SDLX02 - Pipework: Problem of Hovgaard. Spectral analysis

Abstract:

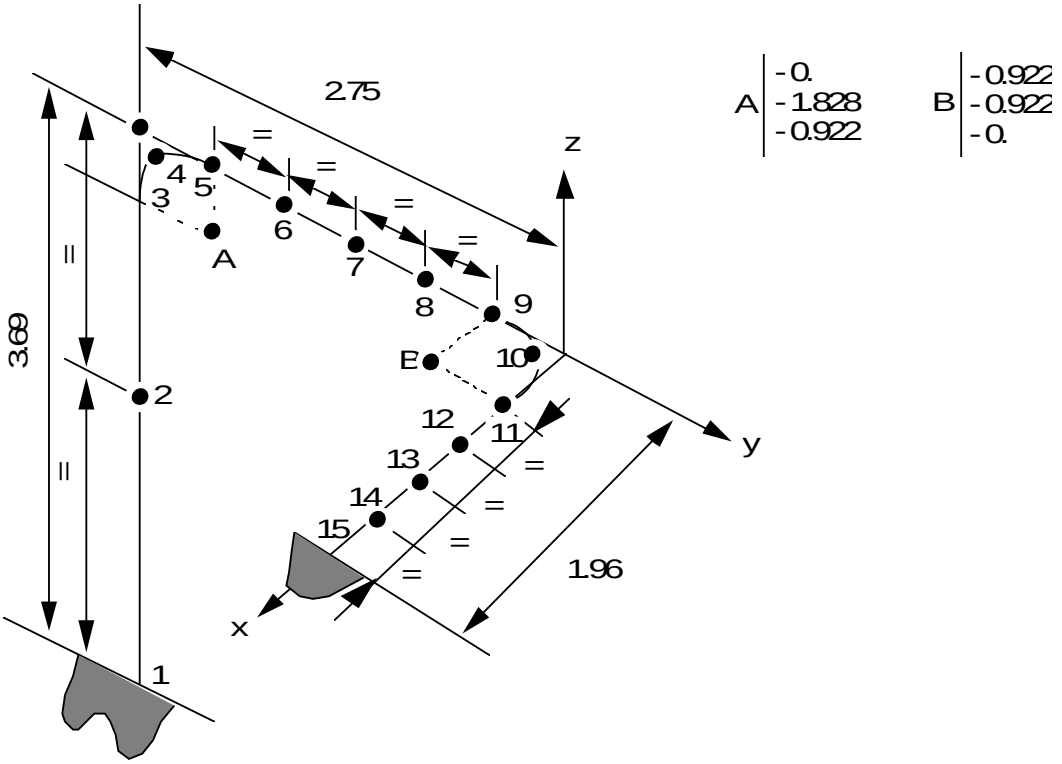
The three-dimensional problem consists *firstly*, to seek the modes of vibration of a mechanical structure made up of a curved beam embed-embedded (problem of Hovgaard), *secondly*, to analyze the response of this structure subjected to a spectrum of acceleration. This test of structural mechanics corresponds to a dynamic analysis of a linear model (assembled structure) having a linear behavior. It understands three modelizations.

Via this problem, one tests the beam element of Timoshenko (straight beam or curve) in bending, the computation of the eigen modes by the method of Lanczos, the computation of the static modes and the computation of a spectral response of a structure subjected to a spectrum of acceleration (one tests also the interpolation of spectrum).

The got results are in concord with the results of reference (compilation of results obtained by other software packages).

1 Problem of reference

1.1 Geometry



- diameter external of the pipe: $0.185\,m$
- thickness of the pipe: $6.12\,m$
- radius of curvature of the elbows: $0.922\,m$

1.2 Material properties

$E=1.658\,E+11\,Pa$ $\nu=0.3$ $\rho=13404.106\,kg/m^3$ (pipe full of water)

1.3 Boundary conditions and loadings

Items 1 and 15 clamped ($u=v=w=\theta_x=\theta_y=\theta_z=0$).

Loading: without object for the modal analysis.

For the spectral analysis: definition of a spectrum of acceleration to the bearings for a damping of 2% .

Frequency (Hz)	1	10	30.100		10000
Acceleration (g) according to x and y	0.2	2.	2.	0.2.0.2	
Acceleration (g) according to Z	0.1	1.	1.	0.1.0.1	

2 Reference solution

2.1 Method of calculating used for the reference solution

Averages of codes: Lice, ADL, TITUS-T.

Guide validation of the Software packages of structural analysis - AFNOR - 1990 (for modal computation). The values provided in the file under are estimated and were corrected thereafter in 1992. However, they were preserved for computations with diagonal mass matrix.

2.2 Results of reference

Modal computation:	the first 9 eigenfrequencies.
Spectral response:	displacement of the nodes $N3$ $N5$ and $N7$ $N9$ $N11$.
	Reaction of bearings to the nodes $N1$ $N15$.
	Generalized forces of the nodes $N3$ $N7$ $N11$.

