SSLP314 – Crack deviated with the interface between two elastic half-planes

Summary:

This case test deals with the problem of a crack deviated in 2 dimensions, under the assumption of the plane constraints. The unit consists of two elastic, linear and isotropic materials, material 1 being located in the higher half-plane.
The crack is defined by two branches. The first branch is located horizontally has the interface of two materials, and is characterized by its length c .
The second is in the prolongation of the first and is tilted has $45°$ by report the horizontal one has, clockwise (characteristic length a). It is the end of this branch, completely included in the material 1, which we study. The deviated crack (connects 1 and 2) is continuous, in a presumedly infinite medium, and the loading applied has this plate, is a uniform traction on the edges superior and inferior.
For this study, the explored parameters are the report of the Young moduli $E2/E1$ being worth $0.25, 1., 4.$ and the report a/c being worth 0.1 and $1.$ One counts in all 6 case tests.
The boundary conditions isostatic block the three modes of rigid bodies plans without revealing reactions to the supports.
Under the action of traction, and considering the angle of the crack, the second branch opens (mode I) and slips (mode II).

This case test validates the use of the operator calculating the rate of refund of energy in breaking process for modelings 2D. The operators used are CALC_THETA and CALC_G (CALC_G and CALC_K_G).

1 Problem of reference

1.1 Geometry

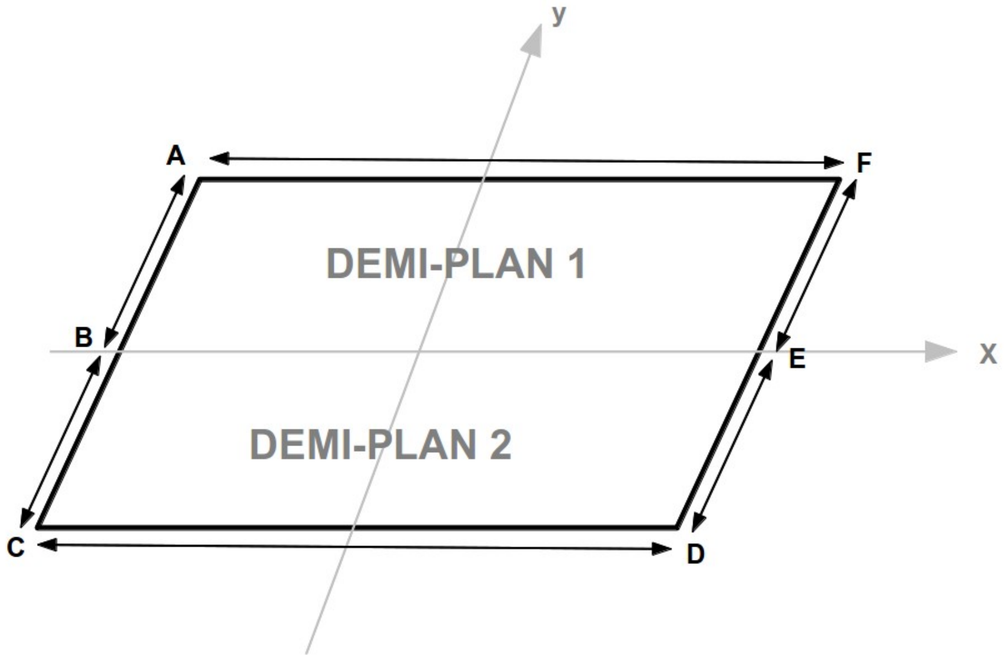

Figure 1.1 Geometry of the problem

Length: $L=20\,cm$
Width: $l=20\,cm$
$AC=CD$

1.2 Properties of material

Material for half-plane 1:

Young modulus	$E=2\times10^{12}\,Pa$
Poisson's ratio	$\nu=0.3$

Material for half-plane 2:

Young modulus	Modeling A, D: $E=8\times10^{12}\,Pa$ Modeling B, E: $E=2\times10^{12}\,Pa$ Modeling C, F: $E=5\times10^{11}\,Pa$
Poisson's ratio	$\nu=0.3$

