SSNV501 – Stamping of a sheet by a hemispherical punch (test of Wagonner)

Abstract:

This test represents a computation of stamping of a sheet by a rigid hemispherical punch in the presence of plastic large deformations. This test is very much used in the simulation of working sheet.

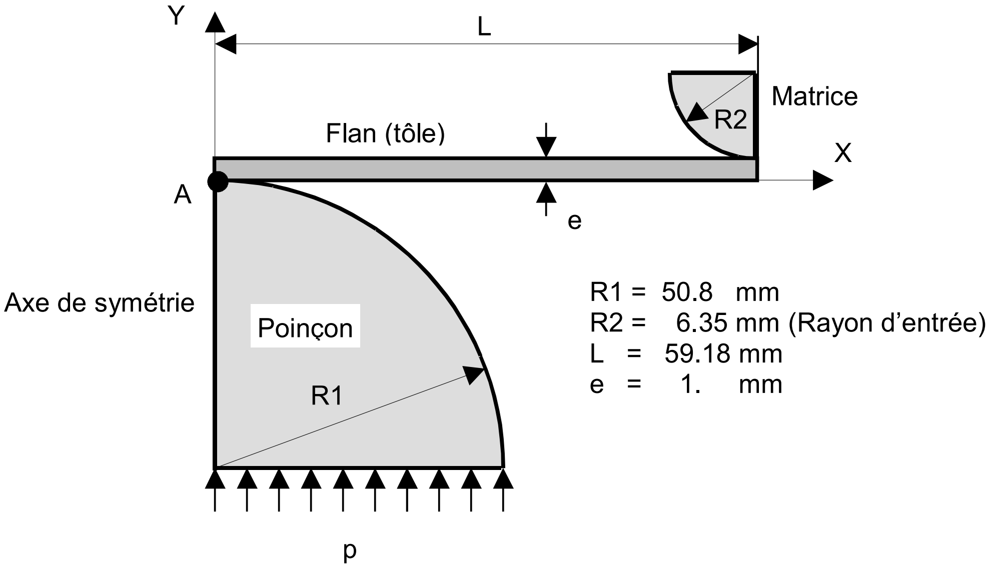
The analyzed results are the vertical displacement of the punch according to the imposed force. They are compared with a numerical reference solution.

Three axisymmetric modelizations are carried out. The contact blank/punch and blank/die are of the standard node - mesh.

1) Modelization a: the coefficient of kinetic friction, contact blank/punch and blank/matrix is null.
2) Modelization b: the coefficient of kinetic friction, contact blank/punch and blank/matrix is equal to 0.15.
3) Modelization C: modelization similar to the modelization A with a finer mesh for the blank.

1 Problem of reference

1.1 Geometry



1.2 Properties of the material

Blank:

$E=69004.\ N/mm^2$	Young modulus
$\nu=0.3$	Poisson's ratio
$\sigma_0=589(10^{-4}+\bar{\varepsilon}^p)^{0.216}$	Model of hardening

Punch, matrix

$E=10^7\ N/mm^2$	Modulus Young
$\nu=0.3$	Poisson's ratio

Contact zones: punch/blank, die/blank

$\mu=0.15$	Coefficient of kinetic friction

1.3 Boundary conditions and loadings

Boundary conditions:

