SDLL124 – Diagram of Campbell of a beam in rotation with 3 discs subjected to the gyroscopy

Summarized:

This test makes it possible to validate the computation of the modes in rotation of a system of rotating shafts with the macro CALC_MODE_ROTATION and of the diagram of Campbell with the macro IMPR_DIAG_CAMPBELL.

In this test, it is about a simple model of rotor with 3 discs, supported by hydrodynamic bearings. This example is drawn from the reference [bib1].

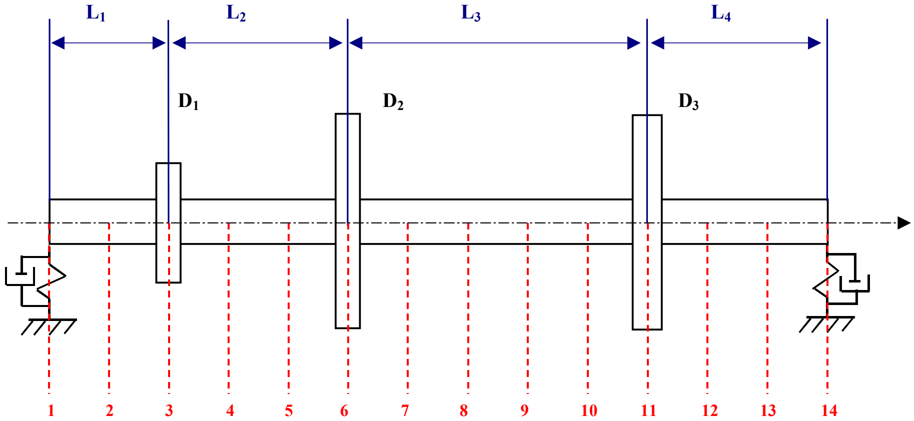
The results of reference result from a computation with ROTORINSA, [bib2], software finite elements intended to envisage the dynamic behavior of rotors in bending.

A good agreement is observed between the results of Code_Aster and the reference solution.

1 Problem of reference

1.1 Geometry

a simple model of rotor supported by 2 bearings (respectively first and last node of the rotor), is composed of 3 discs, the section of the shaft is of $0.05\,m$ radius. It measures $1.3\,m$ (cf appears below).



Appear 1.1-a: Model rotor with 3 discs resulting [bib1]

the respective lengths are:
$L_1=0.2\,m$ $L_2=0.3\,m$ $L_3=0.5\,m$ $L_4=0.3\,m$

1.2 Properties of the material

the characteristics of the material of the shaft and the discs are:

- Young's modulus $E=2.10^{11}$
- Density $\rho=7800\,kg/m^3$
- Poisson's ratio $\nu=0.3$

the characteristics of the discs are:

Disc	D_1	D_2	D_3
Thickness (m)	0.05	0.05	0.06
interior Radius (m)	0.05	0.05	0.05
Radius external (m)	the 0.12	0.20	0.20

characteristics of the bearings are:

$K_{yy}=5.10^7\,N/m$	$K_{zz}=7.10^7\,N/m$	$K_{yz}=K_{zy}=0$
$C_{yy}=5.10^2\,Ns/m$	$C_{zz}=7.10^2\,Ns/m$	$C_{yz}=C_{zy}=0$

1.3 Boundary conditions

to block motions of type rigid body in the direction x , one blocks the degree of freedom DX with the node of the first bearing (first node of the shaft).

2 Reference solution

2.1 Method of calculating

the results of reference are given by ROTORINSA, code with the finite elements intended to envisage the dynamic behavior of rotors in bending. The following parameters were used for the results of reference:

- The computation relates to a number of modes in rotation $NVES=8+4$, in ROTORINSA.
- The beach rotational speeds is defined of 0 with $30000\,tr/mn$ a step $10000\,tr/mn$.

2.2 Quantities and results of reference

the Results of ROTORINSA give the frequencies of the modes in bending.

The computation modes in rotation is carried out with Code_Aster by means of the same modelization as ROTORINSA. The results of Code_Aster give at the same time the frequencies of the modes of bending, torsion and tension/compression. The number of calculated modes is 20.

