SDLL144 – Transient speed of a beam in rotation with a disc

Summary:

This test makes it possible to validate the temporal answer to a transient number of revolutions of a system of rotating shafts. The rotor is full, of circular section and comprises a disc. The laws of rise speed considered here are of type linear (modeling A) and exponential (modeling B).

For this case test, the loading of the standard unbalance is installed on the disc. The comparison relates to the value of the peaks of resonance of displacements of the disc.

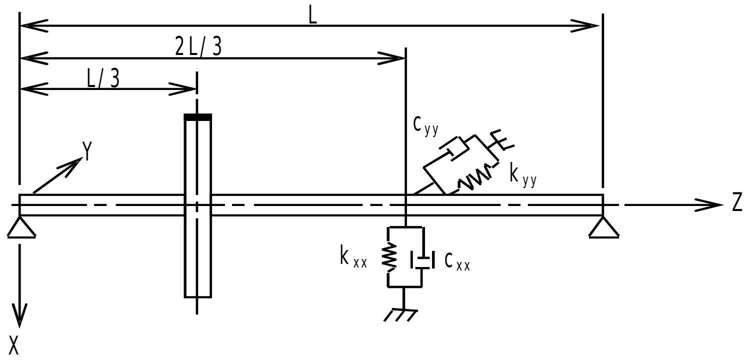
This problem also makes it possible to validate the effect of the matrices of damping and gyroscopic stiffness which were developed for the right beams of Timoshenko and Euler.

The got results are in concord with those given in reference. The references are based on the theory of the beams of Timoshenko.

1 Problem of reference

1.1 Geometry

The structure is made up of a rotor full length L with constant circular section with a disc located at the third its length.



Modeling:

	Mass (kg)	I_{zz} ($kg.m^2$)	$I_{xx}=I_{yy}$ ($kg.m^2$)
Disc	16.47	0.1861	0.09427

Table 1.1-1 : Characteristics of the discs

Length of the beam:

$L=0.4\,m$

Circular section:

Diameter: $D=0.02\,m$

1.2 Properties of material

$E=2.10^{11}\,Pa$

$\nu=0.3$

$\rho=7800\,kg/m^3$

1.3 Boundary conditions

The rotor is pressed on two infinitely rigid stages at the two ends and on an elastic bearing with viscous damping to two thirds its length. The coefficients of the stage are the following:

$K_{xx}=2.10^5\,N.m^{-1}$; $K_{yy}=5.10^5\,N.m^{-1}$; $K_{xy}=K_{yx}=0$

$C_{xx}=4.10^1\,N/(m.s^{-1})$; $C_{yy}=1.10^2\,N/(m.s^{-1})$; $C_{xy}=C_{yx}=0$

2 Reference solution

2.1 Method of calculating used for the reference solution

The reference solutions that are presented in the work of Michel LALANNE and Guy FERRARIS and that obtained with the code CADYRO, software finite elements intended to envisage the dynamic behavior of rotors.

Digital results CADYRO were got with elements beam of the Timoshenko type. Modeling is carried out with 4 nodes (3 elements beams).

2.2 Sizes and results of reference

With a loading of type unbalance, the values tested are the maximas of amplitude for the node corresponding to the disc, and this for two laws of rise of number of revolutions going of 0 with $5000\,tr/min$ (concept of resonance at the critical velocity).

2.3 Uncertainty on the solution

Lower than 5%.

2.4 Bibliographical references

- Michel LALANNE and Guy FERRARIS, Rotordynamics, Prediction in Engineering, JOHN WILEY AND SOUNDS (1990).
- CADYRO, software finite elements intended to envisage the dynamic behavior of rotors in inflection.

3 Modeling A

3.1 Characteristics of modeling and the grid

The rotor is with a grid in 3 finite elements of tree of the type `POU_D_T` regularly distributed and 1 discrete element of type comprises `DIS_TR` for the modeling of the stage.

