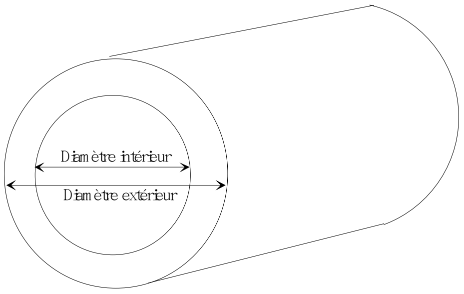
SDLL110 - Long cantilever under excitations fluid-elastic and turbulent beam: summarized tests

ANL:

This benchmark fits in the frame of the resorption of software FLUSTRU [bib1] [bib2]. It leans on two series of results tests obtained at the conclusion of a campaign carried out by laboratory ANL (National Argonne Laboratory - the USA) [bib3]. Taking into account the configuration of this countryside, the comparison computation-tests makes it possible to validate computation by a frequential method of the linear vibratory response of a tubular structure of standard beam on bearings and cantilever, subjected to a transverse external flow on part of its length. Initially, one determines the effects of the coupling fluid-elastic on the dynamic behavior of the beam. Those - Ci result in a variation of the values of the eigenfrequencies, modal dampings and vibratory level of response of the beam, according to the rate of flow. The comparison computation-tests relates to the vibratory level of response. This benchmark in addition aims at preventing the possible regression of one or the other of the features put in work in a computation of this type.

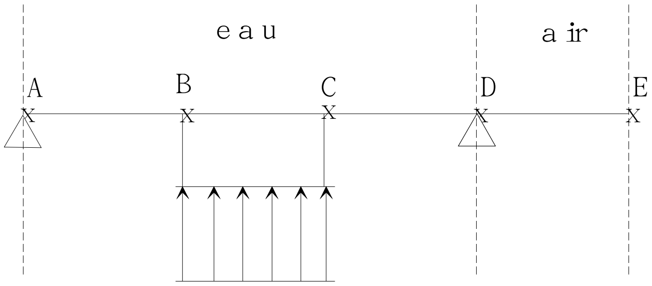
1 Problem of reference

1.1 Geometry



Tubes right of hollow circular section:

Diameter external of the tube: $15{,}90\ mm$
Internal diameter of the tube: 1 $2{,}72\ mm$



Overall length of the tube : $1{,}350\ m$

Length of the part AB : $0{,}305\ m$
Length of the part BC : $0{,}300\ m$
Length of the part CD : $0{,}305\ m$
Length of the part DE : $0{,}440\ m$

1.2 Properties of the materials

the values of the physical quantities characteristic of the elements of structure are:

Tube out of brass:

$$E=1{,}1\,10^{11}\ N/m^2 \qquad \nu=0{,}3 \qquad \rho=8330\ kg/m^3$$

Internal fluid : external

$$\rho_i=1{,}3\ kg/m^3$$

Fluid air : submerged tube out of water on the part its length ranging between the two bearings,
submerged tube in air on the part its unsupported length,
incidental transverse flow on the part BC of the tube.

$\rho_e=1000{,}0\ kg/m^3$ or $1{,}3\ kg/m^3$ according to the external zone

a density equivalent is allotted to structure during computation of its fluid modal base at rest; this equivalent density includes the density of the internal fluid, that of structure and that fluid external; the inertial effect of this last is evaluated via a coefficient of added mass.

1.3 Boundary conditions and loadings

the beam is simply supported at the points A and D. A random loading distributed, transverse on the tube, is imposed on the section BC. This loading is defined, on the one hand using a profile velocity along the excited zone, and on the other hand using an adimensional spectrum of excitation.

2 Reference solution

2.1 experimental Results of reference

Of the experimental results of reference are available for this benchmark; it is the results resulting from two series from tests from countryside ANL [bib3].

2.2 Method of calculating used for the reference solution

See reference [bib1].

