FDLV115 - Harmonic answer of a viscoelastic ring in coupling fluid-structure for the reduction of model

Summary:

The objective of this test is of to check in an elementary way the operator of reduction of model DEFI_BASE_REDUITE on a case of YEWS with a viscoelastic material.

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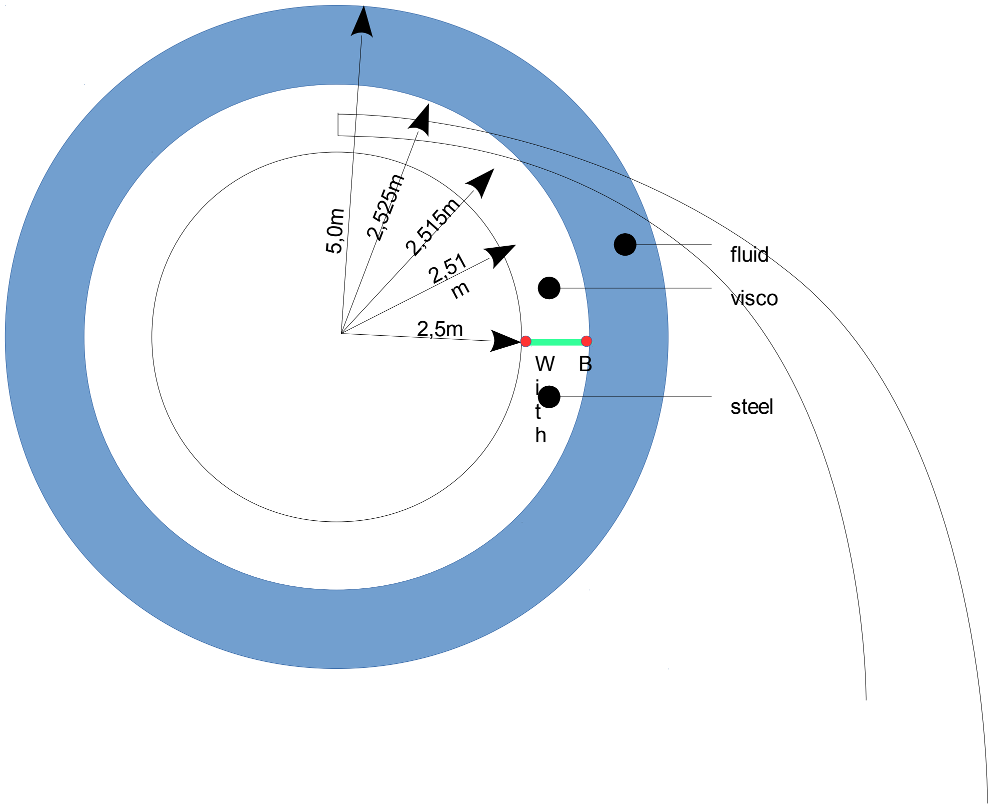
1 Problem of reference

1.1 Geometry

One is considered metal ring plan plunged in a fluid environment with an external border for this last (figure 1.1-1).



In the metal

1.2 Properti

Figure 1.1-1: Geometry (not on the scale)

For the part out of steel, one considers an isotropic elastic material :

- Modulus of elasticity: $E_a = 177\,GPa$
- Poisson's ratio: $\nu_a = 0.3$
- Density: $\rho_a = 7450\,kg.m^{-3}$

For the fluid, it is water with the following characteristics:

- Speed of sound: $c = 1500\,m.s^{-1}$
- Density: $\rho_e = 1000\,kg.m^{-3}$

For the viscoelastic part, one considers material of a model type of the fractional derivative (model of Zener) whose modulus of rigidity depends on the pulsation:

$$G^*(\omega) = \frac{G_0 + G_\infty (i\omega\tau)^\alpha}{1+(i\omega\tau)^\alpha} \quad (1)$$

The characteristics are the following ones:

- Poisson's ratio: $\nu_v = 0.49$ (quasi-incompressible material)
- Density: $\rho_v = 1460\,kg.m^{-3}$
- Coefficients: $G_0 = 2{,}11\,MPa$, $G_\infty = 0{,}59\,GPa$, $\tau = 0{,}44\times 10^{-6}$ and $\alpha = 0{,}53$

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Note: to improve calculation of the modes, one carries out the have-dimensioning of all these quantities compared to water.

