

SDLX02 - Piping: Problem of Hovgaard. Spectral analysis

Summary:

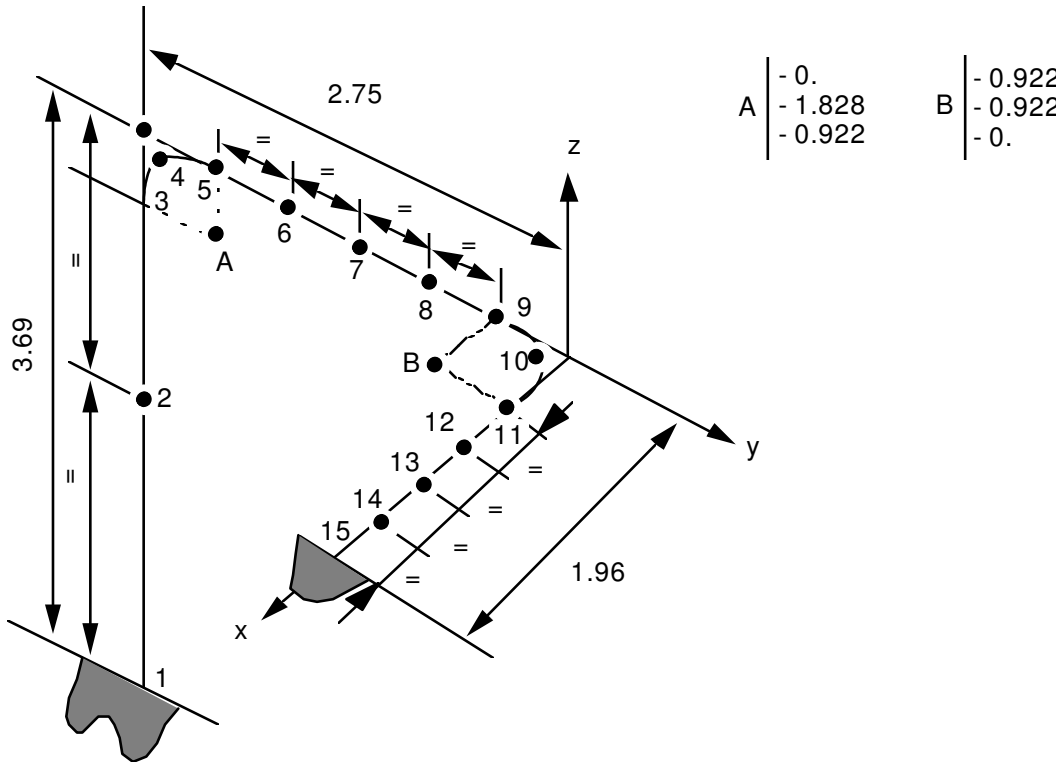
The three-dimensional problem consists *firstly*, to seek the modes of vibration of a mechanical structure made up of an embed-embedded curved beam (problem of Hovgaard), *secondly*, to analyze the answer of this structure subjected to a spectrum of acceleration. This test of mechanics of the structures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

Via this problem, one tests the element of beam of Timoshenko (right beam) in inflection, the calculation of the clean modes by the method of Lanczos, the calculation of the static modes and the calculation 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 got 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

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

1.3 Boundary conditions and loadings

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

Loading: without object for the modal analysis.

For the spectral analysis: definition of a spectrum of acceleration to the supports 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 of validation of the Software packages of structural analysis - AFNOR - 1990 (for modal calculation). The values provided in the card under are estimated and were corrected thereafter in 1992. However, they were preserved for calculations with matrix of diagonal mass.

