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## SSNP307 - Validation of modelization GVNO and constitutive law ENDO\_CARRE in D\_PLAN

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### Summarized:

This test allows the validation of modelization GVNO in 2D , for the modelization D\_PLAN\_GVNO, which makes it possible to carry out the computations of damage regularized by the gradient of the damage, in taking into account only of degrees of freedom of displacement and damage to the nodes. The resolution of the criterion is total, unlike the modelization GRAD\_VARI which carries out a local resolution, Gauss points by Gauss points. One validates simultaneously constitutive law ENDO\_CARRE, of quadratic formulation in damage, which is for the moment the model that one can use with modelization GVNO.

## 1 Problem of reference

### 1.1 Tallies theoretical

the unknowns of the problem are the degrees of freedom of nodal displacement and damage. It is then a question of minimizing an energy of the form:

$$\phi(u, \alpha) = \frac{1}{2} A(d) E \epsilon^2 + \psi(d) + \frac{c}{2} \nabla \alpha \cdot \nabla \alpha$$

Where  $E$  is the Young's modulus of the material,  $A(d)$  the function of stiffness,  $\psi(d)$  dissipation and  $c$  the nonlocal coefficient.

In the case of model ENDO\_CARRE :

$$A(d) = (1-d)^2 \text{ and } \psi(d) = \frac{\sigma_y^2}{E} d$$

the criterion corresponding to model ENDO\_CARRE, for a homogeneous solution ( $\nabla \alpha = 0$ ), is thus written:

$$d = 1 - \left( \frac{W_y}{W_{el}} \right)$$

Where  $W_{el}$  is elastic strain energy and:

$$W_y = \frac{\sigma_y^2}{2E}$$

### 1.2 Geometry

One considers a square on side  $L = 1 \text{ m}$ .

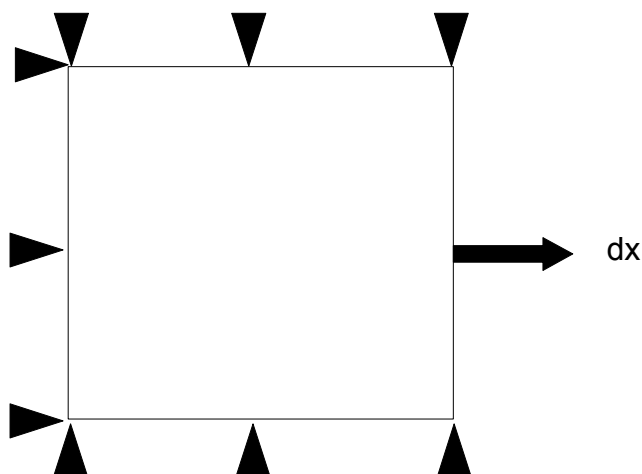


Figure 1 : Representation of the problem

## 1.3 Properties of the material

### 1.3.1 Damage model: elastic material

ENDO\_CARRE Characteristics:

$$E = 1 \text{ Pa}$$

$$\nu = 0.$$

Characteristics related to the damage model:

Elastic limit:

$$SY = 0.01 \text{ Pa}$$

NON-local characteristics:

$$c = 1.0 \text{ N}$$

## 1.4 Boundary conditions and loadings

**Fixed support** : Displacements imposed no one  $DY = 0 \text{ m}$  on stop horizontal bottom and top (  $y=0.$  and  $y=1.$  ) and  $DX = 0 \text{ m}$  on stop left (  $x=0.$  ). See Figure 1.

**Loading 1** : Displacement imposed  $U_1$  on stops vertical right:

At time  $t_1$  :  $DX = 0.01 \text{ m}$

At time  $t_2$  :  $DX = 0.0125 \text{ m}$

At time  $t_3$  :  $DX = 0.02 \text{ m}$

## 2 Reference solution

the imposed loading enables us to obtain a homogeneous solution, equivalent to a bar length  $L$  subjected to a uniaxial loading of tension. One can then express elastic strain energy in the following way:

$$W_{el} = \frac{E}{2} \left( \frac{dx}{L} \right)^2$$

One from of deduced analytically the values of damage associated with times  $t_1$ ,  $t_2$  and  $t_3$  from the formula:

$$d = 1 - \left( \frac{\sigma_y L}{E dx} \right)^2$$

That is to say:  $d_1=0.$ ,  $d_2=0.36$  and  $d_3=0.75$ . It is considered whereas the test is checked if Newton us reference well the same values of damage, with an accuracy of  $10^{-6}$ .

## 3 Modelization

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### 3.1 Characteristics of the modelization

One uses modelization D\_PLAN\_GVNO.

### 3.2 Characteristics of the mesh

The mesh contains 25 elements QUAD8.

### 3.3 Quantities tested and Results

NUME_ORDRE	REFERENCE	VALE_REF	TOLE
1	"ANALYTIQUE"		0.0.1.0E-4%
2	"ANALYTIQUE"	0.36	1.0E-4%
3	"ANALYTIQUE"	0.75	1.0E-4%

Table 1: Comparison of eigenvalues in room and NON-room

## 4 Summary of the results

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convergence was checked starting from criterion `RESI_REFE_REL`. This case test thus allows a simultaneous validation of `D_PLAN_GVNO` and developments related to `RESI_REFE_REL`, which adimensionne residues from values of reference declared in the command file (one declares `SIGM_REFE = SY`).

We find the results of references well, which validates the modelization `GVNO` and constitutive law `ENDO_CARRE` in `2D`, for modelization `D_PLAN_GVNO` and what also validates `RESI_REFE_REL` for `GVNO`.