SHLL103 – Harmonic answer of a rotor with two discs and two nonsymmetrical stages, subjected to the gyroscopic effect

Summary:

This test makes it possible to validate the calculation of the harmonic answer of a system of rotating shafts with taking into account of the gyroscopic effect and the stages nonsymmetrical characteristics.

In this test, there is a model of rotor with two discs, supported by two hydrodynamic bearings, whose matrices of linearized stiffness and damping are nonsymmetrical. This example as well as the corresponding results of reference are drawn from the handbook of qualification of ROTORINSA, [bib2], computation software to the finite elements intended to envisage the dynamic behavior of rotors in inflection.

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

Contents

1 Problem of reference

1.1 Geometry

A model of rotor supported by 2 stages (nodes $B1$ and $B2$ on the figure below), whose matrices of stiffness and damping are nonsymmetrical. It is composed of 2 discs and 3 sections of tree.

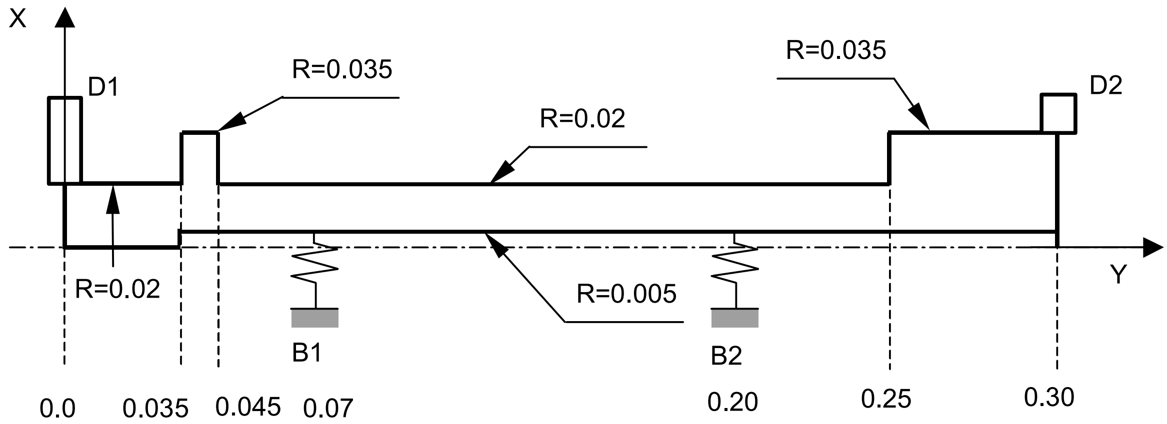


Image 1.1-1: Model of rotor with 2 asymmetrical discs and 2 stages

1.2 Material properties

The geometrical characteristics and material are listed in the following table.

Material		$E=2.10^{11} N/m^2$	$\rho=7800 kg/m^3$	$\nu=0.3$
Disc	$D1$	$M=3.5 kg$	$I_D=3.5\,10^{-3} kg\,m^2$	$I_P=7.10^{-3} kg\,m^2$
	$D2$	$M=3.0 kg$	$I_D=3.0\,10^{-3} kg\,m^2$	$I_P=6.10^{-3} kg\,m^2$

Table 1.2-1 : Geometrical characteristics and material

The characteristics of the stages are indicated in the table which follows.

Stage	$P1$	$K_{xx}=8.10^7 N/m$	$K_{zz}=1.10^8 N/m$
		$K_{xz}=-1.10^7 N/m$	$K_{zx}=-6.10^7 N/m$
		$C_{xx}=8.\,10^3 Ns/m$	$C_{zz}=1.2\,10^4 Ns/m$
		$C_{xz}=-3.\,10^3 Ns/m$	$C_{zx}=-3.10^3 Ns/m$
Stage	$P2$	$K_{xx}=5.10^7 N/m$	$K_{zz}=7.10^7 N/m$
		$K_{xz}=-2.\,10^6 N/m$	$K_{zx}=-4.\,10^7 N/m$
		$C_{xx}=6.\,10^3 Ns/m$	$C_{zz}=8.10^3 Ns/m$
		$C_{xz}=-1.5\,10^3 Ns/m$	$C_{zx}=-1.5\,10^3 Ns/m$

Table 1.2-2 : Characteristics of the stages

1.3 Boundary conditions and loadings

To block the movements of type rigid body in the direction y, the degrees of freedom are blocked DY and DRY with the node stage $B1$.

