SSNV254 – Validation elementary of the law of damage GTN in plane deformation with simulations of an element volume in simple traction

Summary:

This CAS-test makes it possible to validate the algorithm of integration of the law of damage of Gurson – Tvergaard – Needleman (GTN) room and with gradient with the standard finite elements under-integrated or mixed in great deformations. One models there an element volume in simple traction.

Various treated modelings are:

- Modeling A (2D): D_PLAN_IF.
- Modeling B (2D): D_PLAN_GRAD_VARI.
- Modeling C (2D): D_PLAN_GRAD_INCO.
- Modeling D (3D): 3D_IF.
- Modeling E (3D): 3D_GRAD_VARI.
- Modeling F (3D): 3D_GRAD_INCO.
1 Problem of reference

1.1 Geometry

According to modeling 2D (deformation planes) or 3D, a square or a cube on side is respectively considered 0.05 mm (see Figure. 1.1-1). Because of symmetry, only a quarter of the geometry is represented.

![Figure 1.1-a: Geometries of one square (A) and of a cube (b)](image)

1.2 Properties of material

Elasticity:

\[
E = 190000 \text{ MPa} \quad \text{Module of Young}
\]

\[
\nu = 0.3 \quad \text{Poisson's ratio}
\]

Curve of work hardening:

\[
R(\kappa) = 488.36 + 57.13 (1 - \exp(-8613 \kappa)) + 238.73 (1 - \exp(-10.39 \kappa))
\]

Ductile law of damage GTN:

\[
q_1 = 1.5 \quad \text{Parameter of the model GTN}
\]

\[
q_2 = 1.07 \quad \text{Parameter of the model GTN}
\]

\[
f_0 = 0.01 \quad \text{Porosity initial}
\]

\[
f_n = 0 \quad \text{Parameter of germination}
\]

\[
f_c = 0.05 \quad \text{Porosity of coalescence}
\]

\[
\delta = 3 \quad \text{Coefficient of acceleration related to coalescence}
\]

\[
c = 2.22 \text{ N} \quad \text{Nonlocal parameter}
\]

\[
r = 5000 \text{ MPa} \quad \text{Parameter of penalization of Lagrange}
\]
Into particular, the nonlocal parameter $c$ and the parameter of penalization $r$ are used that in the law of GTN with gradient.

In DEFI_MATERIAU, following information must be indicated:

| ELAS          | ECRO_NL       | GTN           | NON_LOCAL
|--------------|--------------|---------------|-------------
| E = 190000   | R0 = 488.361123569 | Q1 = 1.5      | C_GRAD_VAR = 2.22 |
| NAKED = 0.3  | R1 = 57.133673502  | Q2 = 1.07     | PENA_LAGR = 5000 |
|               | GAMMA_1 = 8613    | PORO_INIT = 0.01 |
|               | R2 = 238.731127339 | COAL_Poro = 0.01 |
|               | GAMMA_2 = 10.386585592 | COAL_ACCE = 3 |

1.3 Boundary conditions and loadings

For modeling $2D$ (deformation planes), vertical displacements of all the nodes are controlled: $u_y = 2.2y$, horizontal displacements are blocked for the side $AD$ because of symmetry, horizontal displacements are uniform for the side $BC$ (see Figure 1.1-1 (a) for the geometry).

For modeling $3D$, displacements according to the axis $Y$ of all the nodes are controlled: $u_y = 2.2y$, displacements according to the axis $X$ are blocked for the face $ADHE$ because of symmetry, horizontal displacements are uniform for the face $BCGF$. In addition, displacements according to the axis $Z$ of all the nodes are blocked (see Figure 1.1-1 (b) for the geometry).

Boundary conditions and loadings are imposed of this way of fate that the problem in $2D$ and that in $3D$ are identical between them and homogeneous.

The loading is imposed using identical 1000 pas de time. The pseudo-time of calculation is 1.
2 Reference solution

2.1 Results of reference

The reference solutions are obtained by carrying out same calculations in the code of calculation by finite elements Z-T (developed by Mines ParisTech and ONERA).
3 Modeling A

3.1 Characteristics of modeling

Modeling D_PLAN_SI.

3.2 Characteristics of the grid

The grid is obtained by SALOMÉ.
Many nodes: 8.
Number and types of meshes: 1 QUAD8, 4 SEG3.

3.3 Sizes tested and results

The problem considered here is homogeneous, the constraints (or variables internal) are thus identical to the various points of gauss.

