,Hz$). The phase is in particular very vague. The accuracy of the TEST_RESU is thus not optimal compared to the study which was led with time step of $0,03\,ms$.

4 Modelization B

4.1 Characteristic of the modelization

Modelization : 130 Elements équi-distribute Mesh: beam POU_D_T in x

4.2 the direction Characteristics of

the mesh Many nodes: 131
Number of meshes and types: 130 SEG2

4.3 Quantities tested and results

the results in permanent mode for the displacement of the node C B give for computation 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 Modelization C

the comparison relates to the results with those of computations A and B.

5.1 Characteristic of the modelization

Modelization : 130 Elements équi-distribute Mesh: beam POU_D_T in x

5.2 the direction Characteristics of

the mesh Many nodes: 131
Number of meshes and types: 130 SEG2

5.3 Quantities tested and Computation

	results A	Computation B	Computation C	Variation in % (enters A and C)	Variation in % (enters 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 Modelization D

the comparison relates to the results with those of computations C.

6.1 Characteristic of the modelization

Modelization : 130 Elements équi-distribute Mesh: beam POU_D_T in z

6.2 the direction Characteristics of

the mesh Many nodes: 131
Number of meshes and types: 130 SEG2

6.3 Quantities tested and Computation

	results D (modulo $[2\pi]$)	Computation 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 beam element. The results of transient computation in permanent mode (with or without modal synthesis) result in finding those of harmonic computation.