The loading is a harmonic force at a number of constant revolutions.

2 Reference solution

2.1 Method of calculating

The reference solution is that provided by code ROTORINSA, code finite elements (of standard beam of Timoshenko) intended to envisage the dynamic behavior of rotors in inflection.

2.2 Sizes and results of reference

They are calculations of answer to a harmonic force with four different number of revolutions of the rotor: 0,40000,50000 and 60000 tr/min .
The frequency of excitation of the harmonic force is $1\,Hz$, $25\,Hz$ and $250\,Hz$ successively.

At each number of revolutions of the rotor, two calculations are carried out:

- unit harmonic effort according to X applied to the node of the disc $D2$
- unit harmonic effort according to Z applied to the node of the disc $D2$

Each time, one raises values of the maximas of amplitude and phase to the node of the disc $D2$.

2.3 Bibliographical references

1. ROTORINSA, software finite elements intended to envisage the dynamic behavior of rotors in inflection, LaMCoS UMR5259, INSA-Lyon.

3 Modeling A

3.1 Characteristics of modeling

Modeling : 12 Elements équi-distribute beam `POU_D_T` in the direction y

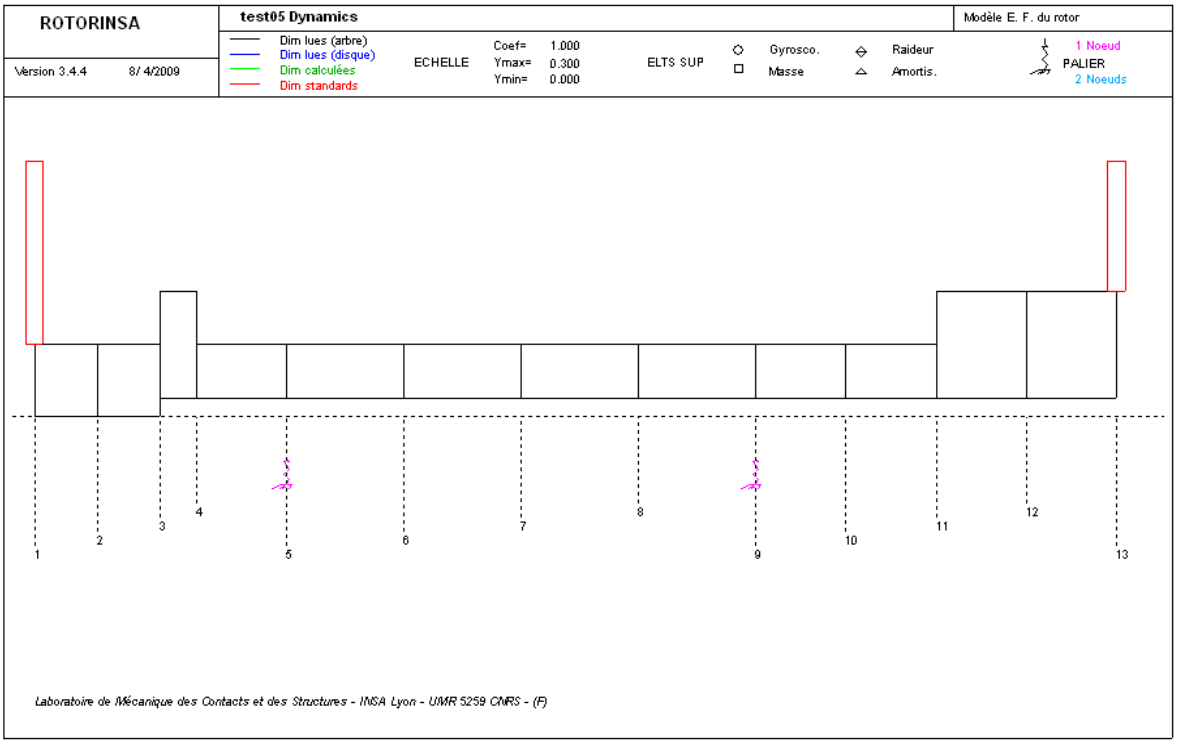
3.2 Characteristics of the grid

The rotor is with a grid in 12 finite elements of tree of the type `POU_D_T` and comprises 4 discrete elements of type `DIS_TR` for the modeling of the discs and stages.