1) the matrix is clamped
2) the periphery of the blank is clamped

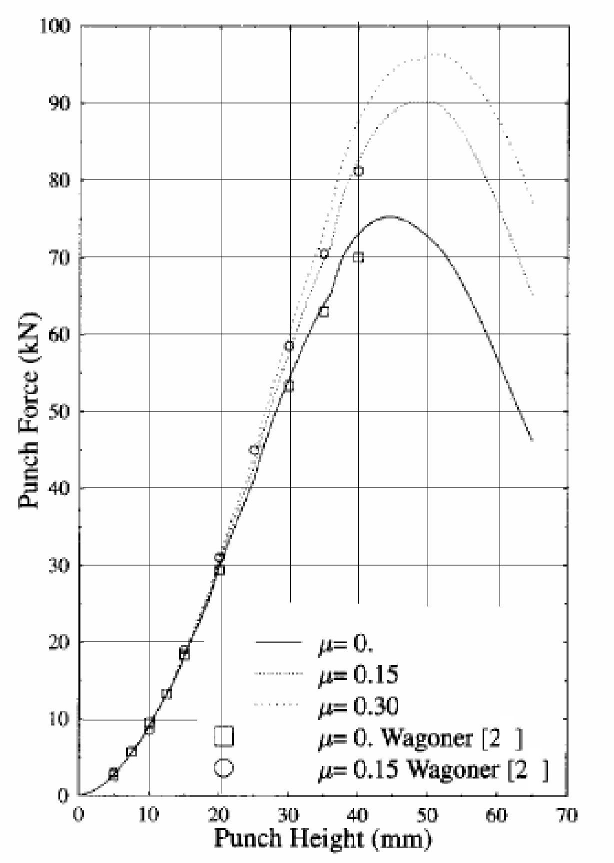
Loading: pressure $p=12.33\mathrm{N}/mm^2$ either force of stamping of $100\,kN$

2 Reference solution

2.1 Method of calculating used for the reference solution

the method of calculating used to simulate the behavior in the contact zone is presented in detail in the references [bib1] and [bib2].

2.2 Results of reference



Chargement (KN)	Déplacement μ=0, (mm)	Déplacement μ=0.15 (mm)
10	10.6	10.6
20	15.4	15.4
30	20.0	20.0
40	24.7	23.8
50	28.2	27.1
60	33.0	30.8
70	37.4	35.2
75	44.0	36.5
80		38.3
90		50.0

Les déplacements sont extraits de [1].

2.3 Uncertainties on the solution

uncertainties related to this reference is lower than 5% (reading of the graphic results).