2.3 Results of reference

After having validated computation by comparing his results with the experimental results of reference resulting from the trial run, one allots to the results of computation the statute of values of reference in order to be able to check non regression code during the future restitutions. These values of reference are valid as from the version NEW 5.03.10 of *Code_Aster*.

2.4 Uncertainty on the solution

the relative variations tolerated on the computed values are very weak so that the benchmark serf also to make sure of non regression future software during the future restitutions.

2.5 Bibliographical references

1. N. GAY: “Software FLUSTRU, version 3.0.1, Note of principle - GAY
2. HT-32/97/014/A N.: “Software FLUSTRU, version 3.0.1, Book of validation” - HT-32/97/017/A
3. S.S. CHEN: “Experiments one fluid elastic instability in tube banks subjected to liquid cross-country race flow”, Newspaper of Sound and Vibration, 1981, vol. 78, n°3, pp. 355-381

3 Modelization A

3.1 Characteristic of the modelization

the tube is modelled using beam elements right of Timoshenko: `POU_D_T`. It is broken up into 270 elements distributed out of four sections. The sections AB and CD understand each one 61 elements, the section BC, 60 elements and the section DE, 88. At the points A and the D degrees of freedom are blocked in the directions x, y and z in translation, and in the direction z in rotation. In accordance with the results of the first series of tests, fluid damping at rest is taken equal to 1,3% and the coefficient of added mass is worth 2,0711.

3.2 Characteristics of the mesh

the nombre total of nodes used for this mesh is of 271.
Meshes, of type SEG2, are 270.
Mesh file is written with the Aster format .

3.3 Stages of computation

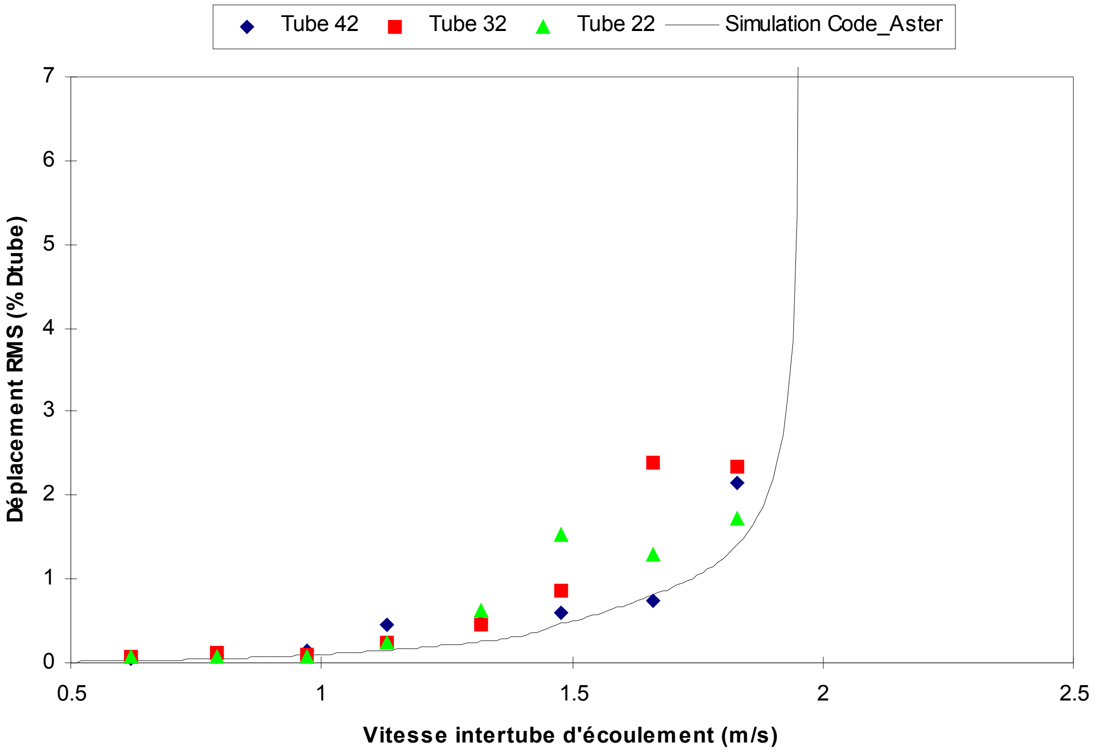
the profile rate of flow and the parameters taking into account fluid-structure coupling are defined using operators `DEFI_FONC_FLUI` and `DEFI_FLUI_STRU`. One taking into account calculates the modal parameters of structure in the forces fluid-elastics using operator `CALC_FLUI_STRU`. The definition of the random excitation is carried out by calling upon operator `DEFI_SPEC_TURB`. The excitation is projected on modal base using operator `PROJ_SPEC_BASE`. The interspectrums of modal response are calculated using operator `DYNA_SPEC_MODAL`. One from of deduced the autospectrums from displacement to the nodes by calling upon operator `REST_SPEC_PHYS`.
One can at the same time calculate spectral response only for one rate of flow, thus these three last stages (`PROJ_SPEC_BASE`, `DYNA_SPEC_MODAL`, `REST_SPEC_PHYS`) are carried out in a loop, in the command file, where one browses the list rates of flow.