Many nodes: 13

Number and type of elements: 12 SEG2

4 POI1



Images 3.2-1: Characteristics of the model finite elements under ROTORINSA

3.3 Loading

Unit harmonic effort, applied to the node corresponding to the disc $D2$.

4 Results

4.1 Rotor with the stop (OMEGA = 0 tr/min)

4.1.1 Unit harmonic effort according to X

Frequency in Hz	Displacement X of reference (m)	Displacement X Code_Aster (m)	Displacement Z of reference (m)	Displacement Z Code_Aster (m)
1	0.10319E-06	0.10331E-06	0.41444E-07	0.41409E-07
25	0.10445E-06	0.10457E-06	0.42396E-07	0.42362E-07
250	0.19043E-06	0.19380E-06	0.70701E-06	0.71396E-06

Table 4.1.1-1 : Displacements X and Z according to the frequency of excitation

Frequency in Hz	Phase X of reference (degrees)	Phase X Code_Aster (degrees)	Phase Z of reference (degrees)	Phase Z Code_Aster (degrees)
1	-0.0265	-0.0264	-0.0644	-0.0652
25	-0.6705	-0.6684	-1.6253	-1.6449
250	-137.1030	-137.7761	139.5277	141.6458

Table 4.1.1-2 : Phases X and Z according to the frequency of excitation

4.1.2 Unit harmonic effort according to Z

Frequency in Hz	Displacement X of reference (m)	Displacement X Code_Aster (m)	Displacement Z of reference (m)	Displacement Z Code_Aster (m)
1	0.26277E-08	0.26302E-08	0.83297E-07	0.8341E-07
25	0.27046E-08	0.27073E-08	0.84098E-07	0.84211E-07
250	0.72302E-07	0.72635E-07	0.32801E-06	0.33019E-06

Table 4.1.2-1 : Displacements X and Z according to the frequency of excitation

Frequency in Hz	Phase X of reference (degrees)	Phase X Code_Aster (degrees)	Phase Z of reference (degrees)	Phase Z Code_Aster (degrees)
1	-179.8568	-179.8576	179.9769	179.9770
25	-176.4619	-176.4823	179.4165	179.4181
250	-5.8731	-6.2622	115.2685	115.3362

Table 4.1.2-2 : Phases X and Z according to the frequency of excitation

4.2 Turning rotor with OMEGA = 40000 tr/min

4.2.1 Unit harmonic effort according to X

Frequency in Hz	Displacement X of reference (m)	Displacement X Code_Aster (m)	Displacement Z of reference (m)	Displacement Z Code_Aster (m)
1	0.10319E-06	0.10331E-06	0.41444E-07	0.41410E-07
25	0.10455E-06	0.10467E-06	0.42518E-07	0.42486E-07
250	0.48971E-07	0.48728E-07	0.23315E-06	0.23324E-06

Table 4.2.1-1 : Displacements X and Z according to the frequency of excitation

Frequency in Hz	Phase X of reference (degrees)	Phase X Code_Aster (degrees)	Phase Z of reference (degrees)	Phase Z Code_Aster (degrees)
1	-0.0068	-0.0067	-0.1637	-0.1647
25	-0.1664	-0.1632	-4.0901	-4.1134
250	-141.0235	-140.1804	98.1335	98.0294

Table 4.2.1-2 : Phases X and Z according to the frequency of excitation

4.2.2 Unit harmonic effort according to Z

Frequency in Hz	Displacement X of reference (m)	Displacement X Code_Aster (m)	Displacement Z of reference (m)	Displacement Z Code_Aster (m)
1	0.26295E-08	0.26320E-08	0.83297E-07	0.83408E-07
25	0.36470E-08	0.36511E-08	0.84180E-07	0.84293E-07
250	0.11311E-06	0.11328E-06	0.10572E-06	0.10612E-06

Table 4.2.2-1 : Displacements X and Z according to the frequency of excitation

Frequency in Hz	Phase X of reference (degrees)	Phase X Code_Aster (degrees)	Phase Z of reference (degrees)	Phase Z Code_Aster (degrees)
1	-177.9360	-177.9355	179.9964	179.9965
25	-138.3688	-138.3625	179.9183	179.9203
250	25.4329	25.4724	103.2116	103.5733

