FORMA08 - Practical works of the formation “advanced Use”: Elastic beam DCB 3D

Summary:

This test $3D$ into quasi-static, enters within the framework of the validation of the propagation of crack per cohesive model. A beam DCB is charged in traction.

1 Problem of reference

1.1 Geometry

One considers a beam here known as doubles Cantilever three-dimensional whose geometry is presented below. It presents an initial cracking of the quarter its length.

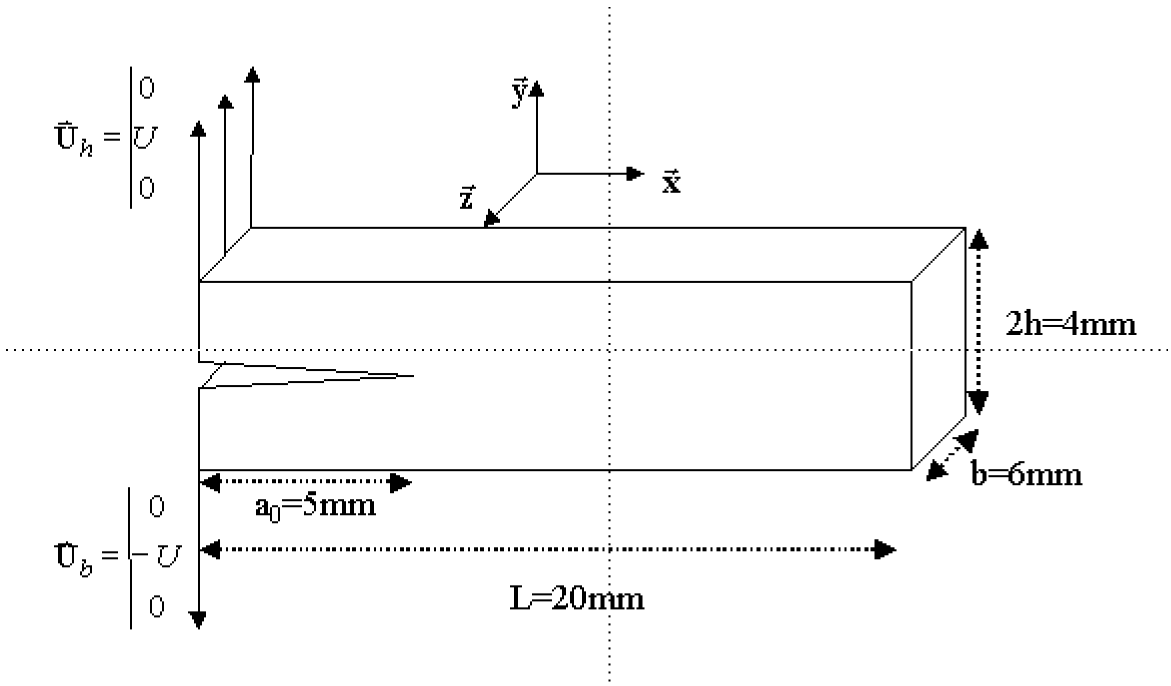

Figure 1.1 : geometry

1.2 Material properties

The material of the beam is supposed to be isotropic linear rubber band with the following characteristics:

- Young modulus: $E=100\text{MPa}$ (yes, it is very very weak!)
- Poisson's ratio: $\nu=0,3$
- Energy of cracking: $G_C=0,9\,MPa.m^{-1}$
- Constraint criticizes cracking: $\sigma_c=4\text{MPa}$

1.3 Boundary conditions and loadings

One imposes a purely vertical displacement of the side faces left of the DCB.
By taking of account symmetry, it is possible to consider only the upper part of the DCB. It is then necessary to add the condition of symmetry like limiting condition of the problem.

2 Reference solution

2.1 Method used for the reference solution

There exists an approximate analytical solution with the cracking of this kind of beam in traction (mode I pure), determined by the method known as of kindness.
This solution is based on the theory of the beams. If the sufficiently slim DCB and the sufficiently small deformations are considered, the equations of Bernoulli can be applied. The arrow U express yourself then according to the bending moment M_f by the relation:

$$\frac{\partial^2 U}{\partial^2 x}=\frac{m_f}{EI}=\frac{Fx}{EI}\Rightarrow U(x)=\frac{F}{EI}\left(\frac{x^3}{6}-\frac{a^2}{2}x+\frac{a^3}{3}\right)$$

with a the length of crack, $I=\frac{bh^3}{12}$ quadratic moment of the beam, and F the force applied to the side faces.
Kindness (relationship between the opening and the force necessary to cause it) is thus expressed:

$$C=\frac{U(0)}{F}=\frac{a^3}{3\mathrm{EI}}$$

The rate of refund of energy associated with a crack length a express yourself consequently:

$$G=\frac{F^2}{2\mathrm{b}}\frac{dC}{da}=\frac{9\mathrm{EI}}{2\mathrm{ba}^4}U^2$$

