SDNL133 – Turning fissured rotor, subjected to a bending stress

Summary:

The object of this test is to validate the modeling of a crack 1D in a rotor. This functionality is available via the option ROTOR_FISS of the operator DYNA_VIBRA.

The cas-test brings into play a beam in slow rotation subjected to one constant bending moment.

One compares the solution with a calculation in 3D carried out with STAT_NON_LINE for the extreme positions of closed crack and open crack.

1 Problem of reference

The objective of this case test is to validate modeling 1D of a rotor fissured (option `ROTOR_FISS` of `DYNA_VIBRA`) who simulates by an equivalent law the behavior of a crack in a line of trees.

The law is established thanks to the calculations 3D carried out into quasi-static (cf modeling D).

One compares the results got by modeling "beam" and the element of crack with calculation 3D for the extreme positions: closed crack and fissures completely to the maximum.

1.1 Geometry

For the fissured rotor one considers a simple cylindrical right beam length $2L=4m$ and of diameter $D=0,8m$. The crack is in the middle of the beam and has a right bottom. The depth of the crack is of 65%.

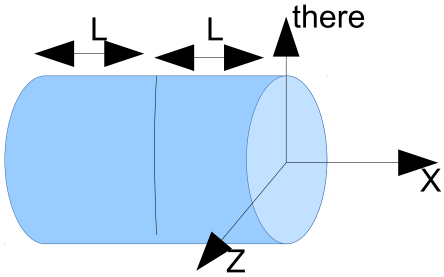

Figure 1: Geometry of the fissured rotor

1.2 Material properties

The rotor has a density of $\rho=7\,800\,kg/m^3$.
The Young modulus is $E=210\,10^9\,N\,m^{-2}$ and the Poisson's ratio is $\nu=0,3$.

1.3 Boundary conditions and loadings

For modelings With, B and C, the beam is embedded on the left and is subjected to one bending moment of unit amplitude according to Y on its right end. It is considered that the crack turns relatively slowly at the speed 5 turns a second ($300\,\text{rpm}$).

For modeling D, the boundary conditions imposed are on the one hand, an embedding within the meaning of the theory of the beams of the one of the ends of the cylinder by means of a connection `3D-POU`, and in addition, a unilateral contact without friction between the lips of the cracks. The imposed loading is one unit bending moment components (M_x, M_y) applied at the loose lead. The orientation of this moment evolves according to the moment of calculation.

1.4 Initial conditions

At the initial state, $t=0$, the crack is closed. It is gradually opened by a linear slope spread out over $0.2\,s$ carrying out the moment according to Y of 0 with $1\,Nm$.

2 Reference solution

The reference solution is a calculation 3D carried out with STA_NON_LINE. One recovers by a postprocessing the deformation of neutral fibre.

3 Modeling A

3.1 Characteristics of modeling

The rotor is modelled by elements of beam of Euler (POU_D_E).
The crack is modelled by the functionality ROTOR_FISS of DYNA_VIBRA. The law of behavior of crack entered by a function, itself given on a bar of unit diameter, independent of the geometry of the rotor (cf modeling D).
DYNA_VIBRA calculate the transient on modal basis. The latter is not orthogonal but made up on the one hand modes of beam of the rotor with crack closed (until $250\,\mathrm{Hz}$) and of the first 2 modes of beam with open crack.

3.2 Characteristics of the grid

Many meshs SEG2	21

3.3 Results: comparison between calculation 3D and calculation 1D

It is noted, by tracing the displacement of the end of the beam subjected to the bending moment, that the crack opens and is closed according to the angle of the bottom of crack compared to the direction of the exerted moment.

