SHLL103 – Harmonic response of a rotor with two discs and two asymmetric bearings, subjected to the Summarized gyroscopic

effect:

This test makes it possible to validate the computation of the harmonic response of a system of rotating shafts with taking into account of the gyroscopic effect and the bearings asymmetric characteristics.

In this test, there is a model of rotor with two discs, supported by two hydrodynamic bearings, whose stiffness matrixes and of damping linearized are asymmetric. 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 bending.

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 bearings (nodes $B1$ and $B2$ on the figure below), whose stiffness matrixes and of damping are asymmetric. It is composed of 2 discs and 3 sections of shaft.

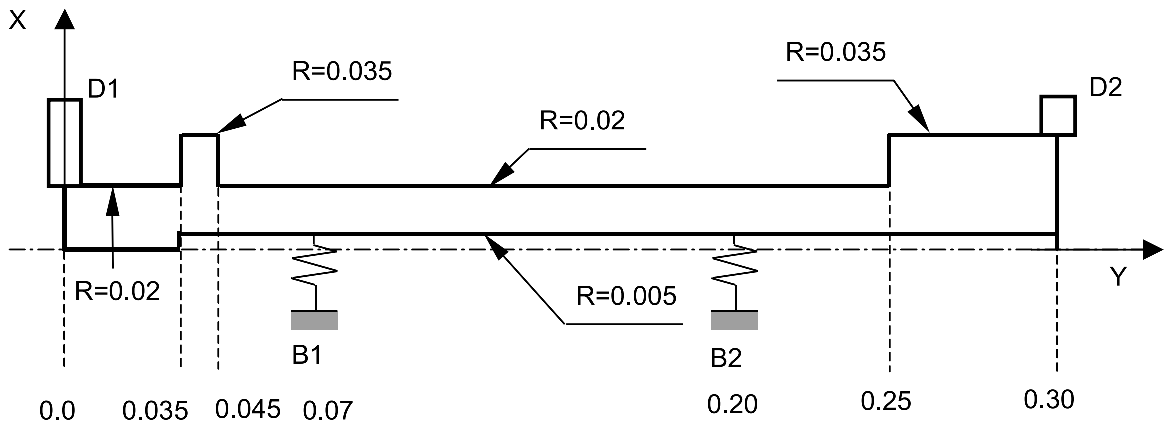


Image 1.1-1: Model rotor with 2 discs and 2 asymmetrical bearings

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 bearings are indicated in the table which follows.

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

Table 1.2-2 : Characteristics of the bearings

1.3 Boundary conditions and loadings

to block motions of type rigid body in the direction y, one blocks the degrees of freedom DY and DRY with the node bearing $B1$.
The loading is a harmonic force at a constant rotational speed.

2 Reference solution

2.1 Method of calculating

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

2.2 Quantities and results of reference

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

A each rotational speed of the rotor, two computations are carried out:
- unit harmonic force according to X applied to the node of the unit $D2$
- disc harmonic force according to Z applied to the node of the disc $D2$

A each time, one records the 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 bending, LaMCoS UMR5259, INSA-Lyon.

