SHLL100 - Harmonic response of a bar per dynamic substructuring

Abstract:

The scope of application of this test relates to the dynamics of structures, and more particularly the harmonic computation of response per dynamic substructuring.

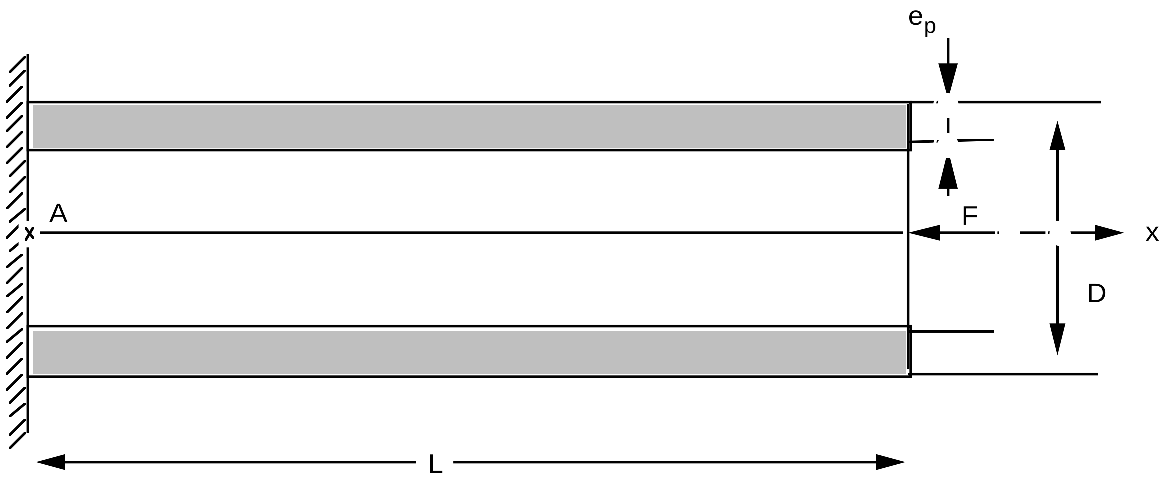
It is a question of calculating the harmonic response in traction and compression of a clamped beam - free modelled by elements of the type “bars”. The modelled structure is damped (damping of Rayleigh by elements).

The results of reference result from a direct harmonic computation. This test thus makes it possible to validate the computational tools of harmonic response per substructuring established in *Code_Aster* and more particularly:

- the catch in depreciation account by element,
- the computation of the second member including the harmonic loading,
- the restitution of the harmonic response on a mesh squelette, including the fields of displacement, velocity and acceleration.

1 Problem of reference

1.1 Geometry



$L=1\,m$

$D=0{,}2\,m$ - Section circular

1.2 Material properties

$E=1.10^{10}\,Pa$

$\nu=0.3$

$\rho=1.10^{4}\,kg/m^{3}$

Damping of Rayleigh per element: $\alpha_e=0.1 \quad \beta_e=0.1$

1.3 Boundary conditions and loadings

Fixed support in the end A : $u(0)=n(0)=w(0)=0$.

For all point: $M(x) \quad n(0)=w(0)=0$.

Harmonic loading in time, at the loose lead:

- directional sense: according to x ,
- amplitude: $100\ N$,
- frequency: $100\ Hz$.

1.4 Initial conditions

Without object for a harmonic computation of response.

2 Reference solution

2.1 Method of calculating used for the reference solution

There exists an analytical solution detailed in the reference [bib2].

Let us use the following notations:

E	:	Young's modulus
L	:	length of the bar
A	:	section of the bar
N	:	normal force directed according to the axis X
α,β	:	damping coefficients of Rayleigh
Ω	:	excitation frequency

and let us pose

$$r=\sqrt{\frac{1+\beta^2/\Omega^2}{1+\alpha^2/\Omega^2}}$$

$$k=p+iq=\Omega\sqrt{\frac{p}{2E}}\left[\sqrt{r-\frac{1-\alpha\beta}{1+\alpha^2\Omega^2}}+i\sqrt{r+\frac{1-\alpha\beta}{1+\alpha^2\Omega^2}}\right]$$

displacement in an unspecified $M(x)$ point is given by:

$$V(x)=\frac{N}{EA}\frac{A}{(p+iq)(1+i\Omega\alpha)}\frac{sh\,px\cos qx+i\,ch\,px\sin qx}{ch\,L\cos qL+i\,sh\,pL\sin qL}$$

	Displacement (m)	**Velocity** (m/s)	**real** (m/s^2)
Acceleration Left	– 7.00 10-11	– 3.18 10-6	2.76 10-5
imaginary Part	5.07 10-9	– 4.40 10-8	– 2.00 10-3

2.2 Results of reference

Fields of displacement, velocity and acceleration of the loose lead of the bar.