2.3 Uncertainty on the solution

About 1% on the first 5 modes.

Between 1 and $2,5\%$ for modes 6 to 9.

2.4 Bibliographical references

1) Guides Technical VPCS AFNOR - 1990

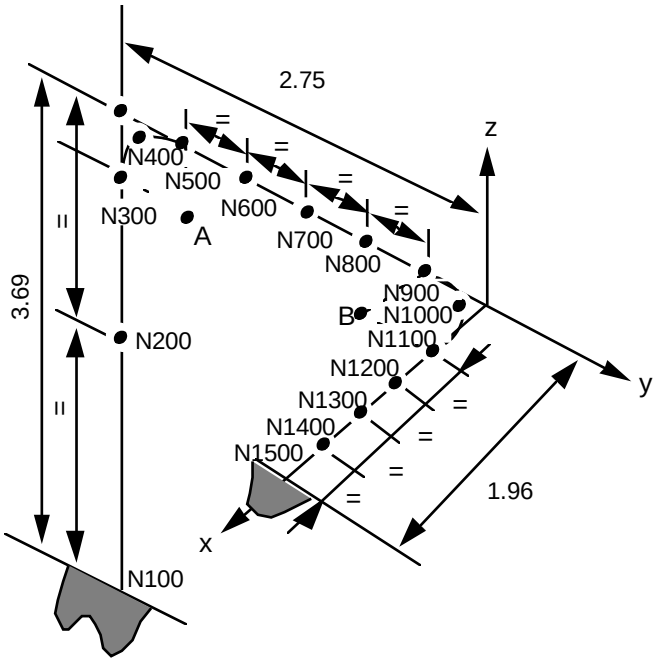
2) W. HOVGAARD “Stress in three dimensional pipe bens”, Trans of ASME vol. 57, FSP 75-12 P 401-416.

3 Modelization A

3.1 Characteristic of the modelization

the curved elements are modelled by elements POU_C_T (2 elements per elbow).

The right elements are modelled by elements POU_D_T.



3.2 Characteristics of the mesh

Many nodes:	15	Number of meshes and types:	10 POU_D_T
			4 POU_C_T

3.3 Remarks

the modes are normalized in the following way: larger component (degree of freedom of translation or rotation) with one.

The total response is obtained by quadratic combination of the directions of the excitations.

3.4 Quantities tested and Frequencies

results of the structure (complete mass matrix).

Eigenfrequencies	Reference
Mode 1	10.39
2	20.02
3	25.45
4	48.32
5	52.60
6	84.81
7	87.16
8	129.31
9	131.69

Frequencies of the structure (mass matrix diagnonale).

Eigen frequency	Reference
1	10.18
2	19.54
3	25.47
4	48.09
5	52.86
6	75.94
7	80.11
8	122.34
9	123.15

Spectral response: one does not take account of the correction of the frequencies due to damping (option CORR_FREQ with not in operator COMB_SISM_MODAL)

Displacement

Identification			Reference
DEPL	*N300*	DX	4.847 10-3
		DY	2.192 10-3
		DZ	2,735 10-6
	N500	DX	4.808 10-3
		DY	2.914 10-3
		DZ	6.507 10-4
	N700	DX	3.588 10-3
		DY	2.914 10-3
		DZ	8.599 10-4
	N900	DX	2.342 10-3
		DY	2.913 10-3
		DZ	1.027 10-3
	N1100	DX	3.009 10-6
		DY	9.375 10-4
		DZ	3.364 10-4

nodal Reaction

Identification			Reference
REAC	*N100*	DX	2132
		DY	1241
		DZ	564.6
		DRX	2352
		DRY	4746
		DRZ	937.3
	N1500	DX	1653
		DY	3354
		DZ	893.7
		DRX	170.8
		DRY	1668
		DRZ	4903

Forces generalized

Identification			Reference
EFGE	*N300*	N	559.9
		VY	430.8
		VZ	914.9
		MT	932.5
		MFY	587.3
		MFZ	620.4
	N700	N	162.5
		VY	1367.
		VZ	225.4
		MT	170.6
		MFY	924.7
		MFZ	2150

spectral Response: one takes account of the correction of the frequencies due to damping (option CORR_FREQ with yes in operator COMB_SISM_MODAL)

Displacement and nodal Reaction

Identification			Reference
DEPL	*N3*	DX	4.847 10-3
		DY	2.192 10-3
	N7	DX	3.588 10
		DY	2.914 10-3
		DRY	1.436 10
REAC_NODA	*N1*	DX	2132.
		DY	1241.
		DZ	564.6
	N15	DRX	170.8
		DRY	166.8
		DRZ	4903.

3.5 Remarks

Values of the spectrum (interpolation).