Many nodes: 4
Number and type of elements: 3 SEG2
1 POI1

3.2 Loading

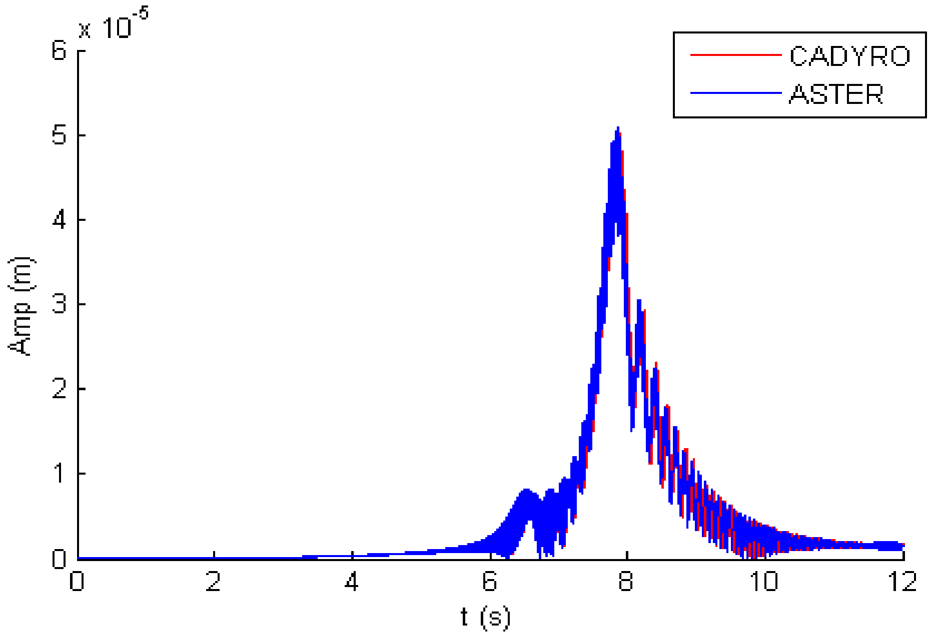
The unbalance is installed on the node disc. It is characterized by a mass of $10^{-4}\,kg$, a distance with neutral fibre of the tree of $0.15\,m$ and an initial dephasing no one. Its value is of $15.10^{-6}\,m.kg$.
The linear law of rise imposed speed is the following one: $\dot{\phi}=416,7\,t$

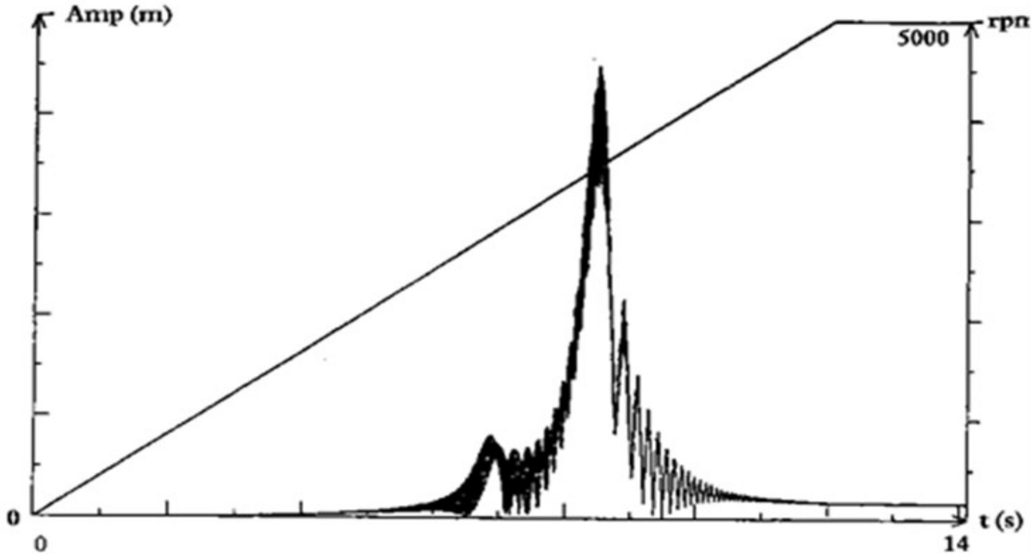
3.3 Results

One tests the moment for which the vibratory eccentricity reaches its maximum as well as the corresponding maximum amplitude.

Result	A^2_{max} (m)	t_{max} (s)
Reference CADYRO	2,5810E-009	7,89
Reference LALANNE	2,1996E-009	8,44
Code_Aster	2,65697E-009	7,872350
Relative error Aster/CADYRO	3,0%	0,22%
Relative error Aster/LALANNE	20,79%	6,72%

Table 3.3-1 : Sizes tested for a linear law of rise of speed




Amp (m)
rpn
5000
0
0
t (s)
14

4 Modeling B

4.1 Characteristics of modeling and the grid

The rotor is with a grid in 3 finite elements of tree of the type `POU_D_T` regularly distributed and 1 discrete element of type comprises `DIS_TR` for the modeling of the stage.

