SDNL112 - Vibratory damage of origin of a clotheshanger of steam generator

Summary

This case of validation is intended to check the not-regression of the features necessary to calculations of damage of vibratory origin of the tubes of steam generators: vibratory tiredness and wear by shocks on an obstacle. The calculation of the vibratory answer is carried out by the method ITMI of Temporal Integration by Integral Method established in the operator DYNA_VIBRA. For that, one studies the nonlinear dynamic response of a tube of steam generator subjected to an external flow. This tube is unstable and comes to impact a support with game.

One calculates initially the effects of the coupling fluid-rubber band (variation of the frequency and the damping of the structure) according to the rate of the flow, then the vibratory answer of the structure for a rate of flow given, and finally wear by shocks or the vibratory tiredness of the structure.

1 Problem of reference

1.1 Geometry

The studied structure is connected at the curved zone of a tube of steam generator. It is supposed to be embedded at its two ends A and C ; these last are supposed to correspond on the way of the tube in the plate top transom of a steam generator. At the point B top of the clotheshanger (still called apex), the structure is guided in a support with game.

Figure 1.1-a: Diagram of the curved zone of a tube of Steam Generator, supposed to be embedded in last plate braces, guided in a support with game

The structure is comparable to a circular beam of section digs overall length of $1{,}74329\,m$ and which understands $250{,}43\ mm$ of right part at each end of the tube.

Diameter external of the tube : $22{,}22\ mm$
Internal diameter of the tube : $19{,}68\ mm$

1.2 Material properties

The values of the characteristics of the various elements of the structure are the following ones:

Inconel 600 tube

$$E = 2{,}02\ 10^{11}\,N/m^2 \qquad \nu = 0{,}3 \qquad \rho = 8330\ kg/m^3$$

Internal fluid: the modelled internal fluid is water under pressure with high temperature; its density ρ_i is supposed to vary in a linear way along the curved zone, enters A and C, of $738{,}58\ kg/m^3$ with $731{,}16\ kg/m^3$.

External fluid: the tube is supposed to be immersed in a diphasic mixture over all its length; the flow of the mixture is transverse with the clotheshanger in any point. The equivalent density of the mixture is obtained using the formula:

$\rho_e = \alpha\,\rho_{gaz} + (1-\alpha)\,\rho_{liquide}$, where α indicate the voluminal gas rate.

This density seems being understood enters $84\,kg/m^3$ and $150\,kg/m^3$. A density equivalent is allotted to the dynamic system during the 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 structure is embedded at the points A and C. A support with game is positioned at the point B ($jeu=1{,}20\ mm$). A random loading distributed, transverse on the tube, is imposed on $(A-C)$. 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.

1.4 Initial conditions

The tube is initially at rest, which results in displacements and speeds worthless at the initial moment.

2 Reference solution

2.1 Method of calculating used for the reference solution

See references [bib1], [bib2] and documentation of *Code_Aster* on the calculation algorithms dynamic into nonlinear with shocks.

2.2 Results of reference

In the absence of experimental results available, one tests only the not-regression of the results.

2.3 Bibliographical references

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

2. NR. GAY, S. GRANGER: “Presentation of a method of the coupling fluid-rubber band in nonlinear mode”, HT - 32/94/015/A.

3 Modeling A

3.1 Characteristics of modeling

The geometrical and material properties of the model are those presented higher. The tube is modelled using elements of right beam of Timoshenko: POU_D_T. It is broken up into 60 elements distributed out of six sections.

Nodes A and C are blocked in the directions x, y and z in translation and rotation.

The damping of the structure in fluid at rest is of 0,4999%.

3.2 Characteristics of the grid

The full number of nodes used for this grid is of 61.
The meshs are 60 and of type SEG2.
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 inter-spectra of modal answer are calculated using the operator DYNA_SPEC_MODAL. One from of deduced the auto--spectra from displacement to the nodes by calling upon the operator REST_SPEC_PHYS.

4 Results of modeling A

4.1 Values tested

The tests ensure to it not regression of the code and relate to Eigen frequencies, reduced damping and the RMS in displacement.

4.2 Remarks

Calculation is carried out with 4 modes and only one rate of flow of $4.811\,m/s$.

5 Modeling B

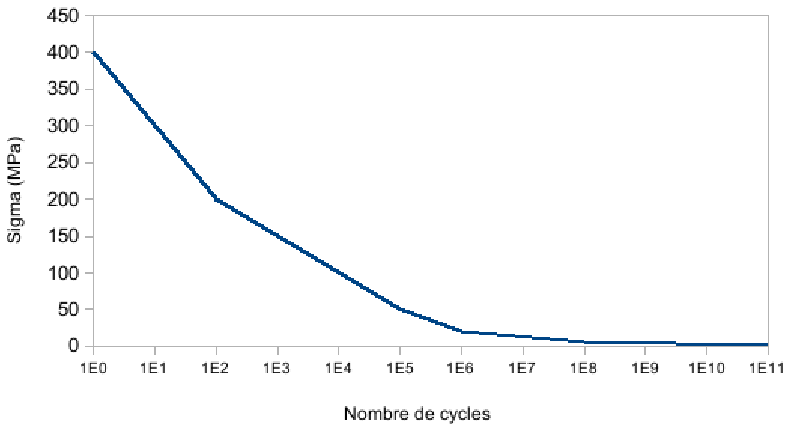
5.1 Characteristics of modeling

The geometrical and material properties of the model are those presented higher. The tube is modelled using elements of right beam of Timoshenko: POU_D_T. It is broken up into 60 elements distributed out of six sections.

