SDLL125 - Pin addition to in rotation with 2 nonsymmetrical discs and 2 stages subjected to the gyroscopy

Summary:

This test makes it possible to validate the calculation of the modes in rotation of a system of rotating shafts according to the axis of rotation Z with order CALC_MODE_ROTATION and DE to highlight instability. This validation relates to the positive number of revolutions as well (modeling A) that the negative number of revolutions (modeling B). Modeling C, as for it, validates the taking into account of a system of rotating shafts according to the axis of rotation Y.

In this test, there is a model of rotor with two discs, supported by two hydrodynamic bearings, whose matrices of 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], software 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.

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 3 discs, and 3 sections of tree.

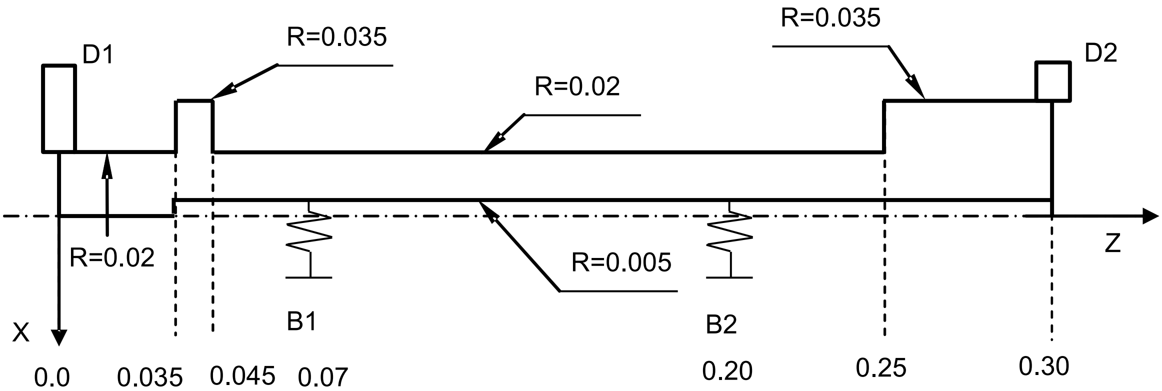

Figure 1.1-a- has: Model of rotor with 2 asymmetrical discs and 2 stages

1.2 Properties of material

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	$D1$	$M=3.5\, kg$	$I_D=3.5\, 10^{-3}\, kg\, m^2$	$I_P=7.10^{-3}\, kg\, m^2$
	$D2$	$M=3.0\, kg$	$I_D=3.0\, 10^{-3}\, kg\, m^2$	$I_P=6.10^{-3}\, kg\, m^2$

1.3 Boundary conditions

To block the movements of type rigid body in the direction Z, the degree of freedom is blocked DZ with the node stage $B1$.

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 inflection. The following parameters were used for the results of reference:

- Calculation relates to a number of modes in rotation $NVES=8+4$, in ROTORINSA.
- The beach number of revolutions is defined of 0 with $60000\,tr/mn$ with a step $5000\,tr/mn$.

2.2 Sizes and results of reference

The Results of ROTORINSA give the frequencies of the modes in inflection.

The calculation of the modes in rotation is carried out with Code_Aster by using same modeling as ROTORINSA. The results of Code_Aster give at the same time the frequencies of the modes of inflection, torsion and traction/compression. The number of calculated modes is 20.

2.3 Bibliographical references

1 MR. LALANNE, G. FERRARIS, “ Rotordynamics Prediction in Engineering “, Second Edition, Wiley, 2001.

2 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

It is about a system of rotating shafts according to the axis Z with positive number of revolutions. The characteristics of the stages are indicated in the table which follows.

