SDLL127 – Line of trees with rotor with circular section variable

Abstract:

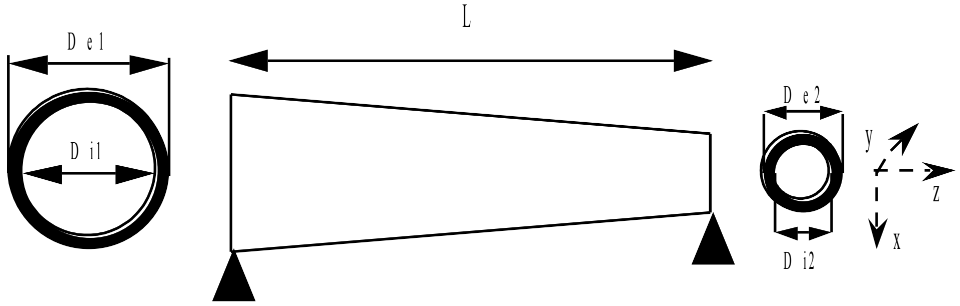
This test makes it possible to validate the computation of the modes in rotation of a system of shafts at rest or turning with a rotor with variable section.

In this test, there is a model of rotor with variable circular section resting on two bearings discs whose stiffness matrixes and of damping are symmetric. This example is drawn from the handbook of qualification of CADYRO, [bib1], software finite elements intended to envisage the dynamic behavior of rotors.

1 Problem of reference

1.1 Geometry

the structure is made up of a rotor from length L to variable circular section with two infinitely rigid bearings on the level of the bearings. The diameters of the section of the rotor vary in a linear way according to the length.



1.2 Properties of the material

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

Material	$E=210^{11} N/m^2$ $\rho=7800\,kg/m^3$	$\nu=0.3$
Length rotor	$L=1\,m$	
Diameter section	external diameter initial	$De1=0{,}2\,m$
	final diameter external	$De2=0{,}1\,m$
Thickness	in any point of the rotor:	$De-Di=0{,}04\,m$

Table 1.2-1

coefficients in translation of the bearings are: $Kxx=Kyy=1.0\mathrm{E}+12\,kg.s^{-2}$
$Kxy=Kyx=0.0\,kg.s-2$

$Cxx=Cyy=Cxy=Cyx=0.0\,kg.s^{-1}$

The coefficients in torsion of the bearings are: $Krz=Kry=1.0\mathrm{E}+12\,kg.s^{-2}$
$Kxy=Kyx=0.0\,kg.s-2$

$Crx=Cry=Cxy=Cyx=0.0\,kg.s^{-1}$

1.3 Boundary conditions

the rotor is leaned on two rigid bearings at the two ends.

2 Reference solution

2.1 Method of calculating

the method used for the reference solution is purely numerical. Indeed, L be results of reference are obtained by a discretization in beam elements with constant circular section.
The values of reference were framed by the results of two modelizations:

1. The first, approaching the exact solution by lower values, consists in assigning to each element the constant circular section of diameter equal to the diameter of the rotor studied with the right of the initial node of the element.
2. The second, approaching the exact solution by higher values, consists in assigning to each element the constant circular section of diameter equal to the diameter of the rotor studied with the right of the final node of the element.

Each modelization uses a regular cutting of the rotor in 2000 beam elements with constant circular section. The numerical results were also compared with those resulting from code CADYRO and uncertainty on the values of reference is of to the more 0.02%.

2.2 Quantities and results of reference

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 12.

2.3 Bibliographical references

• CADYRO, software finite elements intended to envisage the dynamic behavior of rotors in bending.

3 Modelization A

3.1 Characteristic of the modelization

3.2 Characteristics of the mesh

the rotor is with a grid in 40 finite elements of shaft of the type POU_D_T regularly distributed and comprises 2 discrete elements of the type DIS_TR for the modelization of the bearings.

Many nodes: 41

Number and type of elements:
40 SEG2
2 POI1

3.3 Quantities tested and results

the values of the first 12 frequencies to the stop and for rotational speed $4000\, tr/min$, for both méthodes de calcul, are presented in table below

N° Fréq	Rotational speed (tr/mn)	Rotor ASTER with shaft to section variableCalcul $F(Hz)$	ASTER with shaft to constant section finely with a grid $F(Hz)$
10332.8033 2.14400033 1.51331.512 0332.80332. 144000334. 10334.1030 1199.18119 3.81400011 96.301196.3 0401199.18 1193.81400 01202.0612 02.0550160 7.141607.19 40001607.1 41607.1960 2308.41229 1.51400023 04.732304.7 3702308.41 2291.51400 02312.0923 12.0880251 2.222512.22 40002512.2 22512.2290 3162.68316 0.39400031 62.683160.3 9003520.23 3520.23400 03516.4335 16.4311035 20.233520.2 340003524. 023524.021 204733.604 724.144000 4733.60472 4.14			
	4000		
	4000		
	4000		
	4000		
	4000		
	4000		
	4000		
	4000		
	4000		
	4000		

Table 3.3-1 : Eigenfrequencies obtained by computations direct and indirect

4 Modelization B

4.1 Characteristic of the mesh

the rotor is with a grid in 2000 finite elements of shaft of the type POU_D_T regularly distributed and comprises 2 discrete elements of the type DIS_TR for the modelization of the bearings.

Many nodes: 2001

Number and type of elements:
2000 SEG2
2 POI1

4.2 Quantities tested and results

the values of the first 12 frequencies to the stop and for rotational speed $4000\,tr/min$ is presented in table below

N° Fréq	Rotational speed (tr/mn)	Aster computation with shaft to constant section finely with a grid F (Hz)
10332.8740 00331.5720 332.874000 334.163011 99.0540001 196.204011 99.0540001 201.905016 07.1740001 607.176023 06.0040002 302.897023 06.0040002 310.098025 11.6040002 511.609031 60.3940003 160.390035 20.8040003 509.101103 520.804000 3516.40120 4724.14400 04724.10	4000	
	4000	
	4000	
	4000	
	4000	
	4000	
	4000	
	4000	
	4000	
	4000	
	4000	
12	4000	

Table 4.2-1 : Eigenfrequencies obtained by QZ

5 Modelization C

5.1 Characteristic of the mesh

the rotor is with a grid in 2000 finite elements of shaft of the type POU_D_T regularly distributed and comprises 2 discrete elements of the type DIS_TR for the modelization of the bearings.

Many nodes: 2001

Number and type of elements:
2000 SEG2
2 POI1

5.2 Quantities tested and results

the values of the first 12 frequencies to the stop and for rotational speed $4000\,tr/min$ is presented in table below

N° Fréq	Rotational speed (tr/mn)	Aster computation with shaft to constant section finely with a grid F (Hz)
10332.7440 00331.4520 332.744000 334.043011 98.7240001 195.874011 98.7240001 201.575016 07.2040001 607.196023 06.0040002 302.427023 06.0040002 309.608025 12.5840002 511.589031 60.4040003 160.400035 20.2040003 508.601103 520.204000 3515.90120 4724.15400 04724.20	4000	
	4000	
	4000	
	4000	
	4000	
	4000	
	4000	
	4000	
	4000	
	4000	
	4000	
12		
	4000	

Table 5.2-1 : Eigenfrequencies obtained by QZ

6 Summary of the results

This benchmark makes it possible to numerically validate the taking into account lines of trees to variable circular section. The got results are in concord with the values of reference, resulting from two very fine modelizations approaching the exact solution by lower and higher values.