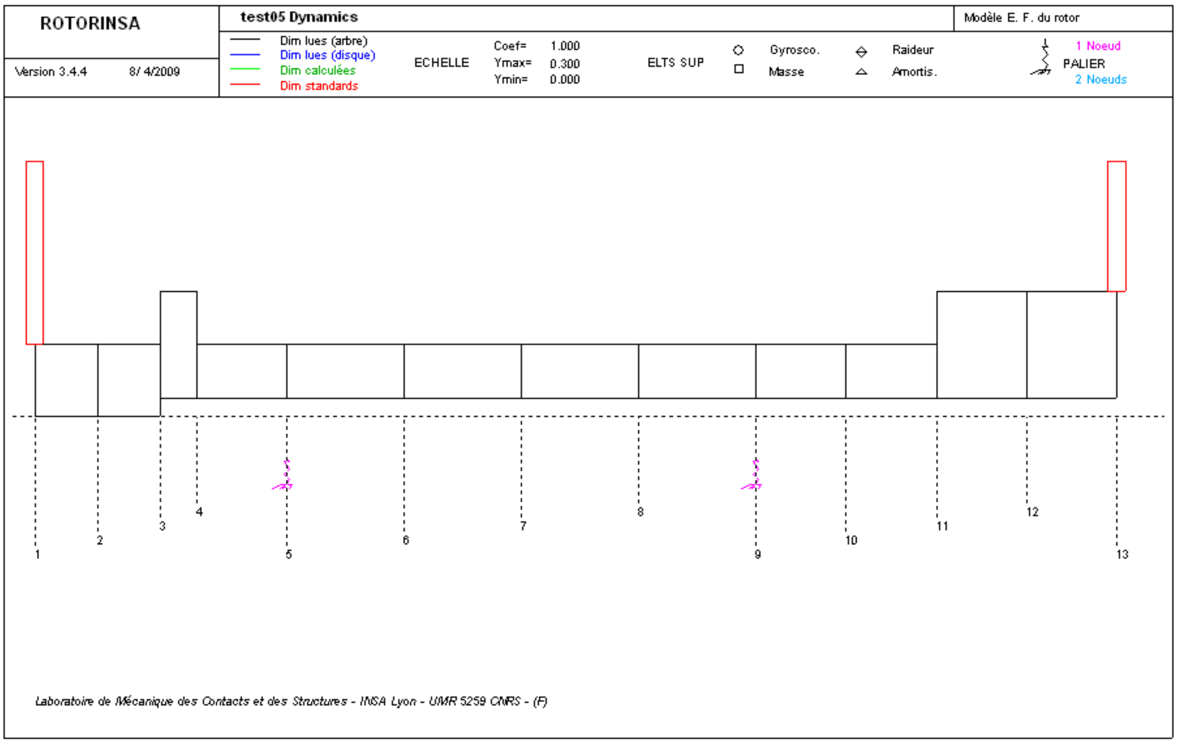
3 Modelization A

3.1 Characteristic of the modelization

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

3.2 Characteristics of the mesh

the rotor is with a grid in 12 finite elements of shaft of the type POU_D_T and comprises 4 discrete elements of the type DIS_TR for the modelization of the discs and the bearings.
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 unit

Loading harmonic Force, applied to the node corresponding to the disc $D2$.

4 Rotor

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

4.1.1 unit harmonic Force according to X

Frequency in Hz	Displacement X of reference (m)	Code_Aster X Displacement (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 excitation frequency

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 unit

4.1.2 excitation frequency harmonic Force 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 excitation frequency

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 excitation frequency

4.2 Rotor turning to OMEGA = 40000 tr/min

4.2.1 unit harmonic Force according to X

Frequency in Hz	Displacement X of reference	Code_Aster X	Displacement Z of	Displacement Z

	(m)	Displacement (m)	reference (m)	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 excitation frequency

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 unit

4.2.2 excitation frequency harmonic Force according to Z

Frequency in Hz	Displacement X of reference (m)	Code_Aster X Displacement (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 excitation frequency

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 excitation frequency

4.3 Rotor turning to OMEGA = 50000 tr/min

4.3.1 unit harmonic Force according to X

Frequency in Hz	Displacement X of reference (m)	Code_Aster X Displacement (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 excitation frequency

Frequency in Hz	Phase X of reference	Phase X Code_Aster (degrees)	Phase Z of reference (degrees)	Phase Z Code_Aster (degrees)

	(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 unit

4.3.2 excitation frequency harmonic Force according to Z

Frequency in Hz	Displacement X of reference (m)	Code_Aster X Displacement (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 excitation frequency

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 excitation frequency

4.4 Rotor turning to OMEGA = 60000 tr/min

4.4.1 unit harmonic Force according to X

Frequency in Hz	Displacement X of reference (m)	Code_Aster X Displacement (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 excitation frequency

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 unit

4.4.2 excitation frequency harmonic Force according to Z

Frequency in Hz	Displacement X of reference (m)	Code_Aster X Displacement (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 excitation frequency

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 excitation frequency

5 Summary of the results

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