SSNP151 – Test-tube Compact Tension (CT) in 2D and 3D with the law CZM_TRA_MIX

Summary:

This test of mécanic nonlinear statics makes it possible to make sure of the regression of a functionality of Code_Aster EN breaking process. The functionality tested is the ductile law of rupture: CZM_TRA_MIX [R7.02.11].

A test-tube Compact Tension (CT) is solicited in traction. The evolution of the force during the propagation of the ductile rupture is calculated.

The modeling of the test-tube is carried out with elements 2D (QUA8) or of the elements 3D (HEXA20).
1 Problem of reference

1.1 Geometry and loading

One considers a test-tube Compact Tension (CT) of thickness 25 mm. The geometry understands a rigid pin to which the loading is applied.

Figure 1: Geometry

1.2 Properties of material

To describe the behavior of material of the axisymmetric test-tube (voluminal material), one uses an elastoplastic law of behaviour with an isotropic work hardening (law VMIS_ISOT_TRAC).

One takes: $E = 207 \text{ GPa}$ and $\nu = 0.3$ and the curve of work hardening retained is given below:

Figure 2: Isotropic curve of work hardening of voluminal material.

For the elements of interface the following parameters are used in the law CZM_TRA_MIX:

- $\sigma_c = 1800 \text{ MPa}$
- $G_c = 150 \text{ MPa} \cdot \text{mm}$
- $\delta_e = 0.01 \text{ mm}$
- $\delta_p = 0.06 \text{ mm}$
- $\delta_c = 0.117 \text{ mm}$

The law which results from this is schematized below.
Figure 3: Law of behavior of the elements of interface.

NB: Only half of the crack is modelled thanks to the symmetry of the problem, the tenacity of materials is of $2G_c$.

Lastly, the rigid pin has an elastic behavior (law $ELAS$) with: $E = 1 \times 10^9 \text{ MPa}$, $\nu = 0.3$

### 1.3 Boundary conditions and loading

The boundary conditions imposed on the pin are the following ones:
- displacement in $X$ blocked,
- imposed displacement $l$ according to the direction $Y$.

Evolution of displacement $l$ in the course of time is given in the following table:

<table>
<thead>
<tr>
<th>Time [s]</th>
<th>Displacement $l$ [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.4</td>
<td>1.6</td>
</tr>
</tbody>
</table>

The cohesive zone is represented by the elements of interface on the ligament of the test-tube. The boundary conditions on the elements of interface are:
- displacement in $X$ imposed identical on the two lips of the cohesive zone,
- displacement in $Y$ blocked on the lower lip.
2 Reference solution

2.1 Sizes and results of reference

The force applied to the test-tube (REAC_NODA) was calculated. The results calculated in this case test result from a former execution DE Code_Aster, it acts of a case test of not-regression.
3  Modeling A

Modeling in plane deformations.

3.1  Characteristics of modeling

The modeling of the ductile rupture is carried out with modeling PLAN_INTERFACE and the law CZM_TRA_MIX. The elements of volume are modelled EN plane deformations D_PLAN.

3.2  Characteristics of the grid

The grid of entry is linear. It is transformed into a quadratic grid by LINE_QUAD in CREA_MAILLAGE. After the transformation its characteristics are the following ones:

- Many nodes: 2357
- Many elements for the test-tube CT: 663 QUAD8 and 42 TRIA6
- Many elements for the pin: 20 TRIA6.
- Many elements of interface: 40 QUAD8.

![Figure 4: Grid of test-tube CT in 2D.](image)

3.3  Sizes tested and results

Test of nonregression: Force of traction (resulting \(DY\)) on the pin according to displacement \(DY\) pin.

<table>
<thead>
<tr>
<th>Size tested</th>
<th>Type of Reference</th>
<th>Code_Aster</th>
<th>Tolerance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force for a displacement of 0.5 mm</td>
<td>‘NON_REGRESSION’</td>
<td>4269.54</td>
<td>0.10</td>
</tr>
<tr>
<td>Force for a displacement of 1 mm</td>
<td>‘NON_REGRESSION’</td>
<td>4767.59</td>
<td>0.10</td>
</tr>
<tr>
<td>Force for a displacement of 1.5 mm</td>
<td>‘NON_REGRESSION’</td>
<td>5109.77</td>
<td>0.10</td>
</tr>
<tr>
<td>Force for a displacement of 2 mm</td>
<td>‘NON_REGRESSION’</td>
<td>5383.76</td>
<td>0.10</td>
</tr>
</tbody>
</table>
4 Modeling B

Modeling in 3D.

4.1 Characteristics of modeling

The modeling of the ductile rupture is carried out with modeling 3D_INTERFACE and the law CZM_TRA_MIX. The elements of volume are modelled with the model 3D.

4.2 Characteristics of the grid

The grid of entry is linear. It is transformed into a quadratic grid by LINE_QUAD in CREA_MAILLAGE. After the transformation its characteristics are the following ones:

Many nodes: 7160
Many elements for the test-tube $CT$: 1130 $\text{HEXA20}$ and 120 $\text{PRIS15}$
Many elements for the pin: 100 $\text{PRIS15}$
Many elements of interface: 100 $\text{HEXA20}$.

Figure 5: Grid of test-tube CT in 3D.
4.3 Sizes tested and results

Test of nonregression: Force of traction (resulting $DY$) on the pin according to displacement $DY$ pin.

<table>
<thead>
<tr>
<th>Size tested</th>
<th>Type of Reference</th>
<th>Code_Aster</th>
<th>Tolerance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force for a displacement of 0.4 mm</td>
<td>‘NON_REGRESSION’</td>
<td>4.47132E+04</td>
<td>0.10</td>
</tr>
<tr>
<td>Force for a displacement of 0.8 mm</td>
<td>‘NON_REGRESSION’</td>
<td>5.09591E+04</td>
<td>0.10</td>
</tr>
<tr>
<td>Force for a displacement of 1.2 mm</td>
<td>‘NON_REGRESSION’</td>
<td>5.22155E+04</td>
<td>0.10</td>
</tr>
<tr>
<td>Force for a displacement of 1.6 mm</td>
<td>‘NON_REGRESSION’</td>
<td>5.32126E+04</td>
<td>0.10</td>
</tr>
</tbody>
</table>
5 Summary of the results

Only values of nonregression are tested.