Nodes A and C are blocked in the directions X, Y and Z in translation and rotation.

Damping in fluid at rest of the structure is of 0,4999%.

For the calculation of damage, one considers the curve of following tiredness (standard Wöhler), giving the half-amplitude of constraint according to the number of cycles:



It should be noted that this curve east does not correspond to the real curve of tiredness for material considered.

5.2 Characteristics of the grid

The full number of nodes used for this grid is of 61.
The meshs are 60 and of type SEG2.
The file of grid is written with the format ASTER.

5.3 Stages of calculation

The profile rate of the flow and the parameters going account the coupling fluid-structure are defined using the operators FONC_FLUI_STRU and DEFI_FLUI_STRU.

- One calculates the modal parameters of the water structure at rest using the operator CALC_MODES.
- One calculates the modal parameters of the structure by taking of account the elastic forces fluid - 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.
- One calculates the random excitations over one determined period, by using the operator GENE_FONC_ALEA.
- For temporal calculation, one recovers the functions of excitation and one uses the method of temporal integration by the integral method established in the operator DYNA_VIBRA. This calculation makes it possible to study the nonlinear dynamic response of a tube of steam generator subjected to an external flow.
- The operator of postprocessing used in order to evaluate the tiredness of the tube is then POST_FATIGUE.

6 Results of modeling B

6.1 Values tested

The tests ensure to it not regression of the code and relate to displacements like on the office plurality of the damage.

6.2 Remarks

Calculation is carried out with 4 modes over one total duration of simulation of 1 second. It is carried out for only one rate of flow ($4{,}811\ m/s$) by direct integration with the integral method. The values tested are the damage and interval RMS of displacement for 1 and 100 cycles at the node of shock. The computing time and the number of pullings making it possible to define the excitation, are too weak to obtain a suitable average statistical representation random phenomenon. Therefore this case test constitutes only one case test of not-regression. To obtain more representative median values, it is enough to lengthen the duration of calculation and the number of pullings.

7 Modeling C

7.1 Characteristics of modeling

The tube is modelled using elements of right beam of Timoshenko: POU_D_T. It is broken up into 60 elements distributed out of six sections.

Nodes A and C are blocked in the directions X, Y and Z in translation and rotation.

Damping in fluid at rest is of 0,4999%.

7.2 Characteristics of the grid

The full number of nodes used for this grid is of 61.
The meshs are 60 and of type SEG2.
The file of grid is written with the format ASTER.

7.3 Features tested

One tests in particular the good taking into account of the simple keyword GROUP_NO order POST_USURE.

7.4 Stages of calculation

The profile rate of the flow and the parameters going account the coupling fluid-structure are defined using the operators FONC_FLUI_STRU and DEFI_FLUI_STRU.

- One calculates the modal parameters of the water structure at rest using the operator CALC_MODES.
- One calculates the modal parameters of the structure by taking of account the elastic forces fluid - 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.
- One calculates the random excitations over one determined period, by using the operator GENE_FONC_ALEA.
- For temporal calculation, one recovers the functions of excitation and one uses the method of temporal integration by the integral method established in the operator DYNA_VIBRA. This calculation makes it possible to study the nonlinear dynamic response of a tube of steam generator subjected to an external flow.
- The operator of postprocessing used in order to evaluate the wear of the tube is then POST_USURE.

8 Results of modeling C

8.1 Values tested

The tests ensure to it not regression of the code and relate to displacements like on value RMS of displacement following OY.

8.2 Remarks

Calculation is carried out with 4 modes over one total duration of simulation of 1 second. It is carried out for only one rate of flow ($4{,}811\ m/s$) by direct integration by the integral method. The values tested are the powers of wear to the node of shock. The computing time and the number of pullings making it possible to define the excitation, are too weak to obtain a suitable average statistical representation random phenomenon. Therefore this case test constitutes only one case test of not-regression. To obtain more representative median values, it is enough to lengthen the duration of calculation and the number of pullings.

9 Conclusion

The single goal of this CAS-test is the checking of the not-regression of the computation channels GEVIBUS -*Code_Aster* during the joint use of the operator `DYNA_VIBRA` with method ITMI of temporal integration by integral method and the operators of post-analyzes of tiredness and wear. With the sight of the got results, one can consider that the not-regression of *Code_Aster* is ensured for the moment.