SSNP311 - Biblio_131. Cracking in mode II of an elastoplastic test-tube

Summary:

This test is resulting from the validation independent of version 3 in breaking process.

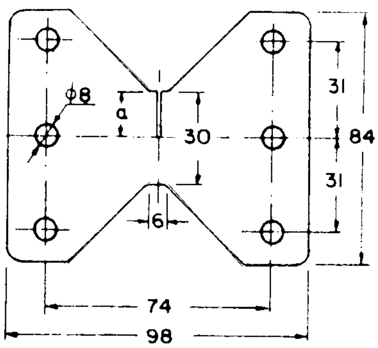
It is about a two-dimensional test in statics which aims at the validation of the calculation of G, and of its nondependence with respect to the crown, in elastoplastic mode in an incremental calculation, on a noncommonplace geometry. The law of behavior used is an elastoplastic law of Von Mises with isotropic work hardening.

This case test understands only one modeling $2D$ plane in which one studies the influence of an incremental load.

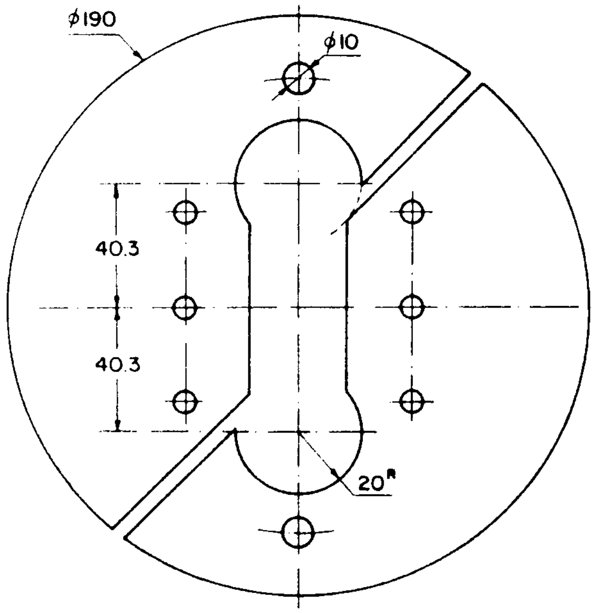
Results got with *Code_Aster* are compared with the calculations carried out using code ADINA.

1 Problem of reference

1.1 Geometry



(a)



(b)

The test-tube in the shape of twin wheel, represented in (A), is fixed at the system of loading (b) by six pins equivalent to articulations.

Dimensions of the parts are expressed in mm.

Test-tube:

thickness B variable	$6{,}36\,;\,6{,}39\,;\,6{,}44\,mm$
overall width	$98\,mm$
distance enters the axes of the pins	$74\,mm$
width of the central part	$6\,mm$
overall height	$84\,mm$
distance between centers of the pins	$31\,mm$
height in the center W	$30\,mm$
length of the crack a	$15, 18$ or $21\,mm$
ligament $b=W-a$	$15, 12$ or $9\,mm$
bore of pins	$8\,mm$

Carry-test-tube:

thickness	$25\,mm$
external diameter	$190\,mm$
distance enters the center of the part and the centers of the circular cavities	$40{,}3\,mm$
ray of the cavities	$20\,mm$
diameter of the 2 holes where the loads are applied	$10\,mm$

1.2 Properties of materials

Test-tube:

The material is elastoplastic, of type Von Mises, with isotropic work hardening, defined by a uniaxial traction diagram.

Young modulus: $E=74{,}2\,GPa$

Poisson's ratio: $\nu=0{,}32$

E tangent (GPa)	σ uniaxial) (MPa)	ε_T uniaxial) ($\%$)
72.74	334.6	0.46
50.69	410.7	0.61
15.00	431.6	0.75
4.75	443.5	1.00
1.82	480.0	3.00
0.80	500.1	5.50
0.0017	505.2	300.0