1.3 Boundary conditions and loadings

For the structure part, one imposes a condition of embedding on the segment AB and a horizontal nodal force $Fx=A,0\times 10^{-5}N$ on the point A .
A condition of interaction fluid-border is carried out by the use of elements 2D_FLUI_STRU with the interface between Lhas structure and fluid. In addition, a condition of impedance is defined on the border external of the fluid, by a loading of the type IMPE and the calculation of the matrices of impedance which are dependent there.

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2 Reference solution

2.1 Method of calculating

The empirical modes are calculated. One tests the modes by specific of not-regression on various points and different values ddl.

2.2 Sizes and results of reference

One seeks to solve the following system:

$$\left(-i\omega^3 \boldsymbol{I}(\mu)-\omega^2(\mu)\boldsymbol{M}(\mu)+\boldsymbol{K}(\mu)\right)\boldsymbol{u}(\mu)=\boldsymbol{F}(\mu) \quad (2)$$

The coefficient μ represent the parameters of variation, $\boldsymbol{I}$ the matrix of impedance, $\boldsymbol{M}$ the matrix of mass, $\boldsymbol{K}$ the matrix of rigidity and $\boldsymbol{F}$ the second member (applying the nodal force). The variable parameters are the following: ω , E_a , ρ_a and ρ_v .
One writes the system in the following form:

$$f_1(\omega, E_a).\boldsymbol{K}_v+f_2(\omega,\rho_a).\boldsymbol{K}_e+\boldsymbol{K}_f+f_3(\omega,\rho_v).\boldsymbol{M}_e-\omega^2\boldsymbol{M}_f-j\omega^3.\boldsymbol{I}=\boldsymbol{F} \quad (3)$$

Different the contribution was separated: $\boldsymbol{K}_v$ for rigidity coming from the viscoelastic part (calculated by `RIGI_MECA_HYST`), $\boldsymbol{K}_e$ for rigidity coming from the elastic part, $\boldsymbol{K}_f$ for rigidity coming from the fluid part, $\boldsymbol{M}_e$ for the mass coming from the elastic part, $\boldsymbol{M}_f$ for the mass coming from the fluid part and $\boldsymbol{I}$ the matrix of impedance.
And functions:

$$f_1(\omega,E_a)=2\times E_a(1.0+\nu_v)\frac{\dfrac{G_0+G_\infty(jc\omega\tau)^\alpha}{1+(jc\omega\tau)^\alpha}}{\rho_e c^2}+2jE_a(1.0+\nu_v)\frac{\dfrac{G_0+G_\infty(jc\omega\tau)^\alpha}{1+(jc\omega\tau)^\alpha}}{\rho_e c^2}\times\frac{\Im\left(\dfrac{G_0+G_\infty(jc\omega\tau)^\alpha}{1+(jc\omega\tau)^\alpha}\right)}{\Re\left(\dfrac{G_0+G_\infty(jc\omega\tau)^\alpha}{1+(jc\omega\tau)^\alpha}\right)} \quad (4)$$

$$f_2(\omega,\rho_a)=\frac{\rho_a E_e}{\rho_e c^2} \quad (5)$$

$$f_3(\omega,\rho_v)=\frac{-\omega^2\rho_v\rho_a}{\rho_e} \quad (6)$$

For calculation, one varies the four parameters out of ten values (one does not recopy here the value of these parameters which were drawn randomly, to see the command file)

2.3 Uncertainties on the solution

The error on the solution depends on the degree of reduction (many modes empiricalS).

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3 Modeling A

3.1 Characteristics of modeling

A modeling is used 2D_FLUIDE, D_PLAN and 2D_FLUI_STRU in linear dynamics YEWS coupled (formulation (u, p, φ)).
This modeling tests the creation of the empirical modes. Three modes are calculated.

3.2 Characteristics of the grid

The grid contains 10654 elements of the type TRIA3.

3.3 Sizes tested and results

One tests some values (complex) of the base:

Identification	Type of reference
$N5$ – D X – Mode 1	NON_REGRESSION
$N5$ – DY – Mode 1	NON_REGRESSION
$N9$ – NEAR – Mode 1	NON_REGRESSION
$N5$ – D X – Mode 2	NON_REGRESSION
$N5$ – DY – Mode 2	NON_REGRESSION
$N9$ – NEAR – Mode 2	NON_REGRESSION
$N5$ – D X – Mode 3	NON_REGRESSION
$N5$ – DY – Mode 3	NON_REGRESSION
$N9$ – NEAR – Mode 3	NON_REGRESSION

3.4 Remarks

One cannot say anything in the absolute on the precision of these values because ON tests values of not-regression. It is a purely data-processing test.

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