2.3 Bibliographical references

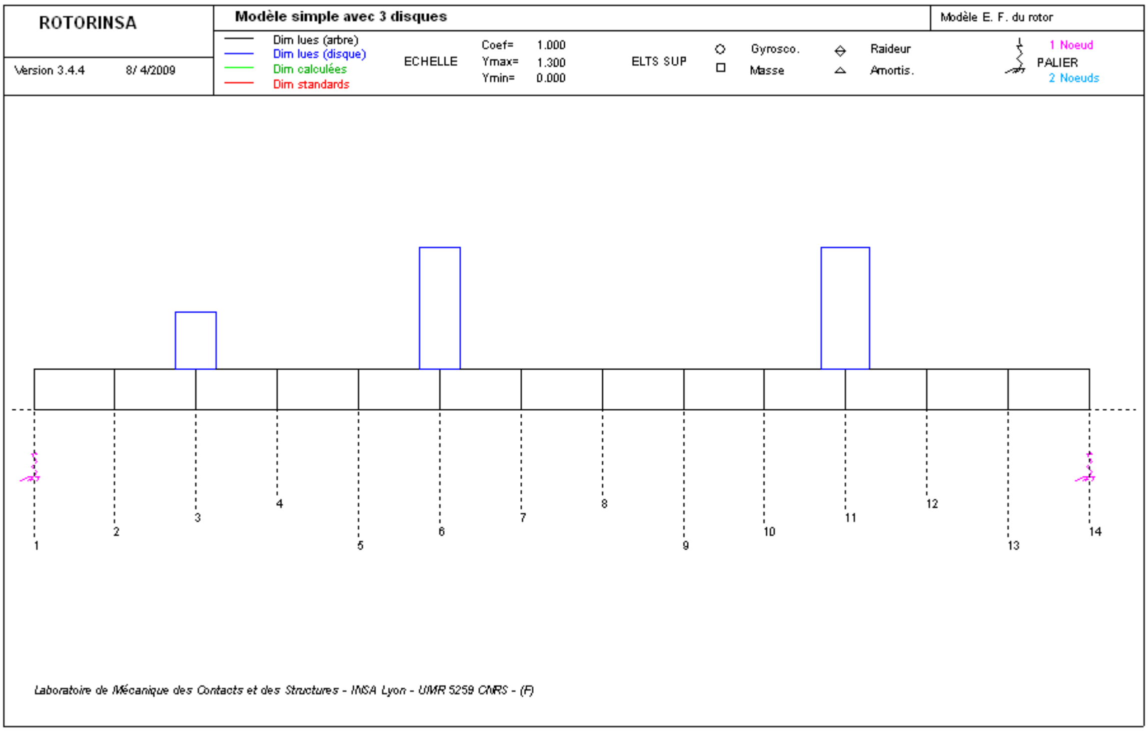
- Mr. LALANNE, G. FERRARIS, “ Rotordynamics Prediction in Engineering ”, Second Edition, Wiley, 2001.
- ROTORINSA, software finite elements intended to envisage the dynamic behavior of rotors in bending, LaMCoS UMR5259, INSA-Lyon.

3 Modelization A

3.1 Characteristic of the mesh

the rotor is with a grid in 13 finite elements of shaft of the type POU_D_T and of the same length and comprises 4 discrete elements of the type DIS_TR for the modelization of the discs and the bearings. It is the same model with the finite elements which was selected for computations by ROTORINSA.

Many nodes: 14
Number and type of elements: 13 SEG2
5 POI1



Appears 1-b: Characteristic of the model finite elements under ROTORINSA.

3.2 Quantities tested and Eigenfrequencies

3.2.1 results according to rotational speed

the values of the first 8 frequencies of bending for the velocities $0\,tr/mn$ and $30000\,tr/mn$, for the two software, are presented in the table below.

N° Fréq in flexionVitess	of rotation (tr/mn)	ROTORINSACode_AsterFacteur			
		$F(Hz)$	of amortissementTolérance	of $F(Hz)$	Tolerance of amortissementréduit106.06148 E+01
			5.03277E-041E-03		1.E-03300005.41119E+01
			2.66235E-041.E-03		1.4E-03
206.30255E+01			3.98814E-041.E-03		1.E-03
	300006.81221E+01		6.52538E-041.E-03		6.E-03
301.69496E+02			3.12313E-031.E-03		2.E-03
	300001.54652E+02		3.04410E-033.E-03		17.E-03
401.85563E+02			2.85327E-031.E-03		2.E-03
	300001.96002E+02		2.76113E-032.E-03		20.E-03

Table 2-a: Eigenfrequencies of type bending for Code_Aster and ROTORINSA

the frequencies obtained are in perfect adequacy with those of ROTORINSA.

In Code_Aster, one observes also frequencies and modes of torsion and modes of tension/compression. These modes are not calculated by ROTORINSA, because it models only the behavior in bending. The values of these frequencies are tested in NON_REGRESSION.