2.2 Results of reference

Modal calculation: the first 9 Eigen frequencies.
displacement of the nodes $N3$ $N5$ and $N7$, $N9$, $N11$.
Spectral response: Reaction of supports to the nodes $N1$, $N15$.
Generalized efforts 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

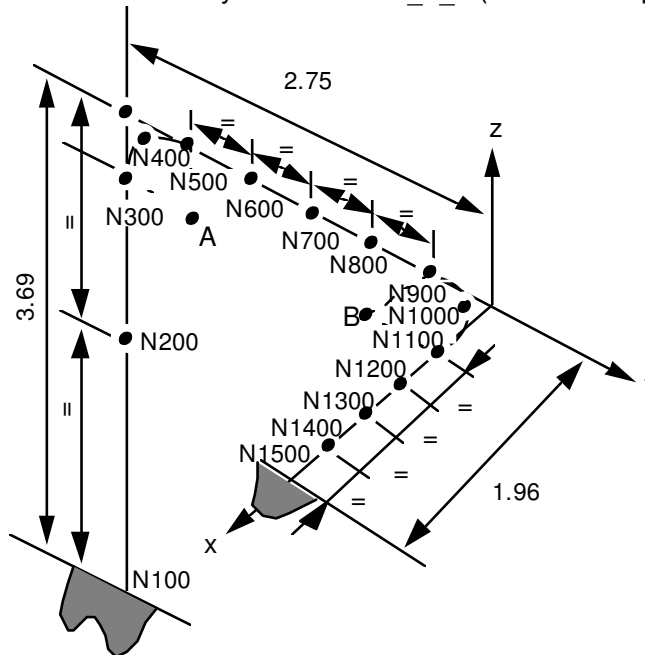
- 1) Technical guide VPCS AFNOR - 1990
- 2) W. HOVGAARD "dimensional Stress in three pipe bents", Trans of ASME vol. 57, FSP 75-12 P 401-416.

3 Modeling A

3.1 Characteristics of modeling

The right elements are modelled by elements `POU_D_T`.

The curved elements are also modelled by elements `POU_D_T` (20 elements per elbow).



3.2 Characteristics of the grid

Many nodes:

51

Many meshes and types:

50 `POU_D_T` (10 for the right parts)

3.3 Remarks

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

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

3.4 Sizes tested and results

Frequencies of the structure (matrix of complete mass).

Eigen frequencies	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 (matrix of mass diagonale).

Eigen frequencies	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 the operator COMB_SISM_MODAL)

Displacement

Identification	Reference
DEPL <i>N300</i>	DX 4,847 10 ⁻³
	DY 2,192 10 ⁻³
	DZ 2,735 10 ⁻⁶
<i>N500</i>	DX 4,808 10 ⁻³
	DY 2,914 10 ⁻³
	DZ 6,507 10 ⁻⁴
<i>N700</i>	DX 3,588 10 ⁻³
	DY 2,914 10 ⁻³
	DZ 8,599 10 ⁻⁴
<i>N900</i>	DX 2,342 10 ⁻³
	DY 2,913 10 ⁻³
	DZ 1,027 10 ⁻³
<i>N1100</i>	DX 3,009 10 ⁻⁶
	DY 9,375 10 ⁻⁴
	DZ 3,364 10 ⁻⁴

Nodal reaction

Identification	Reference
REACTIONAR Y <i>N100</i>	DX 2132.0
	DY 1241.0
	DZ 564.6
	DRX 2352.0
	DRY 4746.0
	MAR
	TIN
	I
	DRZ 937.3
	<i>N1500</i>
DY 3354.0	
DZ 893.7	
DRX 170.8	
DRY 1668.0	
MAR	
TIN	
I	
DRZ 4903.0	

Generalized efforts

Identification		Reference	
EFGE	N300	NR	559.9
		VY	430.8
		VZ	914.9
		MT	932.5
		MFY	587.3
		MFZ	620.4
N700		NR	162.5
		VY	1367.0
		VZ	225.4
		MT	170.6
		MFY	924.7
		MFZ	2150.0

Spectral response: one takes account of the correction of the frequencies due to damping (option CORR_FREQ with yes in the 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	
		MAR		
		TIN		
REAC_NODA	N1	DX	2132.	
		DY	1241.	
		DZ	564.6	
		N15	DRX	170.8
			DRY	166.8
			MAR	
		TIN		
		I		
		DRZ	4903.0	

3.5 Remarks

Values of the spectrum (interpolation).