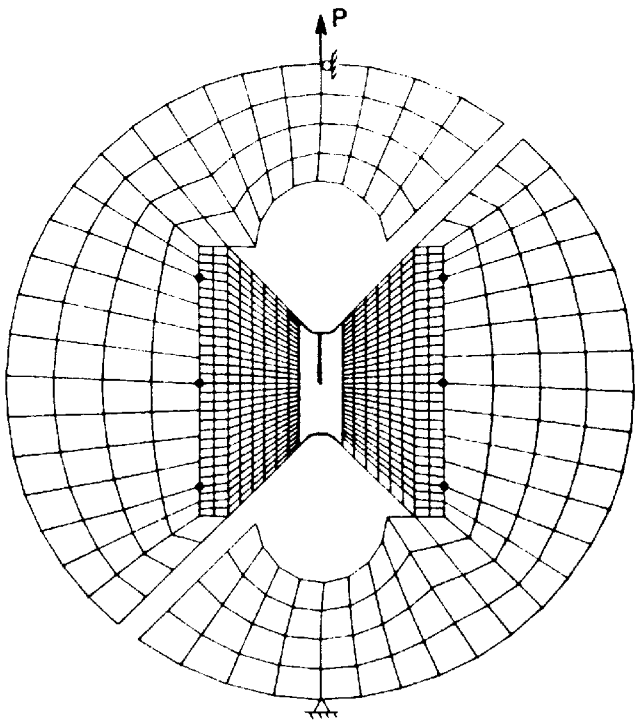
Carry-test-tube:

The material is elastic linear isotropic.

Young modulus: $E=206\,GPa$

Poisson's ratio: $\nu=0{,}3$

1.3 Boundary conditions and loading



The carry-test-tube has a fixed point $UX=UY=0$ to the lower clamp hole and is subjected to a vertical specific loading applied to the higher clamp hole $UX=0$, $FY=P$ variable.

For a length of crack $a/W=0{,}5$:

P vary:

$0\,N$ with $11772\,N$ in 12 pas de $981\,N$

$11772\,N$ with $19620\,N$ in 16 pas de $490{,}5\,N$
$19620\,N$ with $23544\,N$ in 20 pas de $196{,}2\,N$
$23544\,N$ with $25114\,N$ in 16 pas de $98{,}1\,N$

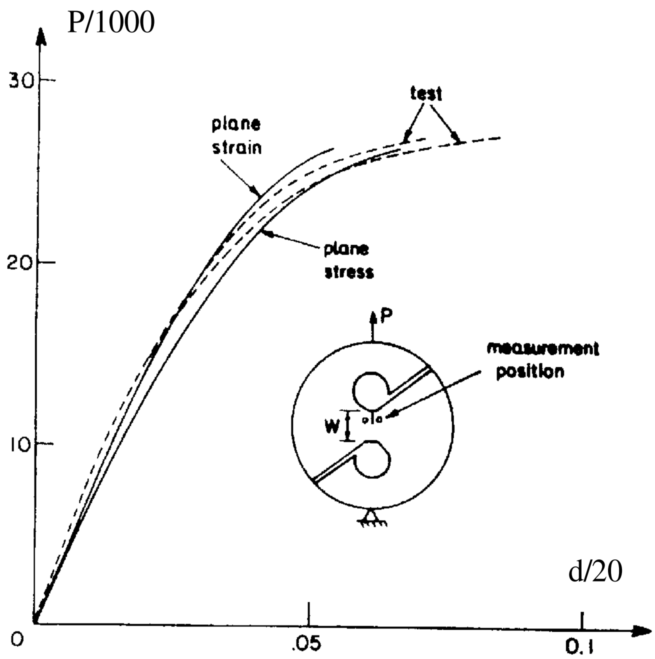
2 Reference solution

2.1 Method of calculating used for the reference solution

Calculation in finite elements with ADINA. Update of the matrix of tangent stiffness by method BFGS (BROYDEN, FLETCHER, GOLDFARB and SHAMNO). Calculation of J by integral of Rice in whom the density of deformation energy is evaluated according to the theory of plasticity of Hencky (reversible elastic model nonlinear equivalent with the incremental theory of plasticity for a monotonous radial loading growing within the space of principal constraints)

