SDNL133 – Turning fissured rotor, subjected to a bending stress

Summarized:

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

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

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

1 Problem of reference

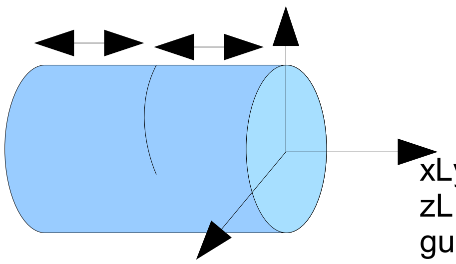
the purpose of this case test is to validate the modelization 1D fissured rotor (option `ROTOR_FISS` of `DYNA_VIBRA`) which simulates by an equivalent model the behavior of a crack in line of trees.

The model is drawn up thanks to the computations 3D carried out into quasi-static (cf modelization D).

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

1.1 Geometry

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



xLy
zLFi
gur
e

1: Geometry of the rotor fissured

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 the modelizations A, B and C, the beam is clamped 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 towers a second ($300\,\mathrm{rpm}$).

For the modelization D, the imposed boundary conditions are on the one hand, a fixed support 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 on the other hand, a unilateral contact without friction between the lips of cracks. The imposed loading is one unit bending moment of components (M_x, M_y) applied at the loose lead. The directional sense of this moment evolves according to the time of computation.

1.4 Initial conditions

In an 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 0 $1\,Nm$.

2 Reference solution

the reference solution is a computation 3D carried out with STA_NON_LINE. One recovers by a postprocessing the deformed shape of neutral fiber.

3 Modelization A

3.1 Characteristic of the modelization

the rotor is modelled by beam elements of Eulerian (POU_D_E).
The crack is modelled by functionality ROTOR_FISS of DYNA_VIBRA. The crack constitutive law entered by a function, itself given on a bar of unit diameter, independent of the geometry of the rotor (cf modelization D).
DYNA_VIBRA calculates the transient on modal base. 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 mesh

Number of meshes SEG2 21

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

One notes, by tracing the displacement of the end of the beam subjected to the bending moment, that the crack compared to the opens and closes according to the angle of the crack tip direction of the exerted moment.

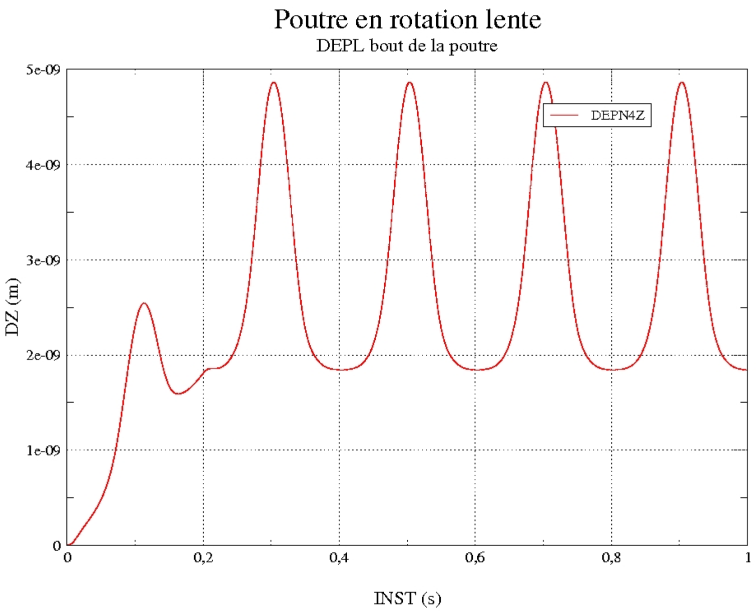


Figure 3:

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

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

Table 3.3-1 gives the numerical values tested in this benchmark. They is displacements in the end of rotor for the situations fissures open and fissures closed.

Standard	identification of reference	Value of reference	Tolerance
Fissures open - DZ boils about it	"AUTRE_ASTER"	4.52765E-09	10%
open Crack - DZ boils about it	"NON_REGRESSION"	4.8308805E-09	0.0001%
Crack closed - DZ boils about it	"AUTRE_ASTER"	4.52765E-09	10%
closed Crack - DZ boils about it	"NON_REGRESSION"	4.8308805E-09	0.0001%