Stage $P1$

$K_{yy}=8.10^7\ N/m$ $K_{xx}=1.10^8\ N/m$
$K_{yx}=-1.10^7\ N/m$ $K_{xy}=-6.10^7\ N/m$
$C_{yy}=8.10^3\ Ns/m$ $C_{xx}=1.2\,10^4\ Ns/m$
$C_{yx}=-3.10^3\ Ns/m$ $C_{xy}=-3.10^3\ Ns/m$

Stage $P2$

$K_{yy}=5.10^7\ N/m$ $K_{xx}=7.10^7\ N/m$
$K_{yx}=-2.10^6\ N/m$ $K_{xy}=-4.10^7\ N/m$
$C_{yy}=6.10^3\ Ns/m$ $C_{xx}=8.10^3\ Ns/m$
$c_{yx}=-1.5\,10^3\ Ns/m$ $C_{xy}=-1.5\,10^3\ Ns/m$

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

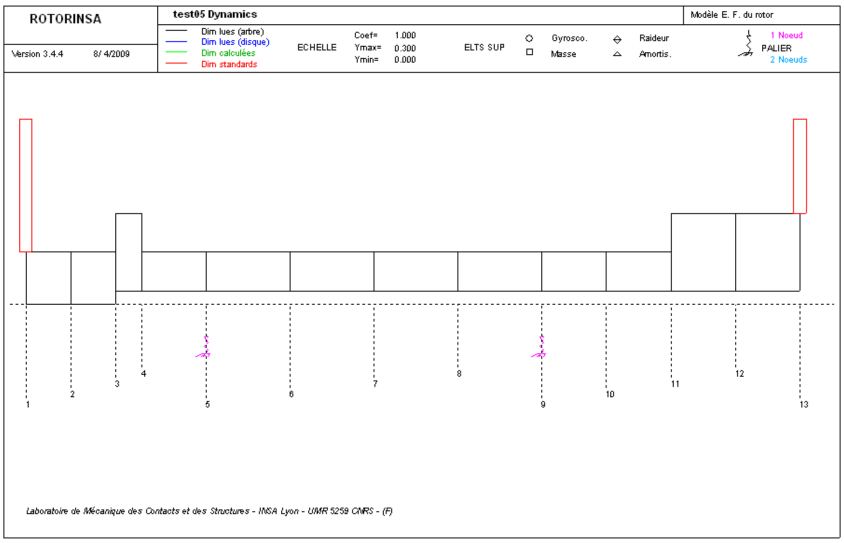

Figure 1-b: Characteristic of the model finite elements under ROTORINSA

3.3 Sizes tested and results

3.3.1 Eigen frequencies according to the number of revolutions

Values of the first 8 frequencies of inflection for speeds $0\,tr/mn$ and $60000\,tr/mn$, for the two software, are presented in the table below

N° Fréq in inflection	Number of revolutions (tr/min)	ROTORINSA		Code_Aster	
		$F(Hz)$	Damping ratio	Tolerances of $F(Hz)$	Tolerances of damping reduced
1	0	2.16212E+02	4.76544E-02	1.E-3	1.E-3
	60000	1.85365E+02	-5.17463E-02	1.E-3	1.1E-3
2	0	2.63539E+02	7.87281E-02	1.E-3	6.E-3
	60000	2.96078E+02	1.55245E-01	1.E-3	5.E-3
3	0	3.83210E+02	5.01438E-02	1.E-3	14.E-3
	60000	3.24718E+02	1.57489 E-03	1.E-3	7.E-3
4	0	4.39642E+02	6.02275E-02	1.E-3	12.E-3
	60000	4.72541E+02	1.59683E-01	1.2E-3	3.E-3

Table 2-a: Eigen frequencies of standard inflection for Code_Aster and ROTORINSA

The frequencies obtained are in perfect adequacy with those of ROTORINSA.
One notes an instability of the first mode, which appears with $16\,760\,tr/mn$.

In Code_Aster, one observes also frequencies and modes of torsion and modes of traction/compression. These modes are not calculated by ROTORINSA, because it models only the behavior in inflection. The values of these frequencies are tested in NON_REGRESSION and this only with the stop. Indeed, the modes of torsion and traction are, by definition, invariants compared to the number of revolutions.

4 Modeling B

4.1 Characteristics of modeling

It is about a system of rotating shafts according to the axis Z with negative number of revolutions. To get the same results as modeling A (with the minus sign less nearer), it is necessary to put a minus sign on the cross terms of the matrices of stiffness and damping. The characteristics of the stages are indicated in the table which follows.