In short in the table below, are presented, the numbers the frequencies calculated and used in the layout of the diagram of Campbell in Code_Aster.

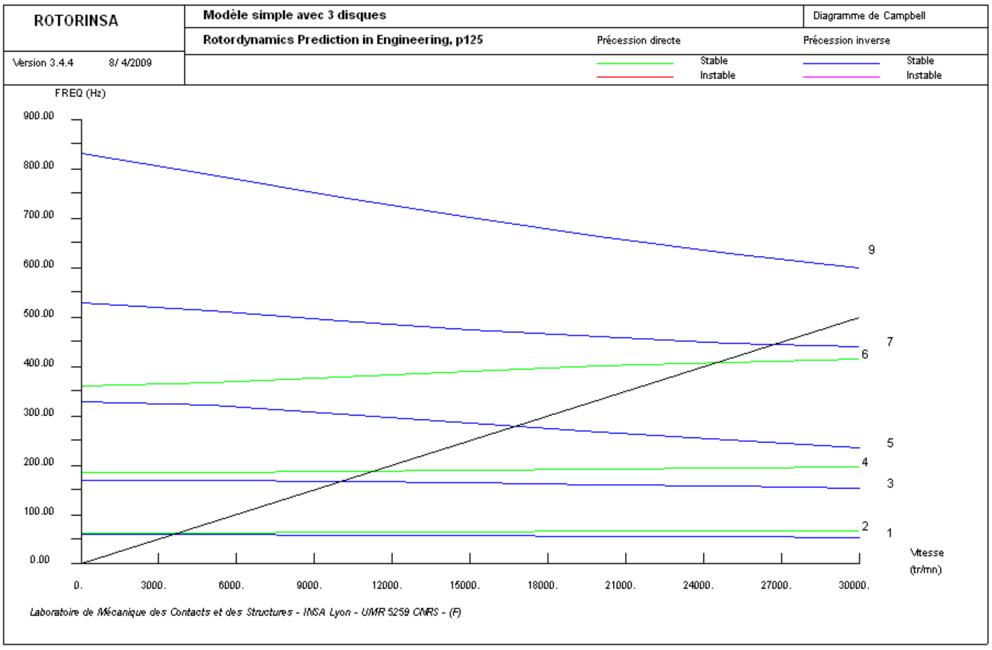
Number of values clean detected: 20
Many frequencies requested for the layout: 11

	calculated	traced
Many total frequencies	20	11
Many frequencies in bending	16	8
Many frequencies torsion	2	2
Number of frequencies tension/compression	2	1

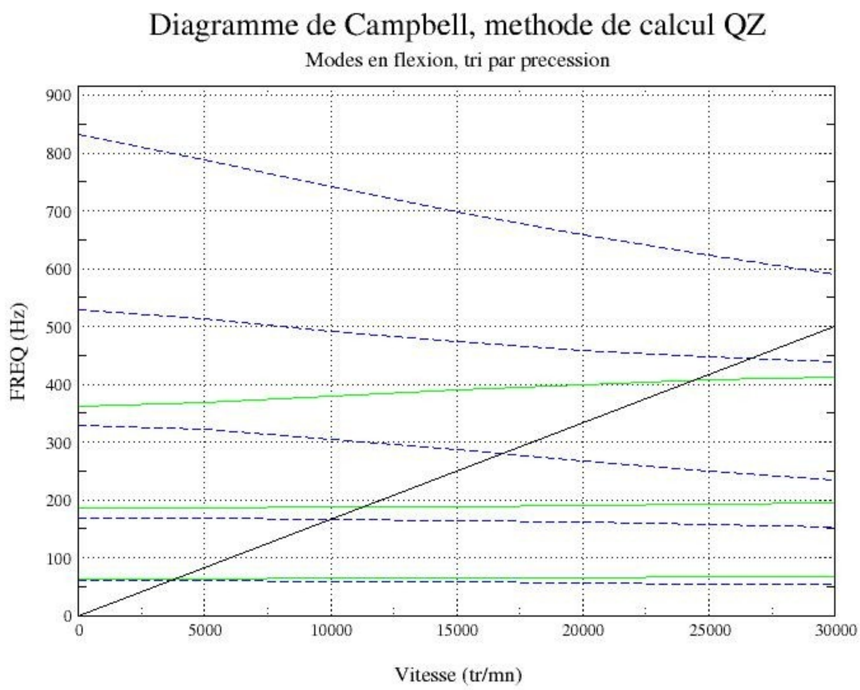
Table 2-d: Calculated and traced frequencies (Code_Aster)

3.2.2 Diagram of Campbell

the diagram of Campbell obtained in Code_Aster while following the modes of bending by sort of the frequencies gradually according to the meaning of the precession corresponds perfectly to that obtained by ROTORINSA.