By supposing the propagation of stable crack and following the law of Griffith, it is possible to determine the length of crack according to the loading.

$$a=\left(\frac{9\mathrm{EI}}{2\mathrm{bG}_c}\right)^{\frac{1}{4}}U^{\frac{1}{2}}$$

By combining the formulas of the arrow and length of crack, one obtains the expression of the force then:

$$F=\frac{(EI)^{\frac{1}{4}}(2\mathrm{b}G_c)^{\frac{3}{4}}}{(3\mathrm{U})^{\frac{1}{2}}}$$

This relation is approximate because of the assumptions and also owing to the fact that she does not answer by exactly the assumptions of the cohesive zones (but of pure Griffith). One can however regard it as a base of comparison to the experimental results.

2.2 Results of reference

With the digital values of the statement analytically, one finds the results following:

$$U=10\mathrm{mm}\Rightarrow F=4{,}86\,N$$

$$U=10{,}651\,mm\Rightarrow F=4{,}71\,N$$

3 Modeling a: ELEMENTS 3D_JOINTS

3.1 Unfolding of the TP

The command file corresponding to the requests is provided: file forma08a.comm.
However, it is preferable to use the file to be supplemented.

3.1.1 Grid

By taking of account the symmetry of the geometry, it is possible to consider only the upper part of beam DCB.
For more speed, a linear grid including only hexahedrons HEXA8 is provided (forma08a.med).
The useful groups of this grid are the following:

- volume of the DCB: groups of meshs DCB_1 and DCB_2
- volume of the cohesive zone: group of meshs DCB_J
- application of displacement: group of meshs and group of nodes DCB_GB (corresponding to the side $X=0$ face of loading), containing a group of nodes NO7 (useful to recover displacement)
- application of symmetry: group of meshs JOINT_B

It is also possible to recreate a free grid in HEXA8 and PENTA6 for this study; it will then be necessary to take care of several points:

- to define an additional zone, low thickness 1 element which will represent the layer of cohesive elements
- to define the groups of meshs necessary to the application of displacement
- to define the surface representing lower lips and higher groups of meshs cohesive zone.

3.1.2 Mechanical calculation

To carry out calculation by using the cohesive law CZM_EXP_REG and of the elements 3D_JOINT .
One will carry out calculation until an imposed displacement of 10 mm by increment of 0.05 mm .

3.1.3 Calculation of the force

To recover the nodal force, to trace it according to imposed displacement, and to compare with the theoretical results.

3.1.4 Visualization of the deformation

To print with the format MED results of mechanical calculation, on the voluminal meshs (not to insert the meshs of joint) and to visualize the deformation.

3.1.5 Influence of the law of behavior

To carry out same calculation and same postprocessings by using the cohesive law CZM_LIN_REG .
To compare the results

3.2 Sizes tested and results

Identification	Reference	% tolerance
Nodal force for an imposed displacement of 10 mm	4.86 N	1.0%

Table 3.1 : Results for Modeling A

4 Modeling b: ELEMENTS 3D_INTERFACE_S

4.1 Unfolding of the TP

The command file corresponding to the requests is provided: file forma08b.comm.
However, it is preferable to use the file to be supplemented.

4.1.1 Grid

By taking of account the symmetry of the geometry, it is possible to consider only the upper part of beam DCB.
For more speed, a linear grid including only hexahedrons HEXA8 is provided (forma08b.med).
The useful groups of this grid are the following:

- volume of the DCB: groups of meshs DCB_1 and DCB_2
- volume of the cohesive zone: group of meshs DCB_J
- application of displacement: group of meshs DCB_GB, containing a group of nodes NO7 (useful to recover displacement)
- application of symmetry: group of meshs JOINT_B

4.1.2 Mechanical calculation

To carry out calculation by using the cohesive law CZM_OUV_MIX and of the elements 3D_INTERFACE.

To think of the convergence criteria to be used…

One will carry out the first calculation until a displacement imposed of $10\,mm$ by increment of $0{,}05\,mm$.

4.1.3 Calculation of the force

To recover the nodal force, to trace it according to imposed displacement, and to compare with the theoretical results.

4.1.4 Installation of piloting

One now proposes to use the tools for piloting. To use the piloting of type elastic prediction with a selection of type residue on imposed displacement and the meshs of interface, and to ask time limits of 4.5 per increment of 0.05. What does one note? Does the curve force displacement is conforms to the analytical curve?

4.1.5 Visualization of the deformation

To print with the format MED results of the mechanical calculation controlled, on the voluminal meshs (not to insert the meshs of joint) and to visualize the deformation.

4.2 Sizes tested and results

Identification	Reference	% tolerance
Nodal force for an imposed displacement of 10.561 mm	4.71 N	5.0%

Table 4.1 : Results of Modeling B