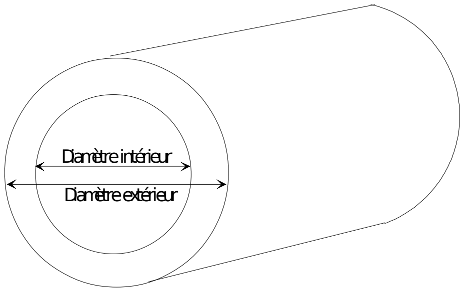
SDLL110 - Long cantilever under excitations fluid-rubber band and turbulent beam: tests ANL

Summary:

This CAS-test lies within the scope of the resorption of software FLUSTRU [bib1] [bib2]. It is based on two series of test results 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 calculation-tests makes it possible to validate calculation by a frequential method of the linear vibratory answer of a tubular structure of standard beam on supports and cantilever, subjected to a transverse external flow on part of its length. Initially, one determines the effects of the coupling fluid-rubber band on the dynamic behavior of the beam. Those - Ci result in a variation of the values of the Eigen frequencies, modal depreciation and vibratory level of answer of the beam, according to the rate of the flow. The comparison calculation-tests relates to the vibratory level of answer. This CAS-test in addition aims at preventing the possible regression of one or the other of the features put in work in a calculation of this type.

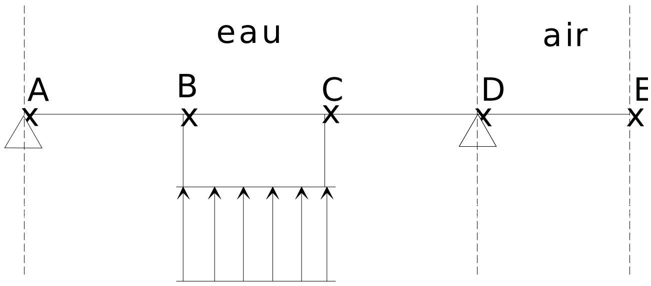
1 Problem of reference

1.1 Geometry



Right tube 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 materials

The values of the physical sizes characteristic of the elements of the structure are:

Brass tube:

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

Internal fluid : air

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

External fluid : submerged tube out of water on the part its length ranging between the two supports,
submerged tube in air on the part its unsupported length,
incidental transverse flow on the part BC 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 the structure during calculation of its modal base in fluid at rest; this equivalent density includes the density of the internal fluid, that of the 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 speed along the excited zone, and on the other hand using an adimensional spectrum of excitation.

2 Reference solution

2.1 Experimental results of reference

Experimental results of reference are available for this CAS-test; 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 calculation by comparing his results with the experimental results of reference resulting from the trial run, one allots to the results of calculation the statute of values of reference in order to be able to check to it not regression of the code at the time as of future restitutions. These values of reference are valid as from 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 CAS-test serf also to be made sure of nonthe future regression of the software during the future restitutions.

2.5 Bibliographical references

1. NR. GAY: "Software FLUSTRU, version 3.0.1, Note of principle - HT-32/97/014/A
2. NR. GAY: "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 Modeling A

3.1 Characteristics of modeling

The tube is modelled using elements of right beam of Timoshenko: POU_D_T. It is broken up into 270 elements distributed out of four sections. Sections AB and CD understand each one 61 elements, the section BC, 60 elements and the section DE, 88. At the points A and D the 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, damping in fluid at rest is taken equal to 1,3% and the coefficient of added mass is worth 2.0711.

3.2 Characteristics of the grid

The full number of nodes used for this grid is of 271.
The meshs, of type SEG2, are 270.
The file of grid is written with the format ASTER.

3.3 Stages of calculation

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

3.4 Values tested

[Figure 5.1-a] a comparison of displacement RMS presents 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 similtude of a beam of steam generator,
- and in addition simulation using *Code_Aster*.

These results are presented according to the speed intertube of the incidental flow, expressed in m/s. The experimental results were got for discrete values rates of flow. Calculation having been carried out for 201 values speeds équiréparties on the interval $[0.5 - 2.5 m/s]$, calculated displacement seems a continuous curve in the explored range speeds. In experiments as in calculation, 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 speed of instability of the system. Calculation makes it possible to estimate this speed at $2 m/s$ whereas 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 the structures). In this configuration, the variation calculation-measurement on this significant result for the maintenance of the tubes of steam generators is thus about 10%.