Many nodes: 4
Number and type of elements: 3 SEG2
1 POI1

4.2 Loading

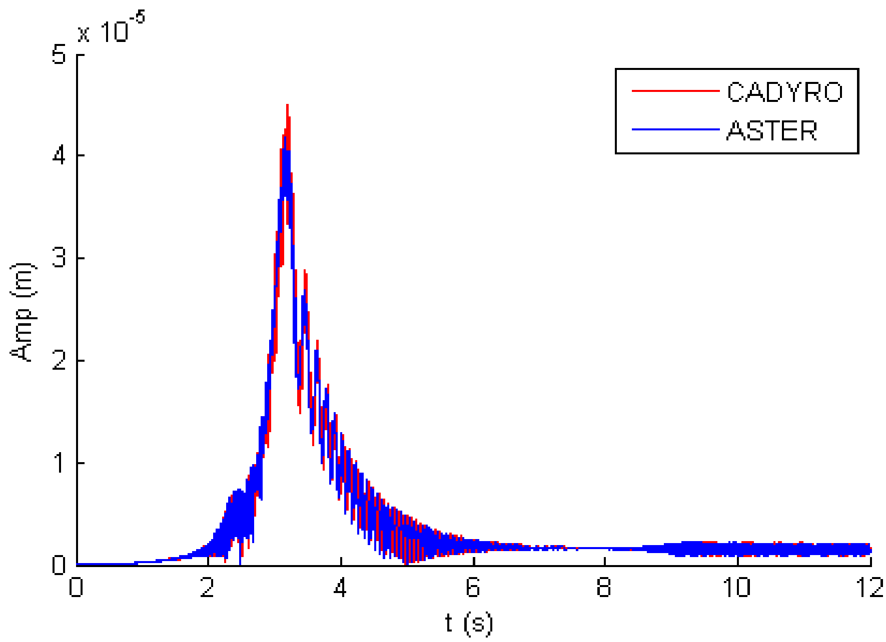
The unbalance is installed on the node disc. It is characterized by a mass of $10^{-4}\,kg$, a distance with neutral fibre of the tree of $0.15\,m$ and an initial dephasing no one. Its value is of $15.10^{-6}\,m.kg$.
The exponential law of rise imposed speed is the following one:
$\dot{\phi}=5100(1-\exp^{-0.3273t})$

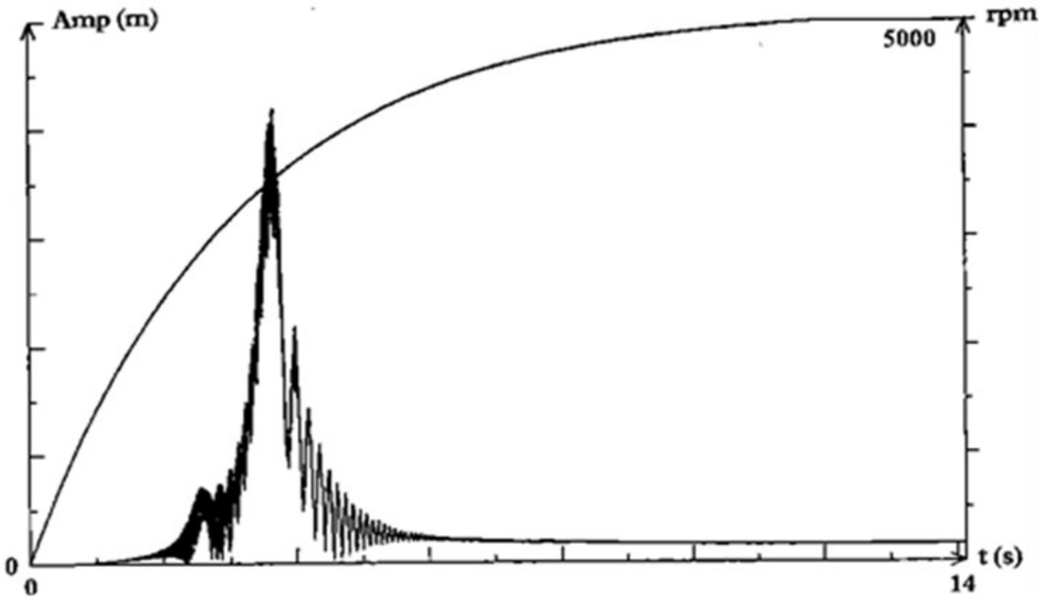
4.3 Results

One tests the moment for which the vibratory eccentricity reaches its maximum as well as the corresponding maximum amplitude.

Result	A_{max}^2 (m)	t_{max} (s)
Reference CADYRO	2,0160E-009	3,19
Reference LALANNE	1,8063E-009	3,5
Code_Aster	2,02639E-009	3,196750
Relative error Aster/CADYRO	0,5%	0,21%
Relative error Aster/LALANNE	12,2%	8,66%

Table 4.3-1 : Sizes tested for an exponential law of rise of speed





5 Summary of the results

One obtains a good correspondence between the results simulated with CADYRO and Code_Aster (relative errors lower than 3%). However, from the important variations (of 20% at the most) are obtained with the results resulting from the bibliography. These variations can be simply explained by the difference of the base of projection. Indeed, the space station used in the bibliography takes into account only the first clean mode of a beam in inflection on simple supports. Code_Aster and CADYRO use a more precise modal base. The method of resolution by modal recombination on an incomplete basis is very sensitive to the effects of truncation which tend to rigidify the structure overall. This results thus in to increase the frequencies of resonance, which explains why the peaks appear for larger number of revolutions and thus later in time (gone up of speed here). One thus notes a good matrix installation of gyroscopic damping and stiffness for the element of beam , in the case of calculation of the temporal answer on modal basis for a transient of rise of speed .