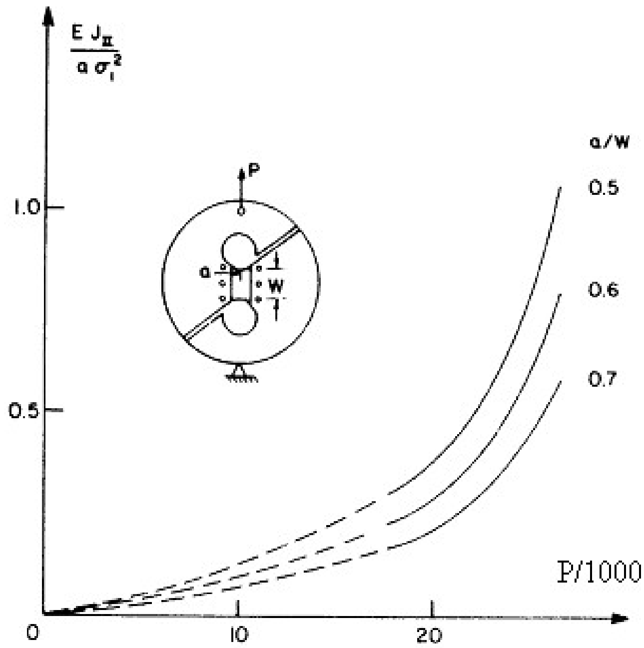
2.2 Results of reference

Response curve charges/displacement



Response curve giving the load $P/1000$ according to displacement $d/20$. Higher curve calculated in plane deformations, curves lower calculated in plane constraints. The curves in stopped feature are experimental results. Constraint of reference $\sigma_{ref}=334,6\,MPa$ (first point on the traction diagram). Thickness of test-tube $B=6,36$ or $6,39\,mm$. Length of crack $a/W=0,5$.

Integral J according to the load



Standardized integral $E\times J_{II}/(a\times\sigma_{ref}^2)$ according to the constraint $P/1000$, where $\sigma_{ref}=334{,}6\,MPa$, for a test-tube thickness $B=6{,}44\,mm$

One also has some tabulées values, for a length of crack $a/W=0{,}5$ and a calculation in plane deformations; the dispersion of J_{II} is related to the choice of the contour of integration around the bottom of crack.

Pas de loading	$P(KN)$	$E\times J_{II}/(a\times\sigma_{ref}^2)$
22	27.66	0.292 to 0.295
36	35.11	0.540 to 0.543
50	38.83	0.798 to 0.813
64	41.49	1.065 to 1.190

2.3 Uncertainty on the solution

The difference between experimental measurements and calculation does not exceed 7%, with regard to the response curve/displacement charges.

Precision of the calculation of J is unknown; the error seems to grow with the level of load, as shows it the increasing dependence of J compared to the contour, which reaches a margin of variation of 12% with the step n° 64.

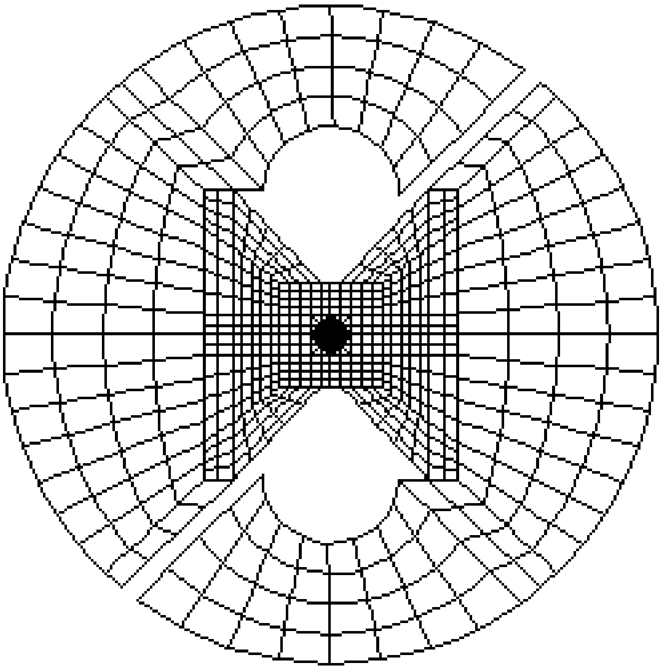
2.4 Bibliographical references

1) LESLIE BANKS-SILLS and DOV SHERMAN: Elasto-plastic analysis of has mode II fractures specimen. Int.J.Fracture, **46**, 105-122, 1993.