3.4 Values tested

It [Figure 5.1-a] presents a comparison of displacement RMS to the point E, expressed as a percentage diameter external of the tube, between:

- on the one hand the first series of tests ANL which related to 3 of the instrumented tubes of the tube bundle in similitude of a beam of steam generator,
- and on the other hand simulation using *Code_Aster*.

These results are presented according to the velocity intertube of incidental flow, expressed in m/s. The experimental results were got for discrete values rates of flow. The computation having been carried out for 201 values velocities équiréparties on the interval $[0.5 \quad 2.5 m/s]$, calculated displacement seems a continuous curve in the explored range velocities. In experiments as in computation, one notes the existence of a strong increase in displacement RMS. This increase is associated with a vibratory instability of the dynamic system, associated with the cancellation of its damping. The rate of flow to which this increase occurs is the velocity of instability of the system. The computation allows to estimate this velocity at $2 m/s$ that the experimental report forecasts a value higher than $1{,}8 m/s$ (the tests of instability are often stopped before instability is reached to avoid the damage of structures). In this configuration, the variation CALCUL-measurement on this result essential for the maintenance of the tubes of steam generators is thus about 10%.



Appears 5.1-a: Displacement RMS at the point E, according to the velocity intertube of flow, expressed as a percentage diameter external of the tube.

3.5 Remarks

the modal deformed shapes under flow are supposed to remain unchanged compared to those calculated out of fluid at rest.

3.6 Tests of non regression

to assure non regression code, one uses operators `TEST_FONCTION` and `TEST_TABLE` in the command file. These two operators allow to test respectively, on the one hand the values of the eigenfrequencies and reduced dampings, and on the other hand displacement RMS. The tolerance is fixed at 1E- 03%.

4 Modelization B

4.1 Characteristic of the modelization

the characteristics of the modelization B are identical to those of the modelization A, except for fluid damping at rest and of the coefficient of added mass to which, in accordance with the results of the second series of tests, have allots the respective values of 1,1% and of added mass of 2,01188.

4.2 Characteristics of the mesh

Identical to those of modelization A.

