SDLX02 - Piping: Problem of Hovgaard. Spectral analysis

Summary:

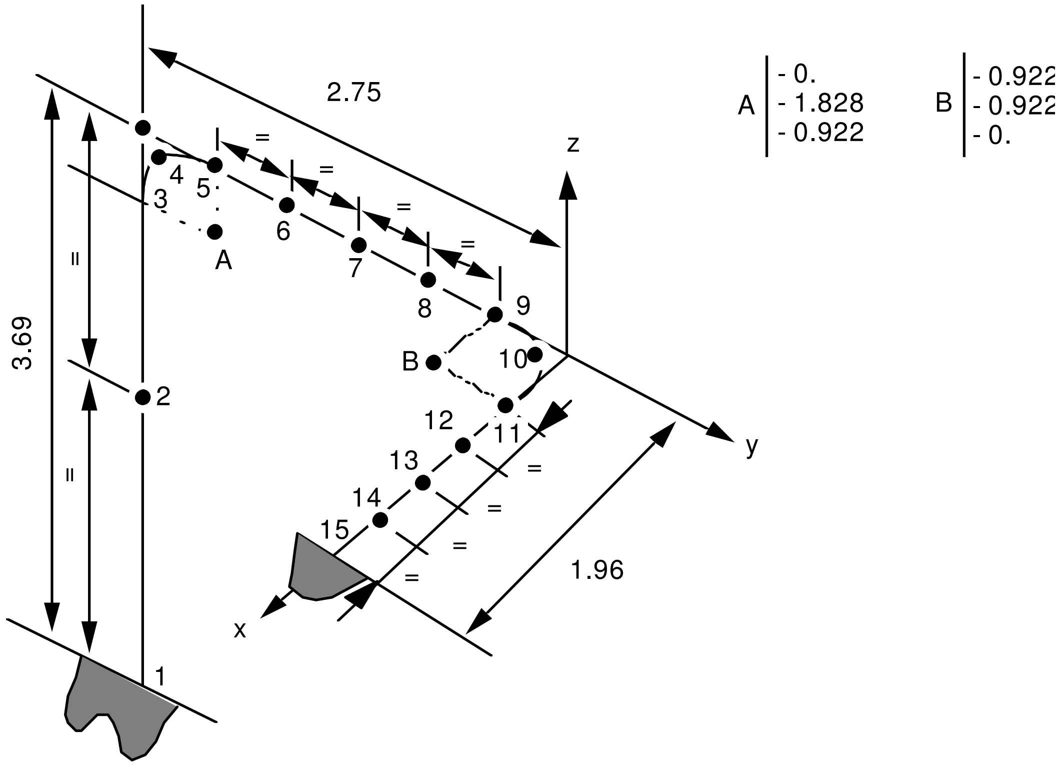
The three-dimensional problem consists *firstly*, to seek the modes of vibration of a mechanical structure made up of an embed-embedded curved beam (problem of Hovgaard), *secondly*, to analyze the answer of this structure subjected to a spectrum of acceleration. This test of mechanics of the structures 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 or curve) 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

$E = 1.658\,E+11\,Pa$ $\nu = 0.3$ $\rho = 13404.106\,kg/m^3$ (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.
Spectral response:	displacement of the nodes $N3$ $N5$ and $N7$, $N9$, $N11$.
	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

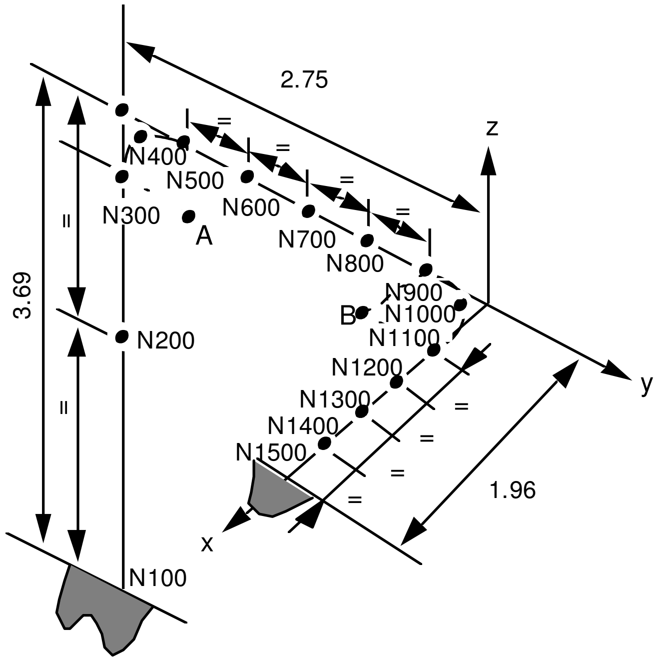
2) W. HOVGAARD “dimensional Stress in three pipe bens”, Trans of ASME vol. 57, FSP 75-12 P 401-416.