Stage	$P1$	$K_{yy}=8.10^7\ N/m$	$K_{xx}=1.10^8\ N/m$
		$K_{yx}=1.10^7\ N/m$	$K_{xy}=6.10^7\ N/m$
		$C_{yy}=8.10^3\ Ns/m$	$C_{xx}=1.2\ 10^4\ Ns/m$
		$C_{yx}=3.10^3\ Ns/m$	$C_{xy}=3.10^3\ Ns/m$
Stage	$P2$	$K_{yy}=5.10^7\ N/m$	$K_{xx}=7.10^7\ N/m$
		$K_{yx}=2.10^6\ N/m$	$K_{xy}=4.10^7\ N/m$
		$C_{yy}=6.10^3\ Ns/m$	$C_{xx}=8.10^3\ Ns/m$
		$C_{yx}=1.5\ 10^3\ Ns/m$	$C_{xy}=1.5\ 10^3\ Ns/m$

Consequently, the precessions of the modes are also reversed, i.e. that the direct modes become retrograde and vice versa.

4.2 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

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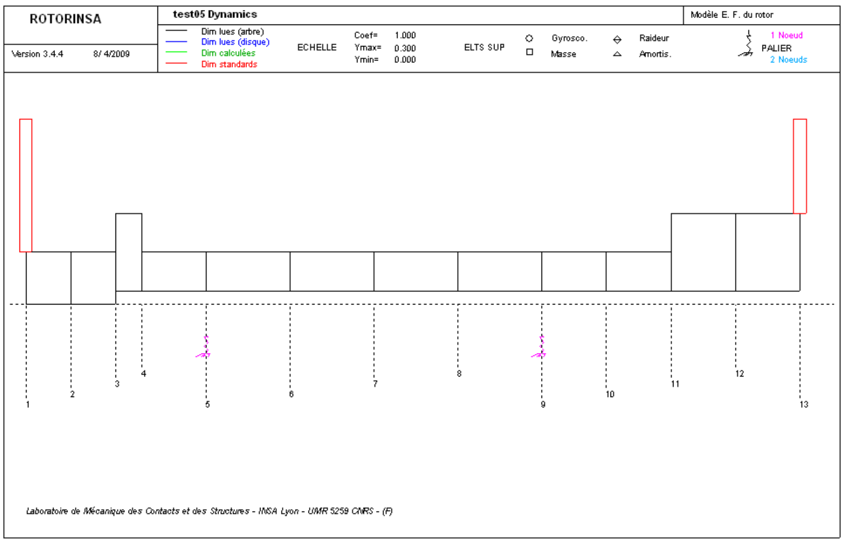

Figure 1-b: Characteristic of the model finite elements under ROTORINSA

4.3 Sizes tested and results

4.3.1 Eigen frequencies according to the number of revolutions

Values of the first 8 frequencies of inflection for speeds $0\,tr/mn$ and $-60000\,tr/mn$, for the two software, are presented in the table below.

N° Fréq in inflection	Number of revolutions (tr/min)	ROTORINSA		Code_Aster	
		$\lvert F\rvert(Hz)$	Damping ratio	Tolerances of $\lvert F\rvert(Hz)$	Tolerances of damping reduced
a1	0	2.16212E+02	4.76544E-02	1.E-3	1.E-3
	-60000	1.85365E+02	-5.17463E-02	1.E-3	1.1E-3
2	0	2.63539E+02	7.87281E-02	1.E-3	6.E-3
	-60000	2.96078E+02	1.55245E-01	1.E-3	5.E-3
3	0	3.83210E+02	5.01438E-02	1.E-3	14.E-3
	-60000	3.24718E+02	1.57489 E-03	1.E-3	70.E-3
4	0	4.39642E+02	6.02275E-02	1.E-3	12.E-3
	-60000	4.72541E+02	1.59683E-01	1.2E-3	3.E-3

Table 2-a: Eigen frequencies of standard inflection for Code_Aster and ROTORINSA

The frequencies obtained are in perfect adequacy with those of ROTORINSA.
One notes an instability of the first mode, which appears with $-16\,760\,tr/mn$.

