SDLX300 - Pipework subjected to an excitation in displacement, velocity, acceleration

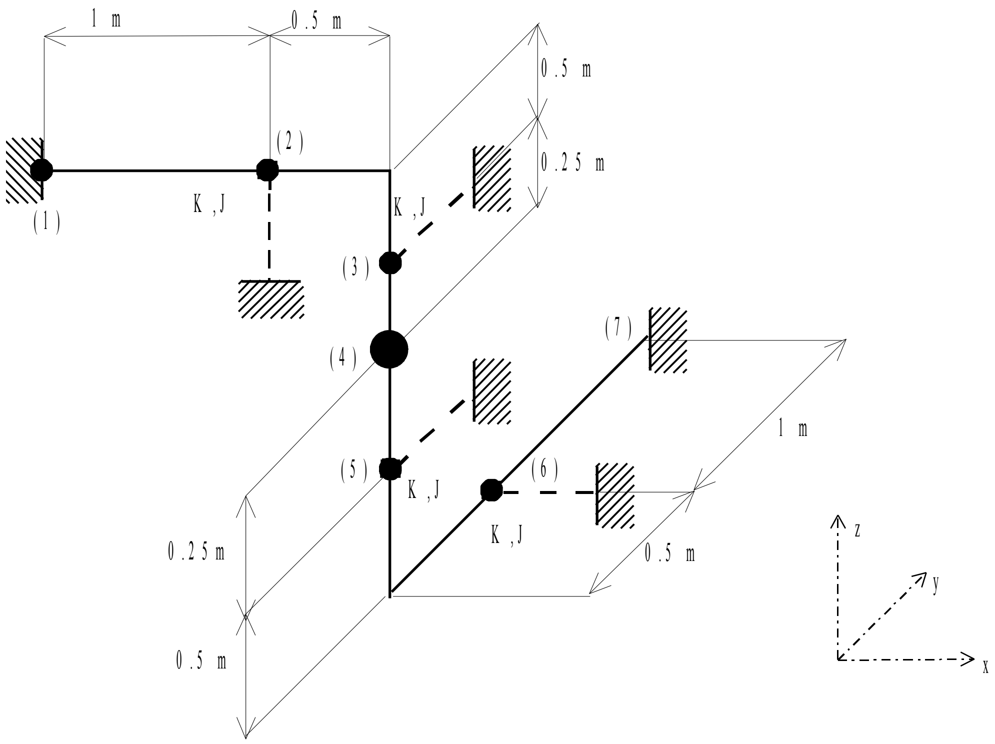
Summarized:

Three-dimensional study of a pipework embedded-rotulée with localised stiffness and mass subjected to an excitation in displacement, velocity and acceleration.

The reference is obtained for 6 modes with CASTEM 2000.

1 Problem of reference

1.1 Geometry



external Diameter	:	$48.E-3\,m$
Thickness	:	$5.E-3\,m$
Radius of curvature of the elbows	:	$0.170\,m$

1.2 Properties of the materials

Density	:	$7960.\,kg.m^{-3}$
Young modulus	:	$1.9\,E+11\,N.m^{-2}$
Poisson's ratio	:	0.3
Lumped mass with node 4	:	$10.\,kg$

1.3 Boundary conditions and loadings

1.3.1 Boundary conditions

With node 1: $dx=dy=dz=0$ (hinge)
With node 7: $dx=dy=dz=drx=dry=drz=0$ (fixed support)

With node 2, self-supporting quality in the direction z
With node 3, self-supporting quality in the direction y
With node 5, self-supporting quality in the direction y
With node 6, self-supporting quality in the direction x

the stiffness brought by each self-supporting quality are:

$K_x = K_y = K_z = 80.\text{E}+3\,N.m^{-1}$
$K_{\theta x} = K_{\theta y} = K_{\theta z} = J = 1.2\,N.m.deg^{-1}$

1.3.2 Loadings

Computation of the static modes

the first computation makes it possible to validate the computation of the static modes.

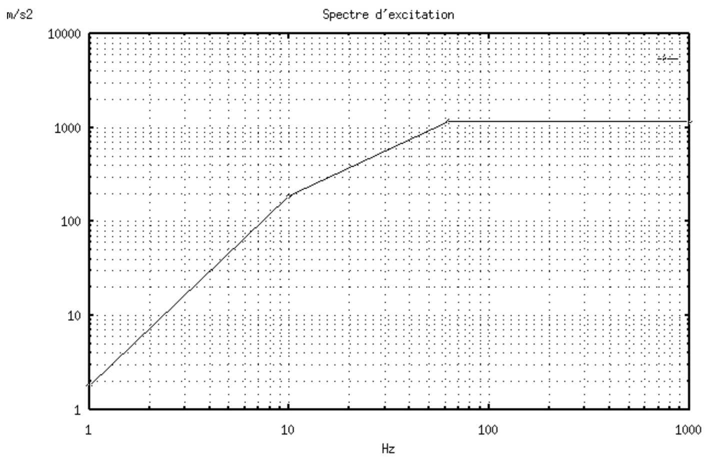
The group of the model is subjected to a constant acceleration according to x value $100\times g$ with $g=9.81\,m.s^{-2}$

Spectral response

One subjects line pipework to an excitation according to x, defined by a response sprectrum such as:

- its value in displacement for frequencies ranging between 1. and 10. Hz, of $d=48.\text{E}-3\text{m}$
- velocity for frequencies ranging between 10. and 63 is its value. Hz, that is to say $v=3.\text{m.s}^{-1}$
- its value in acceleration for frequencies ranging between 63. and 1000. Hz, that is to say $\gamma=120*g$

Below is represented the spectrum of acceleration, determined from the excitation for a reduced damping $\xi=0$.