Table 3.3-1: Summary of the results tested

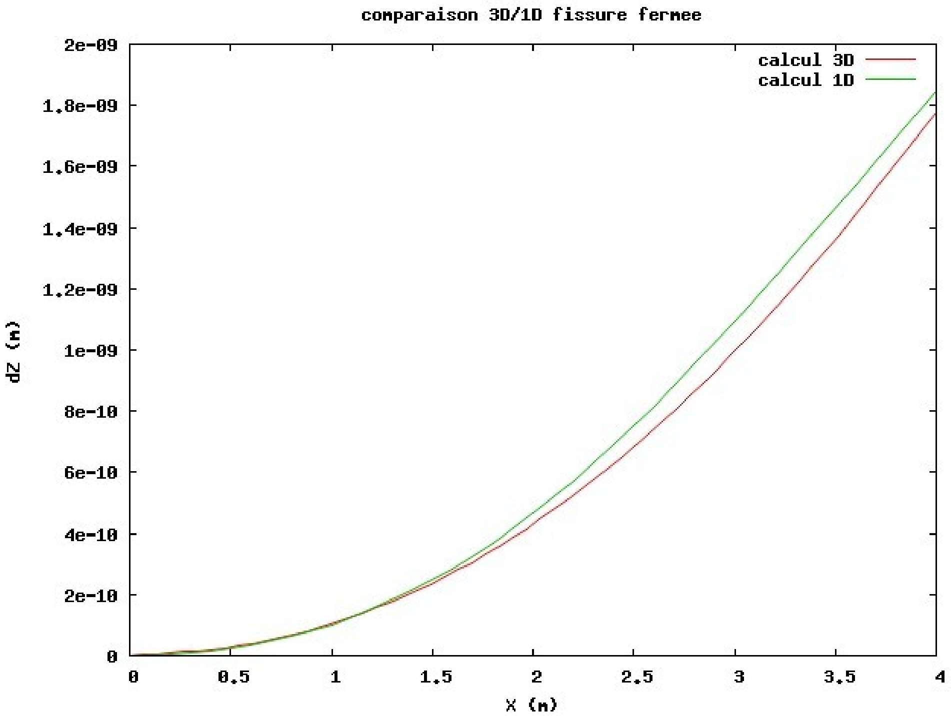


Figure 4: Comparison 1D/3D fissures closed

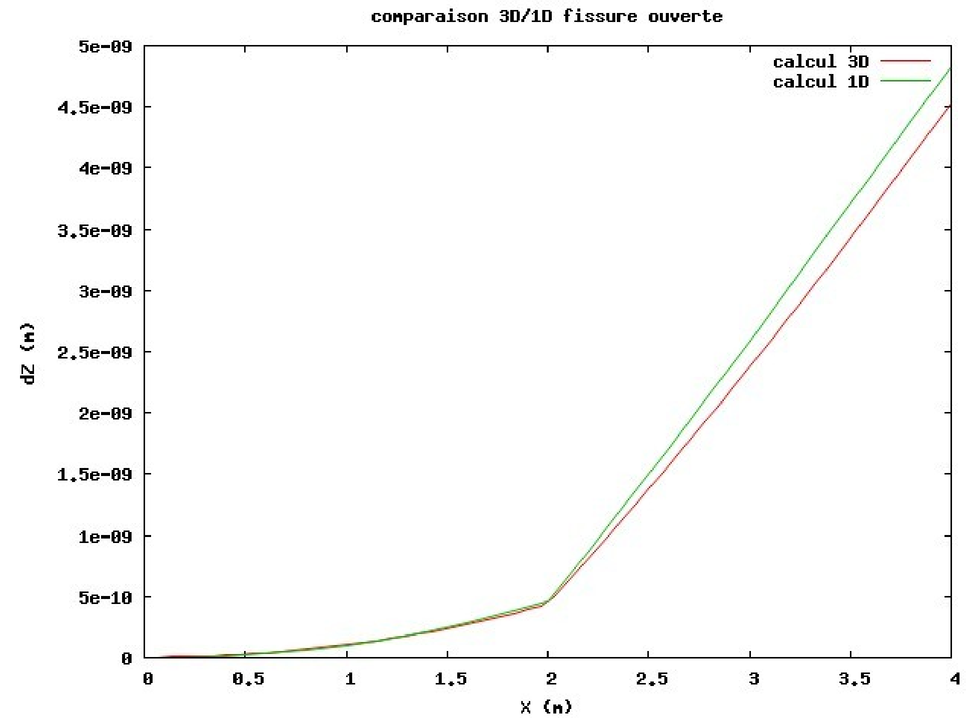


Figure 5: comparison 1D/3D fissures open

4 Modelization B

4.1 Characteristic of the modelization

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

4.2 Characteristics of the mesh

Number of meshes SEG2 21

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

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

Standard	identification of reference	Value of reference	Tolerance
Fissures open - DZ boils about it	"AUTRE_ASTER"	4.52765E-09	10%
open Crack - DZ boils about it	"NON_REGRESSION"	4.8308805E-09	0.0001%
Crack closed - DZ boils about it	"AUTRE_ASTER"	4.52765E-09	10%
closed Crack - DZ boils about it	"NON_REGRESSION"	4.8308805E-09	0.0001%

Table 4.3-1: Summary of the results tested

5 Modelization C

5.1 Characteristic of the modelization

The modelization C takes again modelization A. the difference is the imposition of a transient velocity to the fissured rotor turning by the means of a linear model rotational speed.