In Code_Aster, one observes also frequencies and modes of torsion and modes of traction/compression. These modes are not calculated by ROTORINSA, because it models only the behavior in inflection. The values of these frequencies are tested in `NON_REGRESSION` and this only with the stop. Indeed, the modes of torsion and traction are, by definition, invariants compared to the number of revolutions.

5 Modeling C

5.1 Characteristics of modeling

It is about a system of rotating shafts according to the axis Y with positive number of revolutions. The change of reference mark requires a new setting in data of the characteristics of the stages, which are indicated in the table which follows.

Stage $P1$

$$K_{xx}=8.10^7 N/m \quad K_{zz}=1.10^8 N/m$$
$$K_{xz}=-1.10^7 N/m \quad K_{zx}=-6.10^7 N/m$$
$$C_{xx}=8.10^3 Ns/m \quad C_{zz}=1.2\,10^4 Ns/m$$
$$C_{xz}=-3.10^3 Ns/m \quad C_{zx}=-3.10^3 Ns/m$$

Stage $P2$

$$K_{xx}=5.10^7 N/m \quad K_{zz}=7.10^7 N/m$$
$$K_{xz}=-2.10^6 N/m \quad K_{zx}=-4.10^7 N/m$$
$$C_{xx}=6.10^3 Ns/m \quad C_{zz}=8.10^3 Ns/m$$
$$C_{xz}=-1.5\,10^3 Ns/m \quad C_{zx}=-1.5\,10^3 Ns/m$$

5.2 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.
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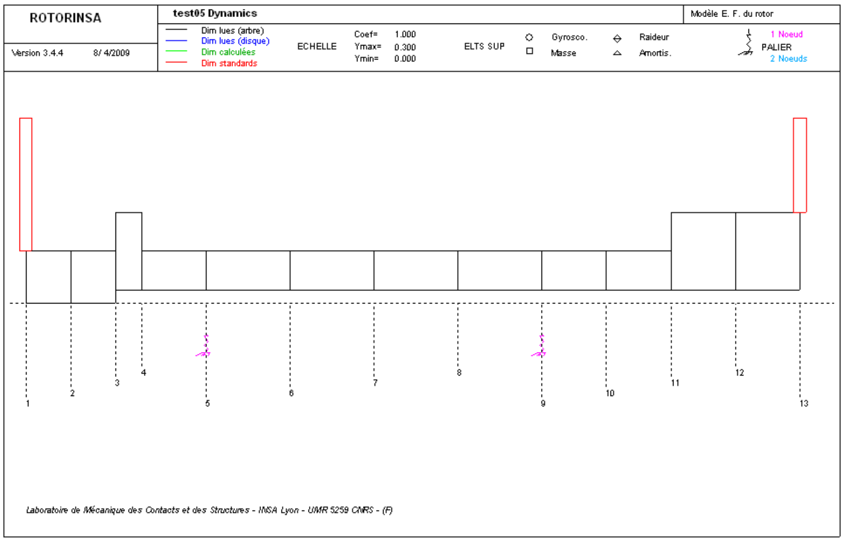

Figure 1-b: Characteristic of the model finite elements under ROTORINSA

5.3 Sizes tested and results

5.3.1 Eigen frequencies according to the number of revolutions

Values of the first 8 frequencies of inflection for speeds $0\,tr/mn$ and $60000\,tr/mn$, for the two software, are presented in the table below.

N° Fréq in inflectio n	Number of revolutions (tr/min)	ROTORINSA		Code_Aster	
		$F(Hz)$	Damping ratio	Tolerances of $F(Hz)$	Tolerances of damping reduced
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6 Summary of the results

This CAS-test allows DE to validate the calculation of the modes in rotation of a system of rotating shafts according to the axis of rotation Z with order CALC_MODE_ROTATION, at the same time for negative and positive number of revolutions since one finds the same results by Code_Aster and ROTORINSA.