The characteristic values used are:

$\gamma(1\,Hz)=1.92\text{m}/s^2$
$\gamma(10\,Hz)=192\,m/s^2$
$\gamma(63\,Hz)=1000\,m/s^2$
$\gamma(1000\,Hz)=1000\,m/s^2$

1.3.3 Compliance of the elbows

the coefficient of compliance C_{flex}, of the elbows is given by regulation RCC-M:

$$C_{flex}=\frac{1.65}{h} \text{ with } h=\frac{ep*r_{courb}}{r_m^2}$$

ep : thickness of the elbow
r_{courb} : radius of curvature of the elbow
r_m : average radius of the elbow

the index of intensification of the stresses I_{sigm} , is given by:

$$I_{sigm}=\frac{0.9}{h^{0.666}}$$

According to regulation RCC-M, the coefficient of compliance and the index of intensification of the stresses are equal to or higher than one. It is not the case in this benchmark.

2 Reference solution

2.1 Méthode de calcul used for the reference solution

the reference is obtained for 6 modes with Castem 2000, for the method of modal recombination CQC.

2.2 Results of reference

Modal computation

Frequencies, effective masses according to x, y, z

static Mode

Displacements with the characteristic nodes

spectral Response

Displacements and generalized forces with the characteristic nodes
Reaction to the fixed support

the results are got with 6 modes for modal recombination CQC.

2.3 Uncertainty on the solution

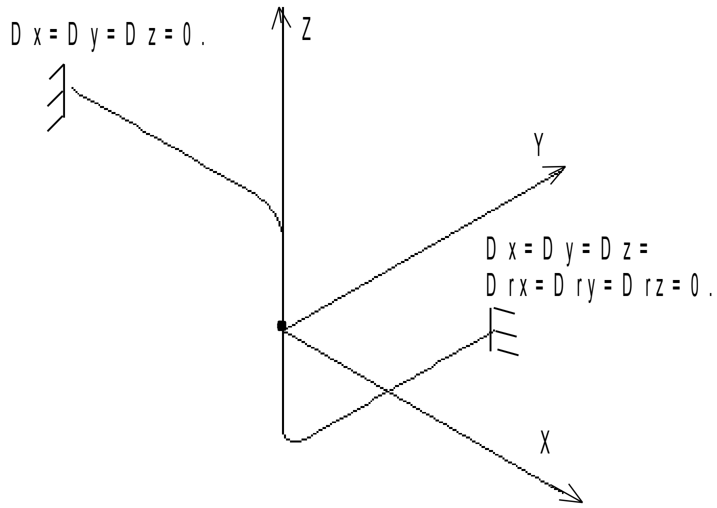
Comparison between bibliographical

2.4 codes References

[1] B. Kurth - P. Pasquet: Computation of a pipework - Test Castem2000 DCN - Cherbourg. Reference CISI 93020

3 Modelization A

3.1 Characteristic of the modelization



3.2 Characteristics of the mesh

The mesh consists of 88 elements beam including 10 elements curved beam of Timoshenko and 78 elements straight beam of Timoshenko.

4 Quantities tested and results of the modelization A

4.1 Computation of modal base

Eigenfrequencies of structure (Hz)

Number of mode	Reference
1	1.6848E+01
2	2.0762E+01
3	2.2386E+01
4	4.4822E+01
5	5.2218E+01
6	7.9692E+01

effective Masses according to the direction x (kg)

Number of mode	Reference
1	1.6134E+00
2	4.4041E-01
3	1.8187E+01
4	1.0628E-02
5	3.8555E-02
6	7.7799E-02

effective Masses according to the direction y (kg)

Number of mode	Reference
1	9.2479E+00
2	1.1224E+01
3	1.7076E-01
4	6.7896E-01
5	1.1784E-03
6	4.2460E-02

effective Masses according to the direction z (kg)

Number of mode	Reference
1	1.3324E+01
2	1.1625E+01
3	2.8852E+00
4	4.1979E-01
5	2.5868E-01
6	6.5858E-01

4.2 Loading a: Computation of the static modes

Displacements (m)

Direction	Nodes	Reference
Ux	2	1.001E-04
	3	3.169E-02
	4	4.830E-02
	5	6.162E-02
	6	4.527E-02
Uy	2	3.823E-03
	3	7.525E-03
	4	5.556E-03
	5	3.777E-03
	6	– 4.516E-06
Uz	2	– 6.607E-03
	3	1.032E-02
	4	1.031E-02
	5	1.031E-02
	6	5.632E-03

