SSNA111 - Indentation of a solid mass by a punch

Summary:

This test relates to the study of a conical punch deforming an elastoplastic massive structure.

The unit is modelled with elements axisymmetric and subjected to an imposed displacement and contact.
1 Problem of reference

1.1 Geometry

The problem is axisymmetric (of axis $Y$). The punch consists of only one triangular element. It is supposed in initial contact with the solid mass at the point $A$; this point is thus topologically confused between the punch and the solid mass.

1.2 Material properties

The solid mass consists of an elastoplastic material with linear isotropic work hardening:

\[ E = 2,0 \times 10^5 \text{MPa} \]
\[ \nu = 0.3 \]
\[ \sigma_y = 300 \text{MPa} \]
\[ E_T = 5000 \]

The punch is supposed to be rigid and one approximates it by an elastic material with a large Young modulus:

\[ E = 2,0 \times 10^9 \text{MPa} \]
\[ \nu = 0.3 \]
1.3 Boundary conditions and loadings

The base of the solid mass is embedded and its left side is imposed on $DX = 0$. Horizontal displacement is imposed on 0. The vertical displacement of the punch is imposed on $u_A = -0.4$ mm, then gone up 0.008 mm (elastic return) according to the following graph:

![Graph showing boundary conditions and loadings](image)

2 Reference solution

2.1 Results of reference

The results calculated in this CAS-test are displacements and rotations of node A ($DEPL$). It result from a former execution from Code_Aster. It is a case test of nonregression, except for the point A.
3 Modeling A

3.1 Characteristics of modeling

Modeling AXIS.

3.2 Characteristics of the grid

The grid consists of 1803 nodes and 1852 meshes of which a mesh TRIA3 for the rigid punch, and 1715 meshes QUAD4 for the solid mass (the rest of the meshes being meshes SEG2 for surface slave of the contact).

3.3 Characteristics of the behavior

Incremental elastic behavior for the punch (COMPORTEMENT/ELAS).

Elastoplastic behavior in great deformations with linear isotropic work hardening for the solid mass (COMPORTEMENT/VMIS_ISOT_LINE/SIMO_MIEHE).

3.4 Characteristics of the contact

Method of discrete contact with algorithm of the active constraints, pairing MAIT_ESCL and normal MAIT_ESCL.

3.5 Sizes tested and results

<table>
<thead>
<tr>
<th>Value tested</th>
<th>Moment</th>
<th>Reference</th>
<th>Type</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement $DY$ in $A$</td>
<td>0.5</td>
<td>-0.25</td>
<td>Analytical</td>
<td>-0.80%</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>-0.24798</td>
<td>Not-regression</td>
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<tr>
<td>Force of reaction $DX$ in $A$</td>
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<td>3.2482</td>
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<tr>
<td>Force of reaction $DY$ in $A$</td>
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<td>-8.7703</td>
<td>Not-regression</td>
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<tr>
<td>Displacement $DY$ in $A$</td>
<td>1.0</td>
<td>-0.392</td>
<td>Analytical</td>
<td>-0.60%</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>-0.38944</td>
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<td>-4.8966</td>
<td>Not-regression</td>
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</tr>
</tbody>
</table>

3.6 Remarks

The force of nodal reaction is in N/rad since the problem is axisymmetric. The difference on the analytical values of displacement come owing to the fact that the rigid punch is modelled by a material with a Young modulus of finished rigidity.
4 Modeling B

4.1 Characteristics of modeling

Modeling AXIS.

4.2 Characteristics of the grid

The grid consists of 1803 nodes and 1852 meshes of which a mesh TRIA3 for the rigid punch, and 1715 meshes QUAD4 for the solid mass (the rest of the meshes being meshes SEG2 for surface slave of the contact).

4.3 Characteristics of the behavior

Incremental elastic behavior for the punch (COMPORTEMENT/ELAS).

Elastoplastic behavior in great deformations with linear isotropic work hardening for the solid mass (COMPORTEMENT/VMIS_ISOT_LINE/SIMO_MIEHE).

4.4 Characteristics of the contact

Method of contact continues, pairing MAIT_ESCL, normal MAIT_ESCL and pairing is fixed, of normal \((0,-1,0)\). Integration with the nodes and coefficient of regularization of Lagrangian increased being worth 1000.

4.5 Sizes tested and results

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4.6 Remarks

The force of nodal reaction is in \(N/\text{rad}\) since the problem is axisymmetric. The difference on the analytical values of displacement come owing to the fact that the rigid punch is modelled by a material with one Young modulus of finished rigidity.

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5 Modeling C

5.1 Characteristics of modeling

Modeling \textit{AXIS}.

5.2 Characteristics of the grid

The grid is the same one as that of modeling \textit{With}.

5.3 Characteristics of the behavior

The behavior is the same one that for modeling \textit{With}.

5.4 Characteristics of the contact

The punch being rigid and of linear geometry, it is possible to model the contact by a unilateral connection on $DX$ and $DY$. By projection according to the normal with the punch, the condition of noninterpenetration can be written:

$$2.7 \times DY - (X + DX) < 2.7 \times u_A(t)$$

The unilateral condition is imposed utilizing the algorithm of penalization (\texttt{DEFI_CONTACT/ZONE/ALGO_CONT='PENALISATION'}).

5.5 Sizes tested and results

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<td></td>
</tr>
</tbody>
</table>

5.6 Remarks

The unilateral condition is calculated by considering the normal Master, which leads has a light variation compared to the modeling \textit{A} which uses normal \texttt{MAIT_ESCL}. One however finds the same results by comparison with a modeling of the contact who utili the normal Master for pairing.

The coefficient of penalty poses problems of convergence at the time of the elastic return, one thus imposes a coefficient not too high (1.0 E+3), which generates variations more important compared to modeling \textit{A}. It is possible to increase the coefficient of penalty on the phase of loading, one then finds the same results as for modeling with contact.
6 Summary of the results

This example of nonregression shows a non-linear calculation with contact. The nodal forces are slightly different (0.007%) between two modelings (discrete contact or continues), at the time of the elastic return.