4.3 Étapes of computation

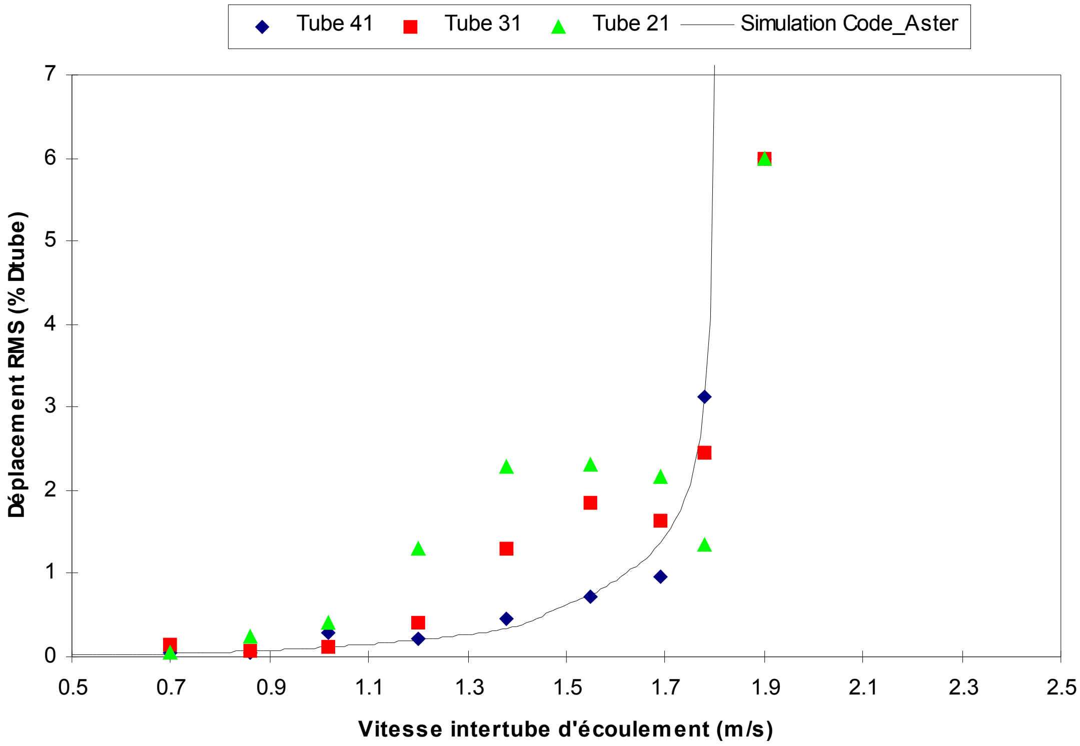
Identical to those of modelization A.

4.4 Fonctionnalités tested

Identical to those of modelization A.

4.5 Valeurs tested

the second series of tests differs from the first primarily by the value of the damping of the dynamic system coupled out of fluid at rest; this last is not more than 1.1% but of 1.3%. [Figure 6.1-a] presents the comparison computation/tests for this new configuration. The vibratory instability of the tube results in abrupt and strong increase in calculated displacement RMS. The velocity to which this increase occurs is the velocity of instability of the system. The computation allows to estimate this velocity with $1.85 m/s$ whereas the experimental report is closer to $1{,}95\ m/s$. The variation computation/measurement for this result essential is thus about 5% for this other configuration.



Appear 6.1-a: Displacement RMS according to the velocity intertube of flow, expressed at the point E expressed as a percentage of the diameter external of the tube.

4.6 Remarks

the modal deformed shapes under flow are supposed to remain unchanged compared to those calculated fluid at rest.

4.7 Tests of non regression

to assure non regression code, one uses operators `TEST_FONCTION` and `TEST_TABLE` in the command file. These two operators allow to test respectively, on the one hand the values of the eigenfrequencies and reduced dampings, and on the other hand displacement RMS. The tolerance is fixed at 1E- 03%.

5 Conclusion

This benchmark contributes to the checking of the validity of computation by the frequential method available in *Code_Aster* of the linear vibratory response of a tubular structure of standard beam simply supported cantilever, subjected to a transverse external flow on part of its length. It leans on two series of results experimental obtained during a trial run realized by laboratory ANL (the USA). It appears that for this configuration, the velocity of instability of the dynamic system, a very important quantity in the optimization of the maintenance of the tubes of steam generators, is approximate from 5 to 10%. In addition, the benchmark leads to results which will be used as values of reference to avoid the regression of the main operators employed in the vibratory computation of the tubes of steam generators.