1.3 Boundary conditions and loadings

For modelings A, B and C:

Imposed displacement:

Embedding on the sides AB , BC	$DX=0$
Embedding of point b:	$DY=0$
Uniform connection on the side: DE	$U_X(N_i)=U_X(N_1)$
Uniform connection on the side: EF	$U_X(N_i)=U_X(N_1)$

For modelings D, E and F:

Imposed displacement:

Embedding of point b:	$DX=0$, $DY=0$
Embedding of the point E:	$DY=0$

For modelings A, B, C, D, E and F:

Imposed loading:

Force contour on the side CD Force contour on the side FA	$F_X=-75\times10^6\ N$ $F_X=75\times10^6\ N$

1.4 Size of the cracks

c : cacrteristic length of the horizontal crack.
a : cacrteristic length of the deviated crack has $45°$.

	c	a
Modeling A, B and C	0,02	0,02
Modeling D, E and F	0,02	0,002

2 Reference solution

2.1 Results of reference

The results of references result from similar modelings carried out under CASTEM_2000.
An Analytical solution exists in the work of Y. MURAKAMI: "Stress Intensity Factor".

2.2 Bibliographical references

1) Y. MURAKAMI: Stress Intensity Factor, box 8.20.
The Society of Materials Science, Japan, Pergamon Close 1987.

3 Modeling A

3.1 Characteristics of modeling A

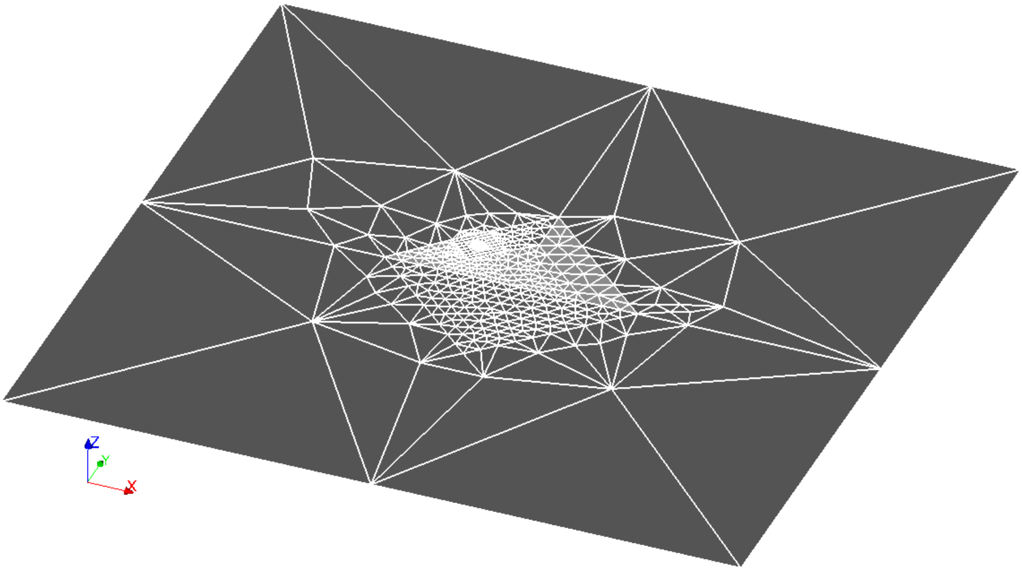

Figure 3.1. Grid of modeling A

Modeling C_PLAN

3.2 Characteristics of the grid

Many nodes: 2044
Many meshs and types: 160 QUAD8 and 756 TRIA6
Length of the first crack $c=0{,}02$.
Length of the second crack $a=0{,}02$.

3.3 Sizes tested and results

Size	Value of reference	Type of reference	Tolerance (%)
G	85.46	'SOURCE_EXTERNE'	0.68
G	85.46	'SOURCE_EXTERNE'	0.48
G	85.46	'SOURCE_EXTERNE'	0.54
G	85.46	'SOURCE_EXTERNE'	0.47
G_IRWIN	85.46	'SOURCE_EXTERNE'	2.54
G_IRWIN	85.46	'SOURCE_EXTERNE'	0.3
G_IRWIN	85.46	'SOURCE_EXTERNE'	0.35
G_IRWIN	85.46	'SOURCE_EXTERNE'	0.2

The got results result coherent with those from CASTEM_2000.
The maximum change for this modeling is of $2{,}54$ %.