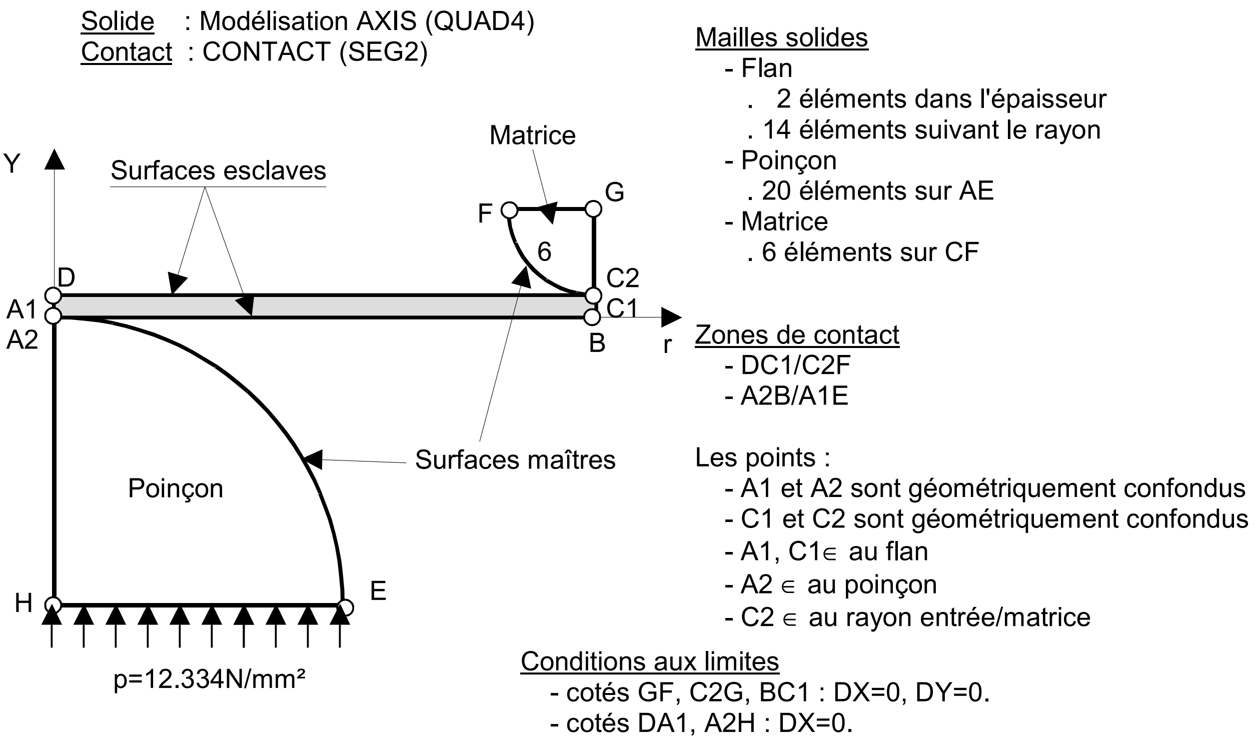
2.4 Bibliographical references

1) P. CHABRAND, F. DUBOIS, J.C. GELIN: “Modelling drawbeads in sheet metal forming”, Int. J. Mechanics, flight 38 n°1 pp 99-77 (1996)

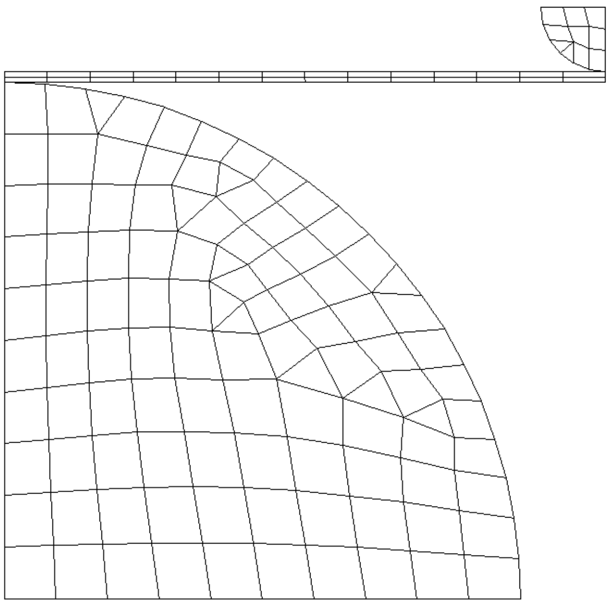
2) R. WAGONER, E. NAKAMACHI and J.K. LEE: A benchmark test for sheet metal forming analysis. Technical RepT. No ERC/NSM-S-90-22, Ohio State University (1988)

3 Modelization A

3.1 Characteristic of the modelization



to avoid motions of rigid bodies, one impose that displacements DY of the points $A1$ (belonging to blank) and $A2$ (belonging to punch) are identical.



3.2 Characteristics of the mesh

Many nodes: 182

Number of meshes: 131 QUAD4, 12 TRIA3 and 84 SEG2

3.3 Quantities tested and results

Identification (Displacement)	Loading ($\times 10^3 N$)	Standard	Reference of reference	Tolerance
DX ($N87$)	10.	10.6	"SOURCE_EXTERNE"	10,00%
DX ($N87$)	20.	15.4	"SOURCE_EXTERNE"	10,00%
DX ($N87$)	30.	20.0	"SOURCE_EXTERNE"	10,00%
DX ($N87$)	40.	24.7	"SOURCE_EXTERNE"	10,00%
DX ($N87$)	50.	28.2	"SOURCE_EXTERNE"	10,00%
DX ($N87$)	60.	33.0	"SOURCE_EXTERNE"	10,00%
DX ($N87$)	70.	37.4	"SOURCE_EXTERNE"	10,00%
DX ($N87$)	75.	44.0	"SOURCE_EXTERNE"	10,00%
DX ($N87$)	10.	10.6	"NON_REGRESSION"	0,1%
DX ($N87$)	20.	15.4	"NON_REGRESSION"	0,1%
DX ($N87$)	30.	20.0	"NON_REGRESSION"	0,1%
DX ($N87$)	40.	24.7	"NON_REGRESSION"	0,1%
DX ($N87$)	50.	28.2	"NON_REGRESSION"	0,1%
DX ($N87$)	60.	33.0	"NON_REGRESSION"	0,1%
DX ($N87$)	70.	37.4	"NON_REGRESSION"	0,1%
DX ($N87$)	75.	44.0	"NON_REGRESSION"	0.00%