5.2 Characteristics of the mesh

Number of meshes SEG2 21

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

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

Standard	identification of reference	Value of reference	Tolerance
Fissures open - DZ boils about it	"AUTRE_ASTER"	4.52765E-09	10%
open Crack - DZ boils about it	"NON_REGRESSION"	4.8308805E-09	0.0001%
Crack closed - DZ boils about it	"AUTRE_ASTER"	4.52765E-09	10%
closed Crack - DZ boils about it	"NON_REGRESSION"	4.8308805E-09	0.0001%

Table 5.3-1: Summary of the results tested

6 Modelization D

6.1 Characteristic of the modelization

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

This modelization D makes it possible to capitalize the procedure of mesh of a standard cylinder fissured as well as script python making it possible to identify the models characterizing the behavior of the fissured rotor studied in the modelizations 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 plane of section) and length $2L=4m$ and of diameter $D=1m$ containing in its median section a transverse crack with right bottom of depth 65%.

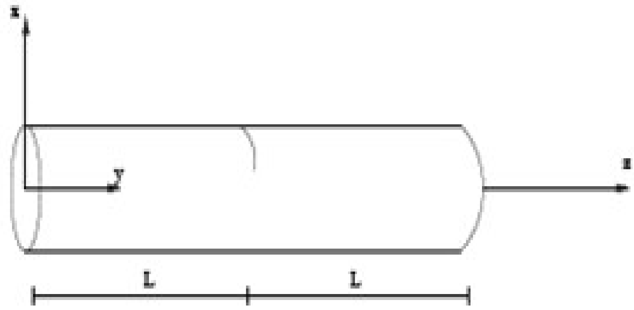


Figure 6: unit fissured test-tube

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

The adimensionnées curves of stiffness and derived obtained depend on the directional sense Φ of the forces applied compared to the angular position of crack .

6.2 Characteristics of the mesh

The mesh contains 6315 nodes and 6720 meshes.

Number of meshes `POI1`	17
Number of meshes `SEG2`	77
Number of meshes `TRIA3`	94
Number of meshes `QUAD4`	932
Number of meshes `PENTA6`	480
Number of meshes `HEXA8`	5120

6.3 Results: Crack constitutive law 1D

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

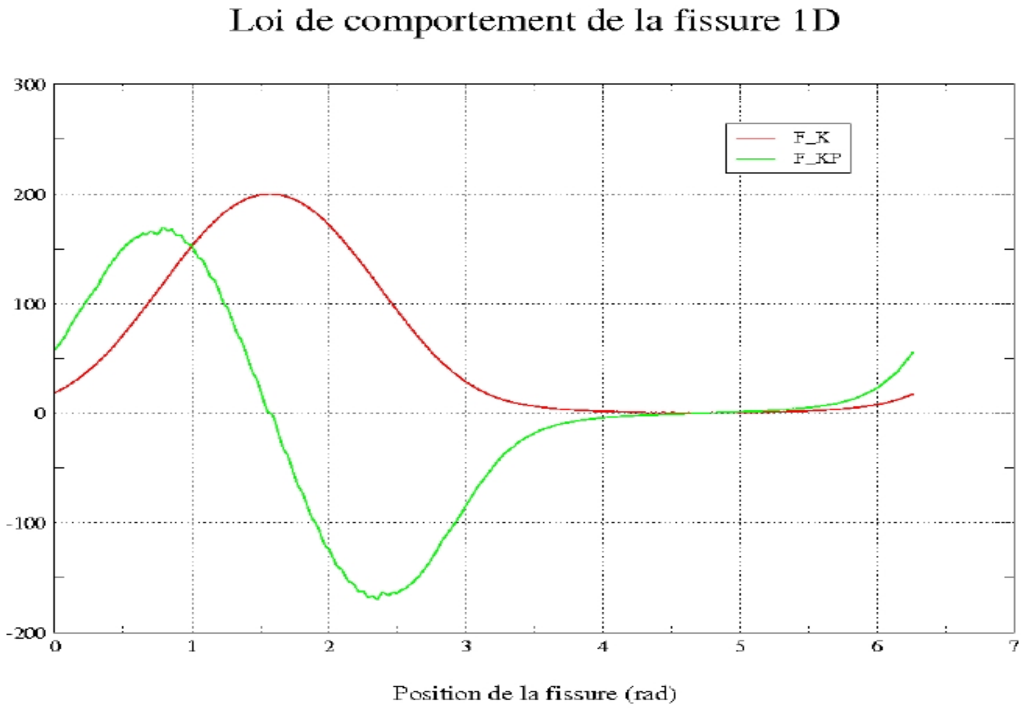


Figure 7: Constitutive law of crack 1D

7 Summary of the results

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