4.3 Loading b: spectral Response

Computation with 6 modes - quadratic modal recombination supplements “CQC”

Displacements (m)

Direction	Nodes	Reference
Ux	2	1.859E-05
	3	1.092E-02
	4	1.722E-02
	5	2.259E-02
	6	1.695E-02
Uy	2	6.765E-03
	3	6.555E-03
	4	5.029E-03
	5	3.398E-03
	6	2.398E-06
Uz	2	1.004E-02
	3	7.574E-03
	4	7.575E-03
	5	7.574E-03
	6	4.238E-03

Reaction (N) and Moment ($N.m$) to node 7

	Reference
Fx	1.284E+03
Fy	3.079E+02
Fz	4.070E+02
Mx	3.748E+02

My	2.301E+02
Mz	1.431E+03

generalized Forces

Table n°1 (*)

Nodes	Components	Reference
2	$Fx(N)$	2.385E+03
	$Fy(N)$	2.275E+02
	$Fz(N)$	5.183E+02
	$Mx(N.m)$	3.067E-01
	$My(N.m)$	7.984E+02
	$Mz(N.m)$	2.367E+02
3	$Fx(N)$	6.092E+02
	$Fy(N)$	2.555E+02
	$Fz(N)$	2.151E+03
	$Mx(N.m)$	3.611E+02
	$My(N.m)$	1.417E+02
	$Mz(N.m)$	1.114E+02
4	$Fx(N)$	8.733E+02
	$Fy(N)$	3.777E+02
	$Fz(N)$	2.665E+03
	$Mx(N.m)$	3.617E+02
	$My(N.m)$	6.081E+02
	$Mz(N.m)$	1.894E+02
5	$Fx(N)$	6.373E+02
	$Fy(N)$	4.489E+02
	$Fz(N)$	1.284E+03
	$Mx(N.m)$	3.615E+02
	$My(N.m)$	3.416E+02
	$Mz(N.m)$	1.766E+02
6	$Fx(N)$	3.078E+02
	$Fy(N)$	1.922E+03
	$Fz(N)$	5.692E+02
	$Mx(N.m)$	2.306E+02
	$My(N.m)$	1.420E+02
	$Mz(N.m)$	3.415+02

* See remark [§ 4.4].

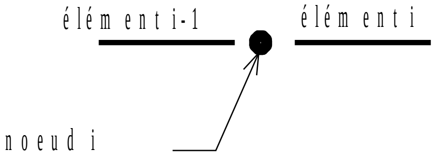
Table n°2 (*)

Nodes	Components	Reference
2	$Fx(N)$	2.387E+03
	$Fy(N)$	4.333E+02
	$Fz(N)$	1.164E+03
	$Mx(N.m)$	2.781E-01
	$My(N.m)$	7.985E+02
	$Mz(N.m)$	2.368E+02
3	$Fx(N)$	9.656E+02
	$Fy(N)$	4.511E+02
	$Fz(N)$	2.955E+03
	$Mx(N.m)$	3.618E+02
	$My(N.m)$	1.429E+02
	$Mz(N.m)$	1.113E+02
4	$Fx(N)$	5.281E+02
	$Fy(N)$	3.928E+02
	$Fz(N)$	8.652E+02
	$Mx(N.m)$	3.616E+02
	$My(N.m)$	6.081E+02
	$Mz(N.m)$	1.894E+02
5	$Fx(N)$	2.223E+02
	$Fy(N)$	2.753E+02
	$Fz(N)$	4.752E+02
	$Mx(N.m)$	3.627E+02
	$My(N.m)$	3.403E+02
	$Mz(N.m)$	1.766E+02
6	$Fx(N)$	3.076E+02
	$Fy(N)$	6.588E+02
	$Fz(N)$	2.842E+02
	$Mx(N.m)$	2.299E+02
	$My(N.m)$	1.418E+02
	$Mz(N.m)$	3.396E+02

* See remark [§ 4.4].

4.4 Remarks

For a given i node, the force generalized for the element $i-1$ and the element i is compared respectively in tables 1 and 2.



5 Summary of the Characteristic

results modal

the variations on the calculated frequencies remain lower than 0.4%.
The maximum change on the significant effective masses is of 4.4% (direction z). A variation of 24% is raised in the direction y , on the effective mass of the mode 6 which accounts for 0.15% of the total mass.

Static modes

the variations are about 1% in the directions y and z , and lower than 0.5% in the direction x .

Spectral response

Displacements
the variations are about 1%, with a variation of 4.6% for node 6 in the direction y (but displacement with node 6 is about 1.e-6 and is not significant compared to the other computed values, about 1.e-3).

Reactions to the generalized fixed support and forces
the average deviation is about 2%. A variation of 12.8%, appears on the level of node 5 for the component Fz of the generalized force. There exists an order of magnitude between the value of the force on the left and on the right of the mass, the variation on the minimal value of the force is of 12.8%, 2.6% on the maximum value, and of 5% on the mean value.