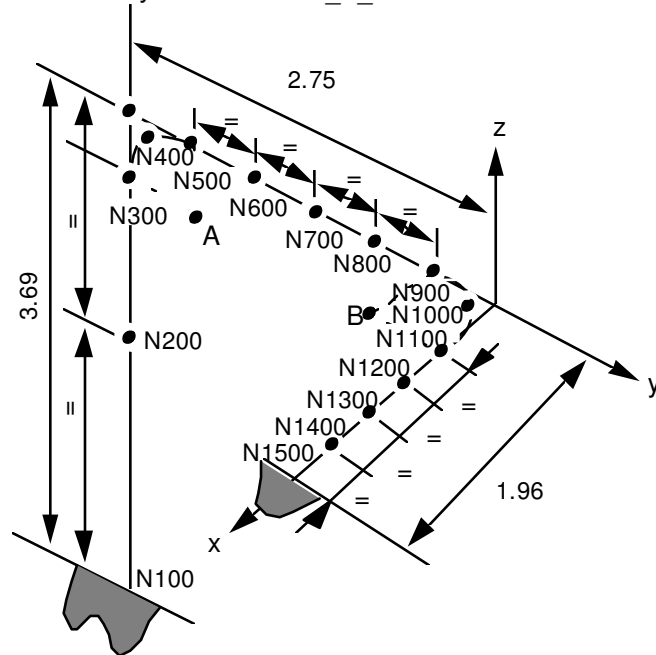
Mode		1,2,3	4	5	6	7	8,9
Following Acclération <i>x</i> and <i>y</i>		19,620	8.06148	6.72586	3.38994	3.04168	1.9620
Acceleration to <i>z</i>	according	9,810	4.03074	3.36293	1.69497	1.52084	0.9810

4 Modeling B

4.1 Characteristics of modeling

The curved elements are modelled by elements `POU_D_T` (20 elements per elbow).

The right elements are modelled by elements `POU_D_TG`.



4.2 Characteristics of the grid

Many nodes: 51 Many meshes and types: 10 `POU_D_TG`
40 `POU_D_T`

4.3 Remarks

The modes are normalized in the following way: larger component (degree of freedom of translation or rotation) with 1 .

4.4 Sizes tested and results

Frequencies of the structure (matrix of complete mass).

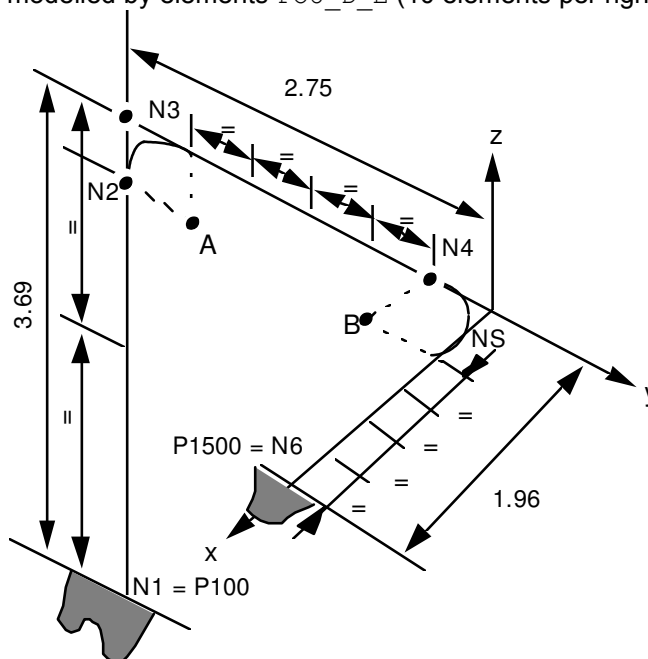
Eigen frequency	Reference
Mode 1	10.39
2	20.02
3	25.45
4	48.32
5	52.60
6	84.81
7	87.16
8	129.31
9	131.69

5 Modeling C

5.1 Characteristics of modeling

The curved elements are modelled by elements `POU_D_T` (10 elements per elbow).

The right elements are modelled by elements `POU_D_E` (10 elements per right beam).



5.2 Characteristics of the grid

Many nodes: 51 Many meshes and types: 30 `POU_D_E`
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 1 .

5.4 Sizes tested and results

Frequencies of the structure (matrix of complete mass).

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 (matrix of diagonal mass).

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 calculation:

The results are in conformity with the card of validation.
By refining the grid (modeling C) one gets correct results.

Spectral response:

The results are rather in conformity with the results of reference, the error is about the hundredth in most tests.