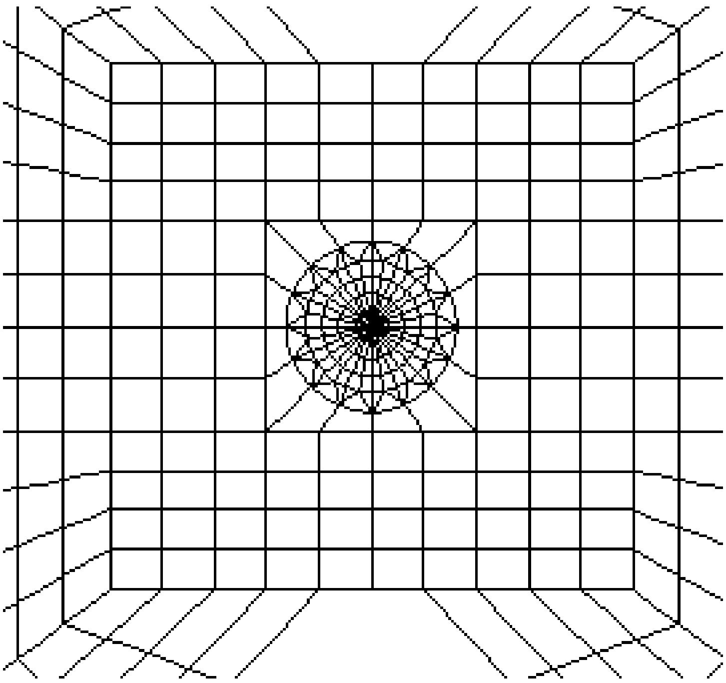
3 Modeling A

3.1 Characteristics of modeling

3.1.1 Grid of the test-tube and the door test-tube



Grid of the test-tube and the door test-tube



Zoom on the bottom of crack

3.1.2 Definition of the rays of the crowns

We define the values of the higher and lower rays, to specify in the order CALC_G :

	1st crown	2nd crown	3rd crown	4th crown
$\text{rinf}(mm)$	1	2	3	4
$\text{rsup}(mm)$	2	3	4	5

3.2 Characteristics of the grid

The grid consists of two objects:

- the door test-tube consists of 718 nodes and 200 elements QUA8.
- the test-tube consists of 1741 nodes and 576 elements including 496 QUA8 and 80 TRI6.

3.3 Sizes tested and results

One notes that in this CAS-test the law of behavior in CALC_G (ELAS_VMIS_TRAC) differ law of behavior of STAT_NON_LINE (VMIS_ISOT_TRAC). This is due to the fact that one wants to calculate G by supposing that the loading is monotonous proportional. The use of the law VMIS_ISOT_TRAC in CALC_G would have resulted in calculating the parameter GTP (see the U2.82.03 document).

Identification	Reference	*Aster*	% difference
Increment of load n° 22			
G, crown n°1 (KN/mm)	6.7451	7.005	3.868
G, crown n°2 (KN/mm)	6.7451	6.99728	3.739
G, crown n°3 (KN/mm)	6.7451	6.9964	3.726
G, crown n°4 (KN/mm)	6.7451	6.998	3.75
Increment of load n°36			
G, crown n°1 (KN/mm)	12.473	13.069	4.786
G, crown n°2 (KN/mm)	12.473	13.094	4.977
G, crown n°3 (KN/mm)	12.473	13.083	4.887
G, crown n°4 (KN/mm)	12.473	13.071	4.795
Increment of load n°50			
G, crown n°1 (KN/mm)	18.433	19.49	5.744
G, crown n°2 (KN/mm)	18.433	19.573	6.184
G, crown n°3 (KN/mm)	18.433	19.577	6.204
G, crown n°4 (KN/mm)	18.433	19.574	6.194
Increment of load n°64			
G, crown n°1 (KN/mm)	24.601	26.84	9.105
G, crown n°2 (KN/mm)	24.601	26.977	9.657
G, crown n°3 (KN/mm)	24.601	26.981	9.672
G, crown n°4 (KN/mm)	24.601	26.983	9.684

4 Summary of the results

The results concerning the rate of refund of energy give 1 maximum change of $9{,}7\%$ compared to the reference solution on the last crown, for a precision announced of 12%. The results are excellent taking into account the non-linear character of the test-tube.