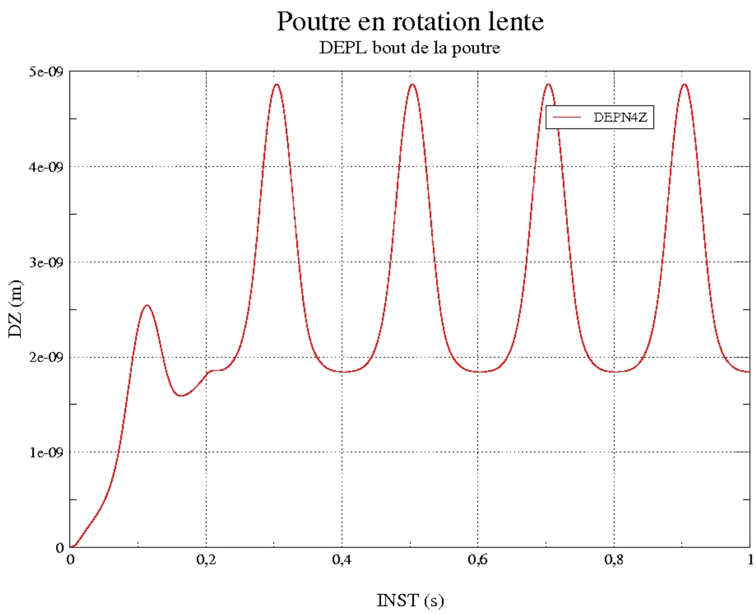

Figure 3:

Displacement of the end of the rotor subjected to the bending moment

One traces neutral fibre of the beam for the closed crack (figure 4) and for the open crack (figure 5). They are comparable.

The table 3.3-1 give the digital values tested in this CAS-test. They is displacements in the end of rotor for the situations fissures open and fissures closed.

Identification	Type of reference	Value of reference	Tolerance
Open crack - DZ in the end	'AUTRE_ASTER'	4.52765E-09	10%
Open crack - DZ in the end	'NON_REGRESSION'	4.8308805E-09	0.0001%
Closed crack - DZ in the end	'AUTRE_ASTER'	1.77757E-09	10%
Closed crack - DZ in the end	'NON_REGRESSION'	1.8442025E-09	0.0001%