3 Modeling A

3.1 Characteristics of modeling

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 grid

Many nodes:	15	Many meshs 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 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 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 the 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
REACTIONARY	*N100*	DX	2132
		DY	1241
		DZ	564.6
		DRX	2352
		DRY MARTINI	4746
		DRZ	937.3
	N1500	DX	1653
		DY	3354
		DZ	893.7
		DRX	170.8
		DRY MARTINI	1668
		DRZ	4903

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.
		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 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 MARTINI	1,436 10
REAC_NODA	*N1*	DX	2132.
		DY	1241.
		DZ	564.6

N15	DRX	170.8
	DRY MARTINI	166.8
	DRZ	4903.

3.5 Remarks

Values of the spectrum (interpolation).

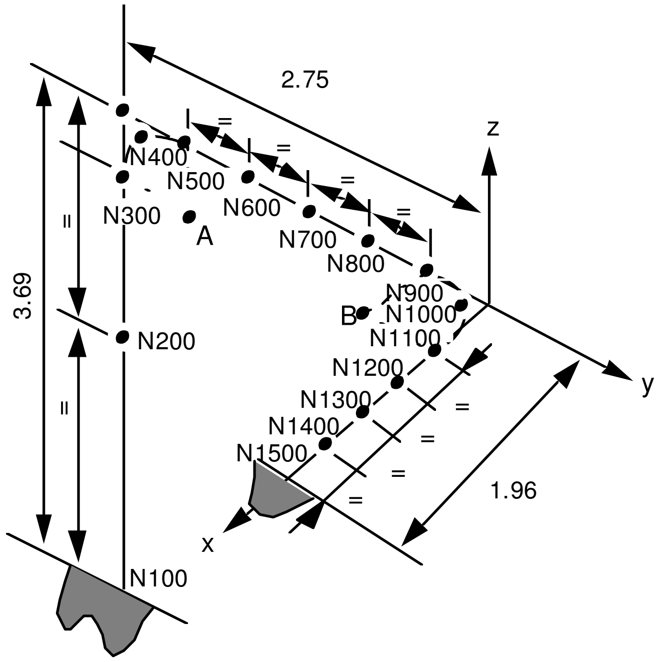
Mode	1,2,3	4	5	6	7	8.9
Following Acclération x and y	19,620	8.06148	6.72586	3.38994	3.04168	1.9620
Acceleration according to z	9,810	4.03074	3.36293	1.69497	1.52084	0.9810

4 Modeling B

4.1 Characteristics of modeling

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 grid

Many nodes:	15	Many meshs 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 Sizes tested and results

Frequencies of the structure (matrix of complete mass).

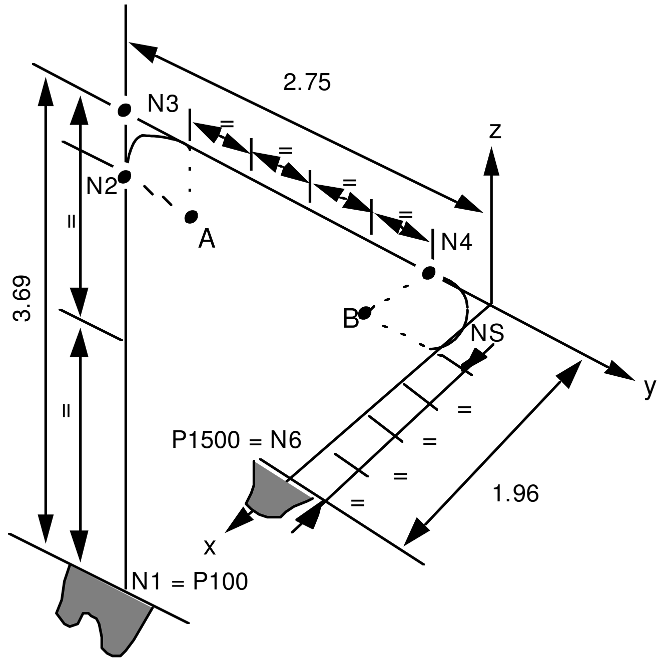
Eigen frequency	Reference
Mode 1	10.39
2	20.02
3	25.45
4	48.32
5	52.60
6	84.81
7	87.16
8	129.31
9	131.69

5 Modeling C

5.1 Characteristics of modeling

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

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



5.2 Characteristics of the grid

Many nodes:	51	Many meshs 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 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 in conformity with the results of reference (the error is lower than the thousandths).