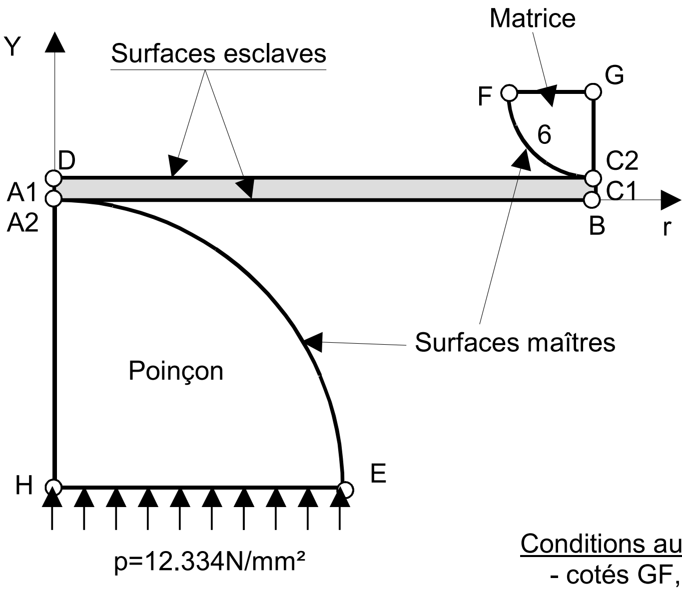
3.4 Remarks

the constitutive law of the material constituting sheet is given linearized under-form.
The computation does not converge any more beyond 75% of the total load.

4 Modelization B

4.1 Characteristic of the modelization

Solide : Modélisation AXIS (QUAD4)
Contact : CONTACT (SEG2)



Mailles solides
- Flan
  . 2 éléments dans l'épaisseur
  . 14 éléments suivant le rayon
- Poinçon
  . 20 éléments sur AE
- Matrice
  . 6 éléments sur CF

Zones de contact
- DC1/C2F
- A2B/A1E

Les points :
- A1 et A2 sont géométriquement confondus
- C1 et C2 sont géométriquement confondus
- A1, C1∈ au flan
- A2 ∈ au poinçon
- C2 ∈ au rayon entrée/matrice

Conditions aux limites
- cotés GF, C2G, BC1 : DX=0, DY=0.
- cotés DA1, A2H : DX=0.

to avoid motions of rigid bodies, one imposes that displacements DY of the points $A1$ (belonging to blank) and $A2$ (belonging to punch) are identical.

4.2 Characteristics of the mesh

Many nodes: 182
Number of meshes: 131 QUAD4, 12 TRIA3 and 84 SEG2

4.3 Quantities tested and results

Identification (Displacement)	Loading ($\times 10^4 N$)	Standard	Reference of reference	Tolerance
DX ($N87$)	0.3	5.00	“SOURCE_EXTERNE”	10.00%
DX ($N87$)	0.6	7.00	“SOURCE_EXTERNE”	10.00%
DX ($N87$)	0.3	5.00	“NON_REGRESSION”	0.10%
DX ($N87$)	0.6	7.00	“NON_REGRESSION”	0.10%