4 Modeling B

4.1 Characteristics of modeling B

Young modulus $E=2\times 10^{12}\,Pa$.
For the rest, to see Modeling A.

4.2 Characteristics of the grid

See Modeling A.

4.3 Sizes tested and results

Size	Value of reference	Type of reference	Tolerance (%)
G	117.07	'SOURCE_EXTERNE'	2.2
G	117.07	'SOURCE_EXTERNE'	3.32
G	117.07	'SOURCE_EXTERNE'	3.37
G	117.07	'SOURCE_EXTERNE'	3.31
G_IRWIN	117.07	'SOURCE_EXTERNE'	0.45
G_IRWIN	117.07	'SOURCE_EXTERNE'	3.21
G_IRWIN	117.07	'SOURCE_EXTERNE'	3.25
G_IRWIN	117.07	'SOURCE_EXTERNE'	3.1

The got results result coherent with those from CASTEM_2000.
The maximum change for this modeling is of $3{,}37$ %.

5 Modeling C

5.1 Characteristics of modeling C

Young modulus $E=5\times 10^{11} Pa$.
For the rest, to see Modeling A.

5.2 Characteristics of the grid

See Modeling A.

5.3 Sizes tested and results

Size	Value of reference	Type of reference	Tolerance (%)
G	181.7	'SOURCE_EXTERNE'	2.44
G	181.7	'SOURCE_EXTERNE'	1.27
G	181.7	'SOURCE_EXTERNE'	1.22
G	181.7	'SOURCE_EXTERNE'	1.29
G_IRWIN	181.7	'SOURCE_EXTERNE'	4.16
G_IRWIN	181.7	'SOURCE_EXTERNE'	1.27
G_IRWIN	181.7	'SOURCE_EXTERNE'	1.23
G_IRWIN	181.7	'SOURCE_EXTERNE'	1.38
G_IRWIN	181.7	'SOURCE_EXTERNE'	1.22

The got results result coherent with those from CASTEM_2000.
The maximum change for this modeling is of $4,16$ %.