Table 4.2.2-2 : Phases X and Z according to the frequency of excitation

4.3 Turning rotor with OMEGA = 50000 tr/min

4.3.1 Unit harmonic effort according to X

Frequency in Hz	Displacement X of reference (m)	Displacement X Code_Aster (m)	Displacement Z of reference (m)	Displacement Z Code_Aster (m)
1	0.10319E-06	0.10331E-06	0.41444E-07	0.41410E-07
25	0.10460E-06	0.10472E-06	0.42577E-07	0.42545E-07
250	0.37618E-07	0.37498E-07	0.19422E-06	0.19431E-06

Table 4.3.1-1 : Displacements X and Z according to the frequency of excitation

Frequency in Hz	Phase X of reference (degrees)	Phase X Code_Aster (degrees)	Phase Z of reference (degrees)	Phase Z Code_Aster (degrees)
1	-0.0019	-0.0018	-0.1886	-0.1895
25	-0.0402	-0.0367	-4.7040	-4.7283
250	-128.6350	-127.5965	94.7082	94.6331

Table 4.3.1-2 : Phases X and Z according to the frequency of excitation

4.3.2 Unit harmonic effort according to Z

Frequency in Hz	Displacement X of reference (m)	Displacement X Code_Aster (m)	Displacement Z of reference (m)	Displacement Z Code_Aster (m)
1	0.26304E-08	0.26329E-08	0.83297E-07	0.83408E-07
25	0.40459E-08	0.40507E-08	0.84217E-07	0.84331E-07
250	0.10980E-06	0.10994E-06	0.89435E-07	0.89793E-07

Table 4.3.2-1 : Displacements X and Z according to the frequency of excitation

Frequency in Hz	Phase X of reference (degrees)	Phase X Code_Aster (degrees)	Phase Z of reference (degrees)	Phase Z Code_Aster (degrees)
1	-177.4564	-177.4555	-179.9987	-179.9986
25	-132.3829	-132.3742	-179.9561	-179.9539
250	28.1427	28.2043	108.0535	108.4359

Table 4.3.2-2 : Phases X and Z according to the frequency of excitation

4.4 Turning rotor with OMEGA = 60000 tr/min

4.4.1 Unit harmonic effort according to X

Frequency in Hz	Displacement X of reference (m)	Displacement X Code_Aster (m)	Displacement Z of reference (m)	Displacement Z Code_Aster (m)
1	0.10319E-06	0.10331E-06	0.41444E-07	0.41410E-07
25	0.10466E-06	0.10478E-06	0.42647E-07	0.42616E-07
250	0.30475E-07	0.30507E-07	0.16473E-06	0.16479E-06

Table 4.4.1-1 : Displacements X and Z according to the frequency of excitation

Frequency in Hz	Phase X of reference (degrees)	Phase X Code_Aster (degrees)	Phase Z of reference (degrees)	Phase Z Code_Aster (degrees)
1	0.0030	0.0313	-0.2134	-0.2144
25	0.0862	0.0899	-5.3164	-5.3416
250	-111.7419	-110.5334	92.0178	91.9669

Table 4.4.1-2 : Phases X and Z according to the frequency of excitation

4.4.2 Unit harmonic effort according to Z

Frequency in Hz	Displacement X of reference (m)	Displacement X Code_Aster (m)	Displacement Z of reference (m)	Displacement Z Code_Aster (m)
1	0.26314E-08	0.26339E-08	0.83297E-07	0.83408E-07
25	0.44804E-08	0.44860E-08	0.84262E-07	0.84375E-07
250	0.10475E-06	0.10486E-06	0.78438E-07	0.78777E-07

Table 4.4.2-1 : Displacements X and Z according to the frequency of excitation

Frequency in Hz	Phase X of reference (degrees)	Phase X Code_Aster (degrees)	Phase Z of reference (degrees)	Phase Z Code_Aster (degrees)
1	-176.9771	-176.9759	-179.9938	-179.9937
25	-127.4844	-127.4742	-179.8303	-179.8279
250	30.2686	30.3438	113.8704	114.2592

Table 4.4.2-2 : Phases X and Z according to the frequency of excitation

5 Summary of the results

It is noted that calculations of *Code_Aster* reproduce those of the reference accurately. One notes a good establishment of the gyroscopic effect for the element of beam and the discrete element, in the case of harmonic calculation.