2.3 Uncertainty on the numerical

solution Solution.

2.4 Bibliographical references

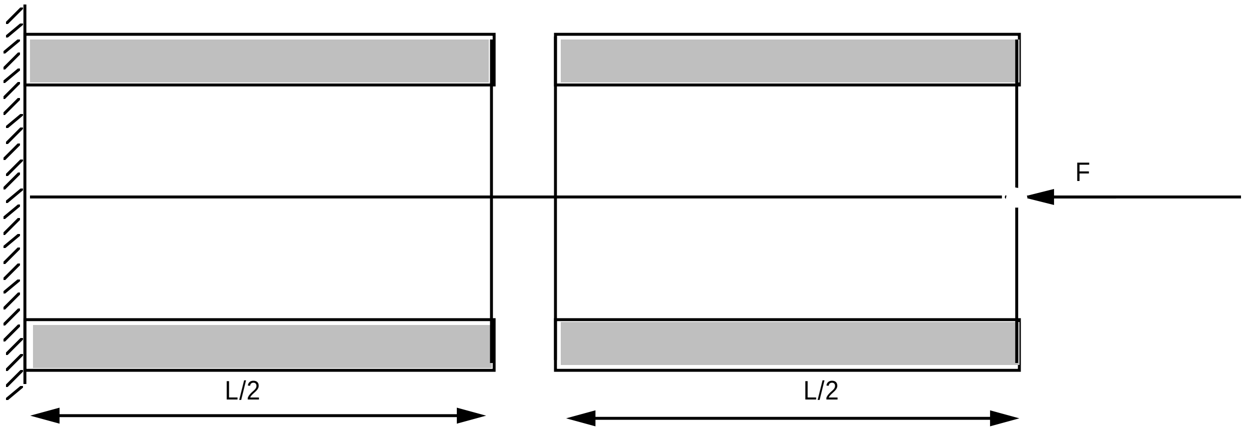
1) T. KERBER “harmonic Substructuring in *the Code_Aster”*, Ratio EDF, HP - 61/93 - 104.

2) G. ROBERT, analytical Solutions in dynamics of structures, Ratio Samtech n°121, March 1996.

3) P. RICHARD, Methods of substructuring in *the Code_Aster*, Ratio interns EDF - DER, HP-61/92-149.

3 Modelization A

3.1 Characteristic of the modelization



the bar is cut out in 2 parts of equal size. Each substructure considered is with a grid in segments to which elements are affected “bars”.

The structure is studied using the method of the harmonic substructuring with interfaces of the HARMONIC type CRAIG-BAMPTON.

Modal base used is made up of 4 eigen modes for substructure of right, of 5 eigen modes for substructure of left to which the harmonic constrained modes associated are added with the interfaces (calculated with $300\,Hz$. This value of the pulsation does not have any influence on result, it is arbitrary [bib3]).

3.2 Characteristics of the mesh

Many nodes: 5

Number of meshes and types: 5 `SEG2`

3.3 Quantities tested and results

Displacement (m)

	Reference	***Aster***	**% difference**	**real**
Tolerance Left	– 7.00 10-11	– 7.00 10-11	– 0.007	2.10-3
imaginary Part	5.07 10-9	5.07 10-9	– 0.097	2.10-3
	real	(m/s)		
Velocity Left	– 3.18 10-6	– 3.18 10-6	– 0.078	2.10-3
imaginary Part	– 4.40 10-8	– 4.40 10-8	0.033	2.10-3
	real	(m/s^2)		
Acceleration Left	2.76 10-5	2.76 10-5	0.133	2.10-3
imaginary Part	– 2.00 10-3	– 2.00 10-3	– 0.019	2.10-3

4 Summary of the results

the accuracy on the complex coordinates the fields of displacement velocity and acceleration is lower than $0{,}1\%$.

This test thus validates the operators of harmonic substructuring.