Table 3.3-1: Summary of the results tested

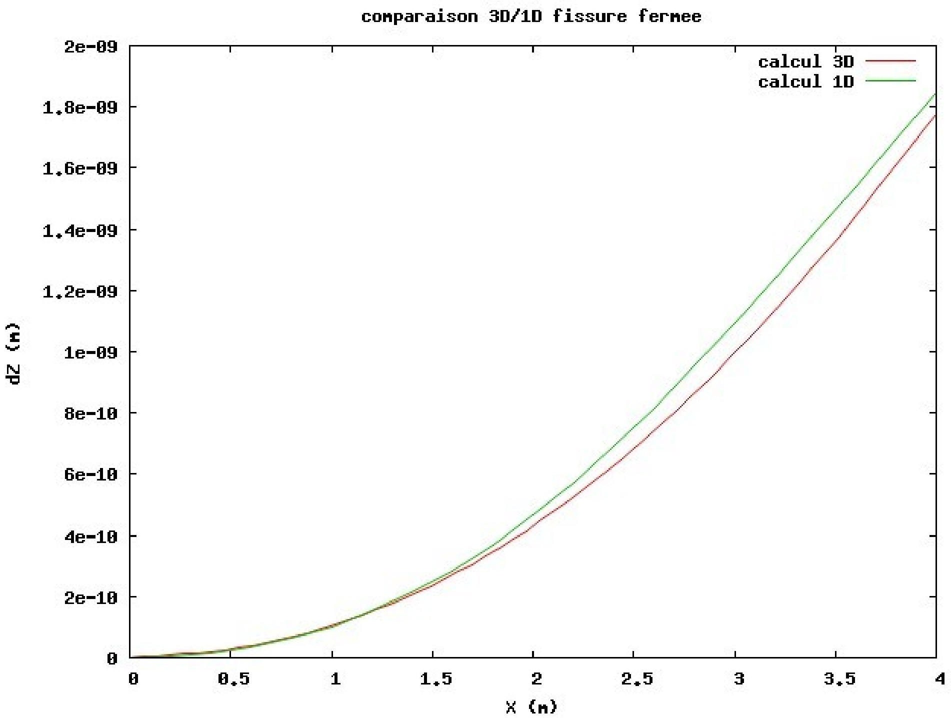

Figure 4: Comparison 1D/3D fissures closed

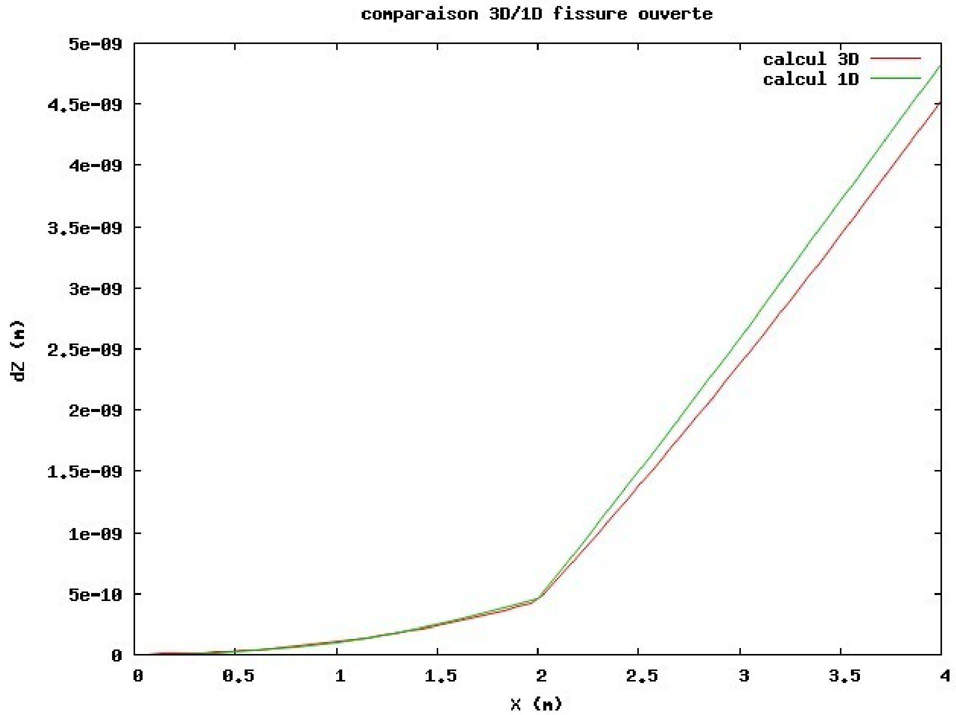

Figure 5: comparison 1D/3D fissures open

4 Modeling B

4.1 Characteristics of modeling

Modeling B takes again modeling A while turning the model of $90°$. The axis of rotation is found according to the axis Y .

4.2 Characteristics of the grid

Many meshs `SEG2` 21

4.3 Results: comparison between calculation 3D and calculation 1D

One finds the same results as those of modeling A, summarized in the table 4.3-1 .

Identification	Type of reference	Value of reference	Tolerance
Open crack - DZ in the end	'AUTRE_ASTER'	4.52765E-09	10%
Open crack - DZ in the end	'NON_REGRESSION'	4.8308805E-09	0.0001%
Closed crack - DZ in the end	'AUTRE_ASTER'	1.77757E-09	10%
Closed crack - DZ in the end	'NON_REGRESSION'	1.8442025E-09	0.0001%

Table 4.3-1: Summary of the results tested

5 Modeling C

5.1 Characteristics of modeling

Modeling C takes again modeling A. the difference is the imposition of a transient speed to the fissured rotor turning by the means of a linear law number of revolutions.

5.2 Characteristics of the grid

Many meshs SEG2 21

5.3 Results: comparison between calculation 3D and calculation 1D

One finds the same results as those of modeling A, summarized in the table 5.3-1 .

Identification	Type of reference	Value of reference	Tolerance
Open crack - DZ in the end	'AUTRE_ASTER'	4.52765E-09	10%
Open crack - DZ in the end	'NON_REGRESSION'	4.8308805E-09	0.0001%
Closed crack - DZ in the end	'AUTRE_ASTER'	1.77757E-09	10%
Closed crack - DZ in the end	'NON_REGRESSION'	1.8442025E-09	0.0001%

Table 5.3-1: Summary of the results tested

6 Modeling D

6.1 Characteristics of modeling

As specified previously, Lcharacterization of the behavior of the fissured rotor has requires the realization of a three-dimensional model of beam fissured in bi--centered inflection.

This modeling D makes it possible to capitalize the procedure of grid of a standard cylinder fissured as well as script python making it possible to identify the laws characterizing the behavior of the fissured rotor studied in modelings A, B and C.

One considers an element of rotor of modulus Young E, of quadratic inertia I (identical in all the directions of the plan of section) and length $2L=4\,m$ and of diameter $D=1\,m$ containing in its median section a transverse crack at right bottom of depth 65%.