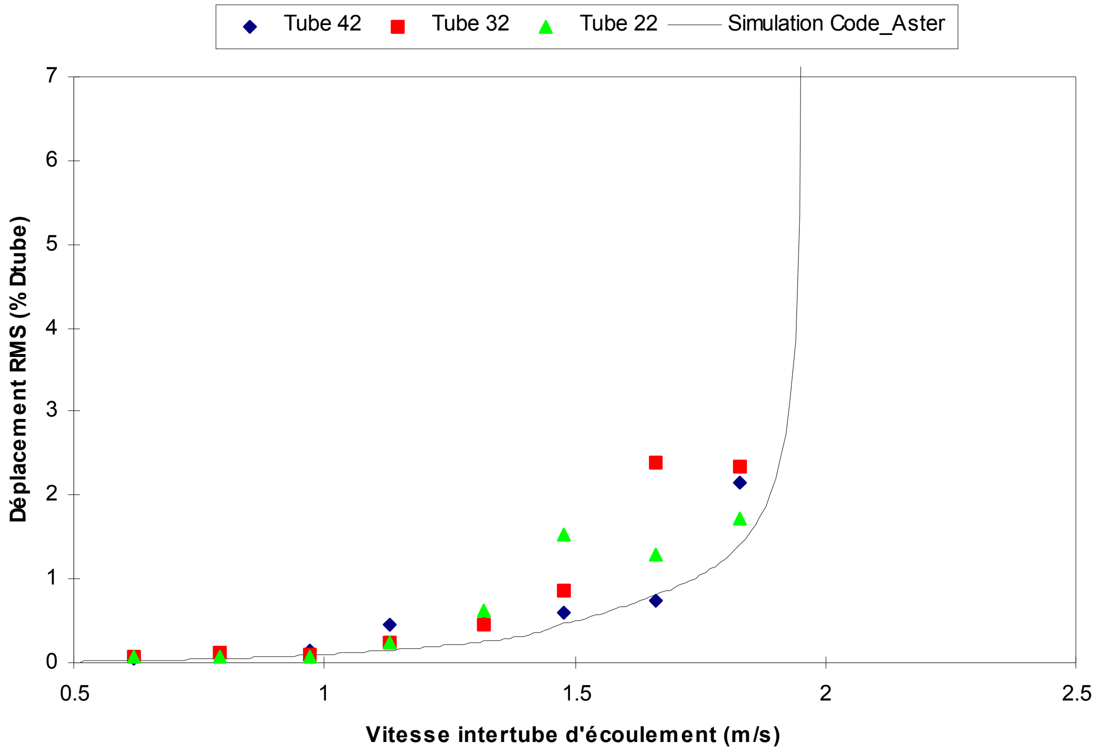


Figure 5.1-a: Displacement RMS at the point E, according to the speed intertube of flow, expressed as a percentage diameter external of the tube.

3.5 Remarks

The modal deformations under flow are supposed to remain unchanged compared to those calculated in fluid at rest.

3.6 Tests of nonregression

To assure to it not regression of the code, the operators are used `TEST_FONCTION` and `TEST_TABLE` in the command file. These two operators allow to test respectively, on the one hand the values of the Eigen frequencies and reduced depreciation, and on the other hand displacement RMS. The tolerance is fixed at 1E- 03%.

4 Modeling B

4.1 Characteristics of modeling

The characteristics of modeling B are identical to those of modeling A, except for damping in fluid 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 grid

Identical to those of modeling A.

4.3 Stages of calculation

Identical to those of modeling A.

4.4 Features tested

Identical to those of modeling A.

4.5 Values tested

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

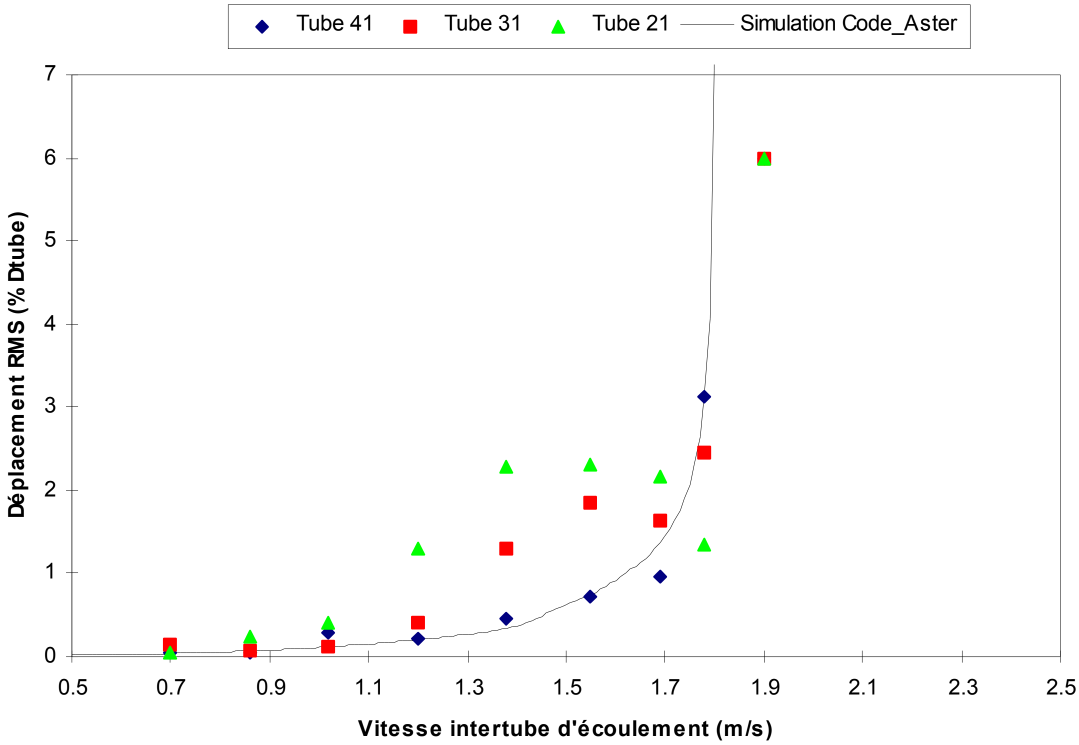


Figure 6.1-a: Displacement RMS according to the speed intertube of flow, expressed at the point E expressed as a percentage of the diameter external of the tube.

4.6 Remarks

The modal deformations under flow are supposed to remain unchanged compared to those calculated fluid at rest.

4.7 Tests of nonregression

To assure to it not regression of the code, the operators are used `TEST_FONCTION` and `TEST_TABLE` in the command file. These two operators allow to test respectively, on the one hand the values of the Eigen frequencies and reduced depreciation, and on the other hand displacement RMS. The tolerance is fixed at 1E- 03%.

5 Conclusion

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