One recovers the following values at moment 0.5 and 0.7: the component $\sigma_{yy}$ tensor of constraint ('SIEF_ELGA', 'SIYY'), the variable of work hardening $\kappa$ ('VARI_ELGA', 'V1') and porosity $f$ ('VARI_ELGA', 'V2').

The following table Rassemble Lbe values obtained by the computation software by finite elements Z-set.

<table>
<thead>
<tr>
<th>INST</th>
<th>Identification</th>
<th>Value of Référence</th>
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</table>
4 Modeling B

4.1 Characteristics of modeling

Modeling D_PLAN_GRAD_VARI.

4.2 Characteristics of the grid

Many nodes: 8.
Number and types of meshes: 1 QUAD8, 4 SEG3.

4.3 Sizes tested and results

The problem considered here is homogeneous, the constraints (or variables internal) are thus identical to the various points of gauss.

One recovers the following values at moment 0.5 and 0.7: the component \( \sigma_{yy} \) tensor of constraint ("SIEF_ELGA", 'SIYY'), the variable of work hardening \( \kappa \) ("VARI_ELGA","V1") and porosity \( f \) ("VARI_ELGA","V2").

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5  Modeling C

5.1  Characteristics of modeling

Modeling D_PLAN_GRAD_INCO.

5.2  Characteristics of the grid

Many nodes: 8.
Number and types of meshes: 1 QUAD8 , 4 SEG3.

5.3  Sizes tested and results

The problem considered here is homogeneous, the constraints (or variables internal) are thus identical to the various points of gauss.

One recovers the following values at moment 0.5 and 0.7: the component $\sigma_{yy}$ tensor of constraint ('SIEF_ELGA','SIYY'), the variable of work hardening $\kappa$ ('VARI_ELGA','V1') and porosity $f$ ('VARI_ELGA', 'V2').

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6 Modeling D

6.1 Characteristics of modeling

Modeling 3D_SI.

6.2 Characteristics of the grid

Many nodes: 20.
Number and types of meshes: 1 HEXA20, 6 QUAD8, 12 SEG3.

6.3 Sizes tested and results

The problem considered here is homogeneous and identical to the problem \( A \) (modeling \( A \)). The constraints (or variables internal) are thus identical to the various points of gauss.

One recovers the following values at moment 0.5 and 0.7: the component \( \sigma_{yy} \) tensor of constraint (‘SIEF_ELGA’, ‘SIYY’), the variable of work hardening \( \kappa \) (‘VARI_ELGA’, ‘V1’) and porosity \( f \) (‘VARI_ELGA’, ‘V2’).

The following table rassemble the values obtained by the computation software by finite elements Z-set.

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7 Modeling E

7.1 Characteristics of modeling

Modeling 3D\_GRAD\_VARI.

7.2 Characteristics of the grid

Many nodes: 20. 
Number and types of meshes: 1 HEXA20, 6 QUAD8, 12 SEG3.

7.3 Sizes tested and results

The problem considered here is homogeneous and identical to the problem $B$ (modeling $B$). The constraints (or variables internal) are thus identical to the various points of gauss.

One recovers the following values at moment 0.5 and 0.7: the component $\sigma_{yy}$ tensor of constraint (‘SIEF\_ELGA’, ‘SIYY’), the variable of work hardening $\kappa$ (‘VARI\_ELGA’,’V1’) and porosity $f$ (‘VARI\_ELGA’,’V2’).

The following table Rassemble Lbe values obtained by the computation software by finite elements Z-set.

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8 Modeling F

8.1 Characteristics of modeling

Modeling 3D_GRAD_INCO.

8.2 Characteristics of the grid

Many nodes: 20.
Number and types of meshes: 1 HEXA20, 6 QUAD8, 12 SEG3.

8.3 Sizes tested and results

The problem considered here is homogeneous and identical to the problem $C$ (modeling $C$). The constraints (or variables internal) are thus identical to the various points of gauss.

One recovers the following values at moment 0.5 and 0.7: the component $\sigma_{yy}$ tensor of constraint ('SIEF_ELGA', 'SIYY'), the variable of work hardening $\kappa$ ('VARI_ELGA', 'V1') and porosity $f$ ('VARI_ELGA', 'V2').

The following table rassemble lbe values obtained by the computation software by finite elements Z-set.

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9 Summary of the results

This CAS-test is carried out on only one nets in $2D$ plane deformation or in $3D$. With the boundary conditions and the loadings given, the answer becomes purely homogeneous. The reference solutions are obtained by carrying out same calculations in the computer code by finite elements Z-set (developed by Mines ParisTech and ONERA). One has one good agreement enters the calculated results and the solution of reference.