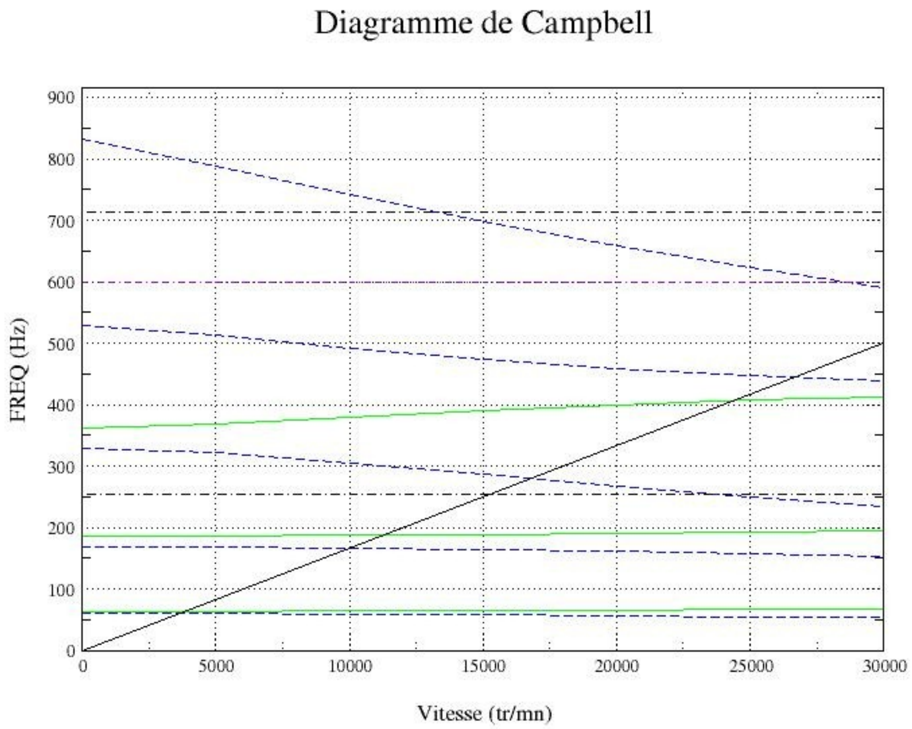


Appear 3.2.2-a: Diagram of Campbell in bending given by ROTORINSA



Appears 3-b: Diagram of Campbell in bending given by Code_Aster

One can also trace the follow-up of the modes of torsion and tension/compression. For this application, these modes are invariants compared to the vistess of rotation and thus the curves of evolution are horizontal lines.



Appear 3-c: Diagram of Campbell in bending, torsion and traction and compression

For the modes of torsion: line color black, style an indent, a dotted line.
For the modes of tension/compression: line color purple, style two indents, a dotted line.

3.2.3 Critical velocities (Points of intersection with the lines $Y=SX$)

the possible critical velocities due to the unbalances or synchronous revolving forces at the speed of the rotor, are obtained by the intersections of the right of slope $S=1$ with the curves of evolution of the frequencies. They are indicated in the output file of unit 25 of the command `IMPR_DIAG_CAMPBELL`.

Table below watch that the points of intersection for the modes in bending obtained are in perfect adequacy with those of ROTORINSA.

ROTORINSA $S=1$		Code-Aster $S=1$	
Velocity (tr/mn)	Frequency (Hz)	Velocity (tr/mn)	Frequency (Hz)
3615.68	60.26	3604.77	60.08
3801.95	63.37	3812.06	63.53
10019.11	166.99	10018.12	166.97
11282.96	188.05	11283.99	188.07
16809.10	280.15	16772.75	279.55
24520.53	408.68	24324.80	405.41

26743.11	445.72	26692.68	444.88

Table 4-a: Critical velocities by Code_Aster and ROTORINSA

Mode in Torsion
Points D intersection with the line $Y=SX$, with $S=1.00$
Velocity = $15240.61\,tr/mn$, Frequency = $254.01\,Hz$

4 Summary of the results

This benchmark makes it possible to validate the functionality Diagram of Campbell since one finds the same results by Code_Aster and ROTORINSA. It also makes it possible to validate the functionality making it possible to use the asymmetric discrete elements.