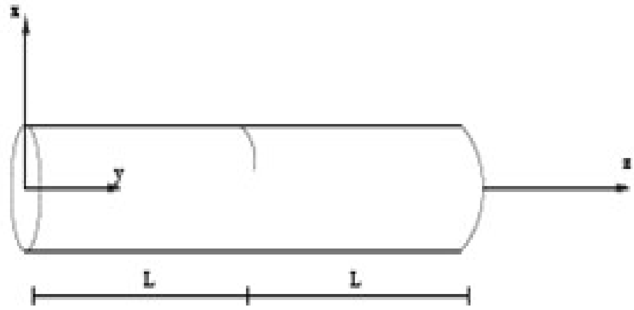

Figure 6: unit fissured test-tube

A nonlinear static calculation is carried out with *Code_Aster* for 36 pas de loading while making evolve orientation Φ_i moment with a step of $10°$ so as to traverse the complete interval $[0°-360°]$. Postprocessing is carried out by a script Python which exploits the file of results resulting from *Code_Aster*. Starting from rotations according to X and Y end of the cylinder under revolving loading imposed for each moment of calculation, script Python makes it possible to calculate the deformation energy, the flexibility associated with the deformations with the fissured cylinder, local rigidity like its derivative.

Adimensionnées curves of stiffness and derived obtained depend on the orientation Φ efforts applied compared to the angular position of the crack .

6.2 Characteristics of the grid

The grid contains 6315 nodes and 6720 meshs.

Many meshs `POI1`	17
Many meshs `SEG2`	77
Many meshs `SORTED3`	94
Many meshs `QUAD4`	932
Many meshs `PENTA6`	480
Many meshs `HEXA8`	5120

6.3 Results: Law of behavior of crack 1D

The law of behavior of the crack 1D is traced on the figure below.

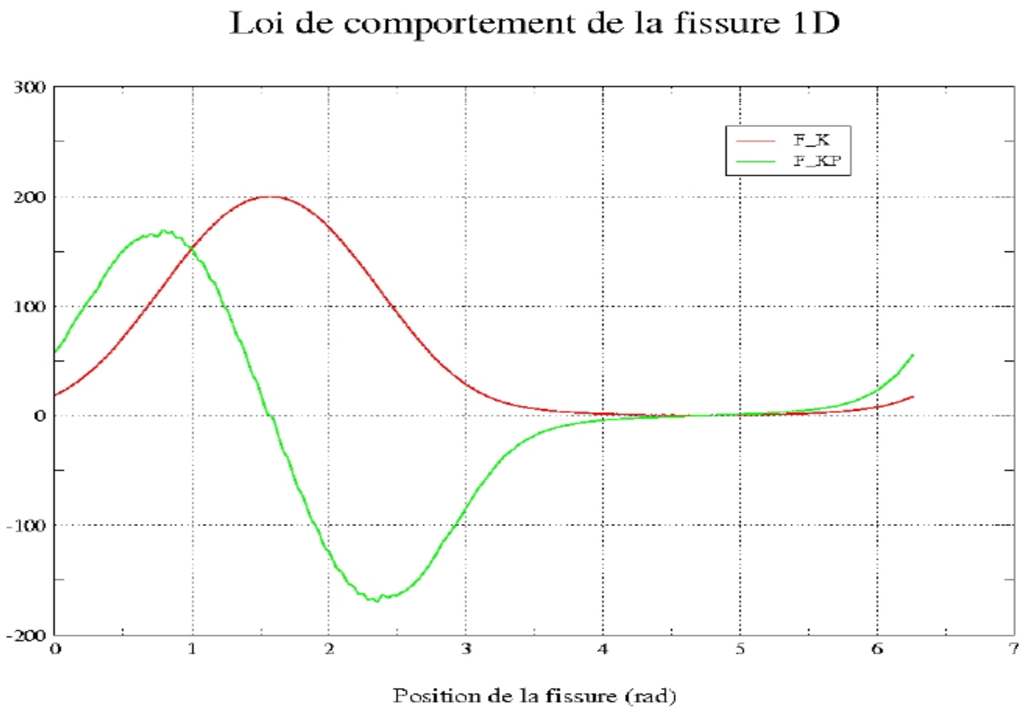

Figure 7: Law of behavior of the crack 1D

7 Summary of the results

The cas-test implements the slow rotation of a fissured beam, embedded with an end and subjected to one bending moment to the other. Modeling 1D of fissured rotor programmed in DYNA_VIBRA compared to the results got in statics with the model are equivalent 3D is thus validated.