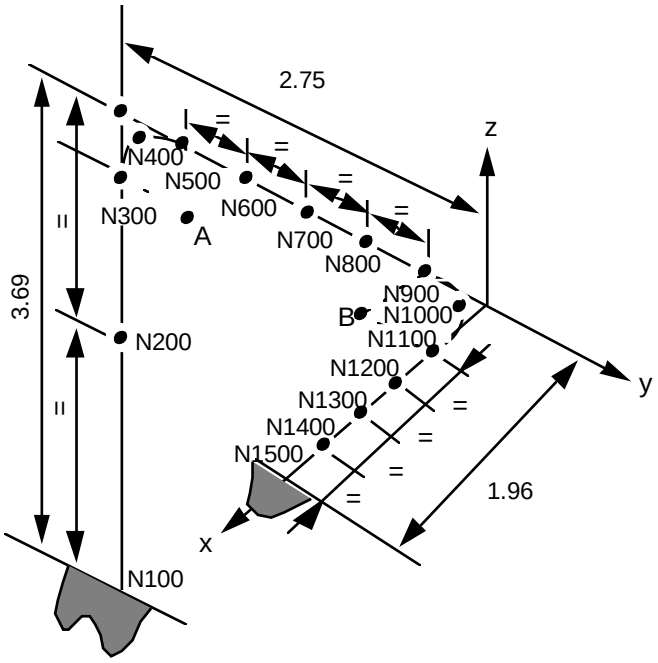
Mode	1,2,3	4	5	6	7	8,9
following Acclération x and y	19.620	8.06148	6.72586	3.38994	3.04168	1.9620
Acceleration according to z	9.810	4.03074	3.36293	1.69497	1.52084	0.9810

4 Modelization B

4.1 Characteristic of the modelization

the curved elements are modelled by elements POU_C_T (2 elements per elbow).

The right elements are modelled by elements POU_D_T_G.



4.2 Characteristics of the mesh

Many nodes: 15 Number of meshes and types: 10 POU_D_T_G
4 POU_C_T

4.3 Remarks

the modes are normalized in the following way: larger component (degree of freedom of translation or rotation) with one.

4.4 Quantities tested and Frequencies

results of the structure (complete mass matrix).

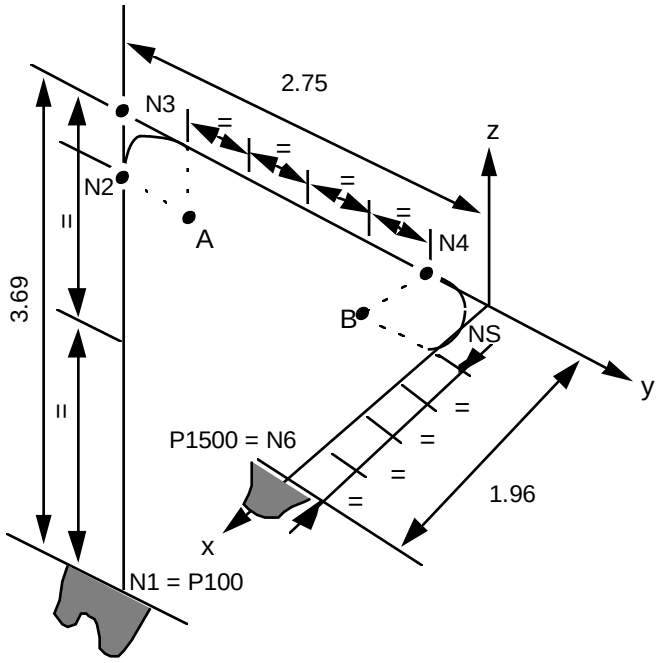
Eigen frequency	Reference
Mode 1	10.39
2	20.02
3	25.45
4	48.32
5	52.60
6	84.81
7	87.16
8	129.31
9	131.69

5 Modelization C

5.1 Characteristic of the modelization

the curved elements are modelled by elements POU_C_T (10 elements per elbow).

The right elements are modelled by elements POU_D_T_G (10 elements per straight beam).



5.2 Characteristics of the mesh

Many nodes:	51	Number of meshes and types:	30 POU_D_T_G 20 POU_C_T

5.3 Remarks

the modes are normalized in the following way: larger component (degree of freedom of translation or rotation) with one.

5.4 Quantities tested and Frequencies

results of the structure (complete mass matrix).

Eigen frequency	Reference
Mode 1	10.39
2	20.02
3	25.45
4	48.32
5	52.60
6	84.81
7	87.16
8	129.31

Frequencies of the structure (diagonal mass matrix).

Reference
10.39
20.02
25.45
48.32
52.60
84.81
87.16
129.31

6 Summary of the results and general remarks

Modal computation:

The results are in conformity with the file of validation.

By refining the mesh (modelization C) one gets correct results.

Spectral response:

The results are in conformity with the results of reference (the error is lower than the thousandths).