6 Modeling D

6.1 Characteristics of modeling D

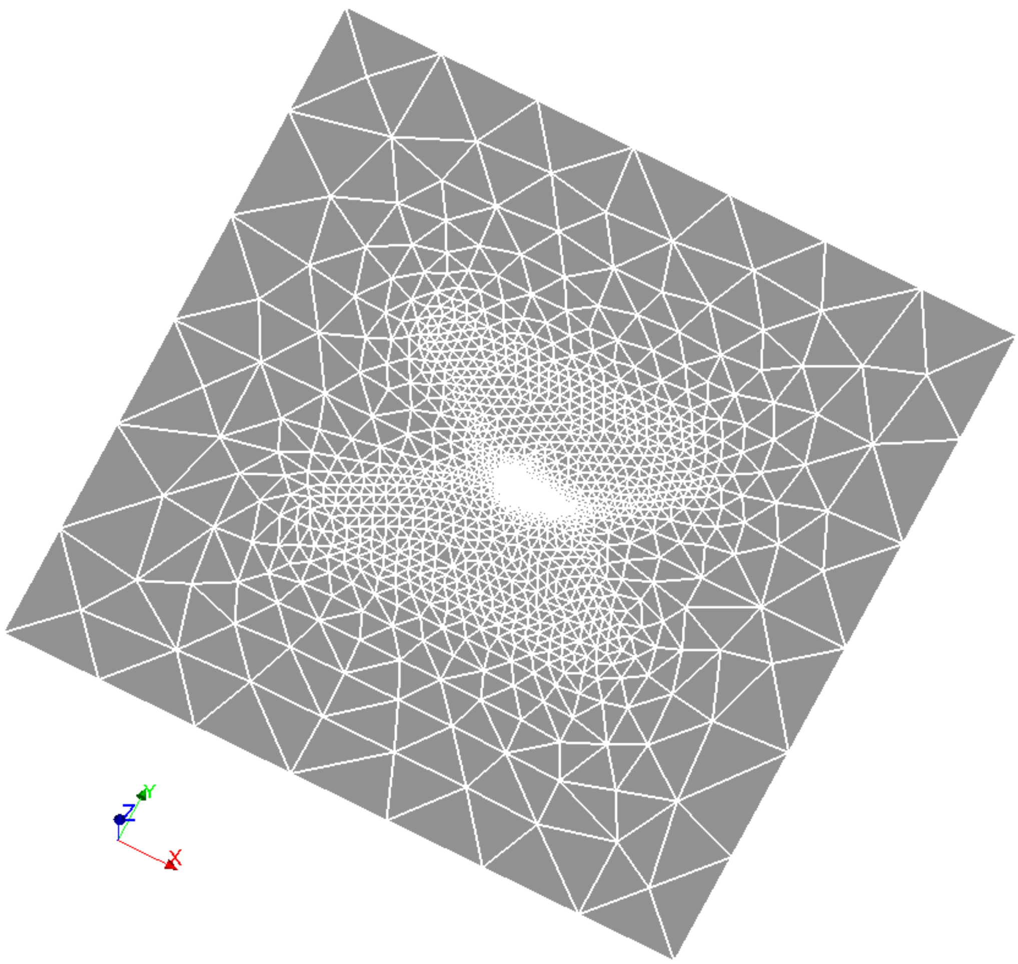

Figure 6.1. Grid of modeling D

Modeling `C_PLAN`

6.2 Characteristics of the grid

Many nodes: 7030
Many meshs and types: 160 QUAD8 and 3212 TRIA6
Length of the first crack $c=0,02$.
Length of the second crack $a=0,002$.

6.3 Sizes tested and results

Size	Value of reference	Type of reference	Tolerance (%)
`G`	39.098	`'NON_REGRESSION'`	-
`G_IRWIN`	39.093	`'NON_REGRESSION'`	-

The results got in this case test are validated only in not-regression.
It is noted that the solution is extracted from CASTEM, but keyword VALE_REFE was not filled, we thus do not know the relative difference between the solution provided by CASTEM and that provided not Code_Aster.

7 Modeling E

7.1 Characteristics of modeling E

Young modulus $E=2\times10^{12}\,Pa$.
For the rest, to see Modeling D.

7.2 Characteristics of the grid

See Modeling D.

7.3 Sizes tested and results

Size	Value of reference	Type of reference	Tolerance (%)
G	51.989	'NON_REGRESSION'	-
G_IRWIN	51.951	'NON_REGRESSION'	-

The results got in this case test are validated only in not-regression.
It is noted that the solution is extracted from CASTEM, but keyword VALE_REFE was not filled, we thus do not know the relative difference between the solution provided by CASTEM and that provided not Code_Aster.

8 Modeling F

8.1 Characteristics of modeling F

Young modulus $E=5\times10^{11} Pa$.
For the rest, to see Modeling D.

8.2 Characteristics of the grid

See Modeling D.

8.3 Sizes tested and results

Size	Value of reference	Type of reference	Tolerance (%)
G	77.075	'NON_REGRESSION'	-
G_IRWIN	77.03	'SOURCE_EXTERNE'	0.12
G_IRWIN	77.03	'SOURCE_EXTERNE'	0.08

The got results result coherent with those from CASTEM_2000.
The maximum change for this modeling is of $0,12$ %.

9 Summary of the results

The various operators of aiming Code_Aster has post-to treat the rate of refund of energy in breaking process used in this case test give good performances.
On 6 modelings the maximum relative variation met is of $4,16$ % for modeling C.

Note:

Values of coefficient K_I and K_{II} obtained are excellent if the moduli of rigidity are equal, and when the lengths of branches are equal.
In all the treated cases, the crowns of integration for the calculation of G and of K, are confined has only one material. As there is a doubt about the precision of the results of reference, it is necessary to refer has the original publication of ISIDA NOGHUCHI before making a final judgment on the precision of the results got by finite elements.