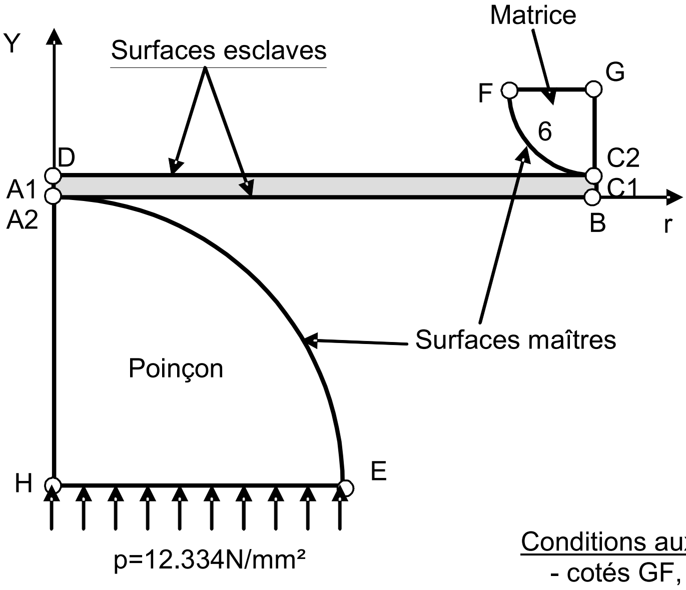
4.4 Remarks

the constitutive law of the material constituting sheet is given in linearized form.
Computations were carried out up to 6% of the loading, they can continue without problem up to 78% of the total load, beyond computation does not converge more.

5 Modelization C

5.1 Characteristic of the modelization

Solide : Modélisation AXIS (QUAD4)
Contact : CONTACT (SEG2)



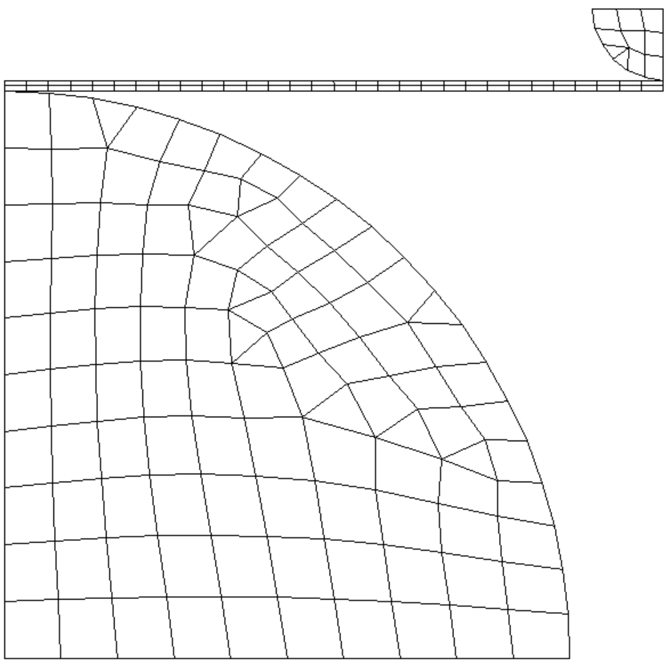
Mailles solides
- Flan
  . 2 éléments dans l'épaisseur
  . 30 éléments suivant le rayon
- Poinçon
  . 20 éléments sur AE
- Rayon entrée/matrice
  . 6 éléments sur CF

Zones de contact
- DC1/C2F
- A2B/A1E

Les points :
- A1 et A2 sont géométriquement confondus
- C1 et C2 sont géométriquement confondus
- A1, C1∈ au flan
- A2 ∈ au poinçon
- C2 ∈ au rayon entrée/matrice

Conditions aux limites
- cotés GF, C2G, BC1 : DX=0, DY=0.
- cotés DA1, A2H : DX=0.

to avoid motions of rigid bodies, one imposes that displacements DY of the points $A1$ (belonging to blank) and $A2$ (belonging to punch) are identical.



5.2 Characteristics of the mesh

Many nodes: 230
Number of meshes: 291 meshes (163 `QUAD4`, 12 `TRIA3` and 116 `SEG2`)

5.3 Quantities tested and results

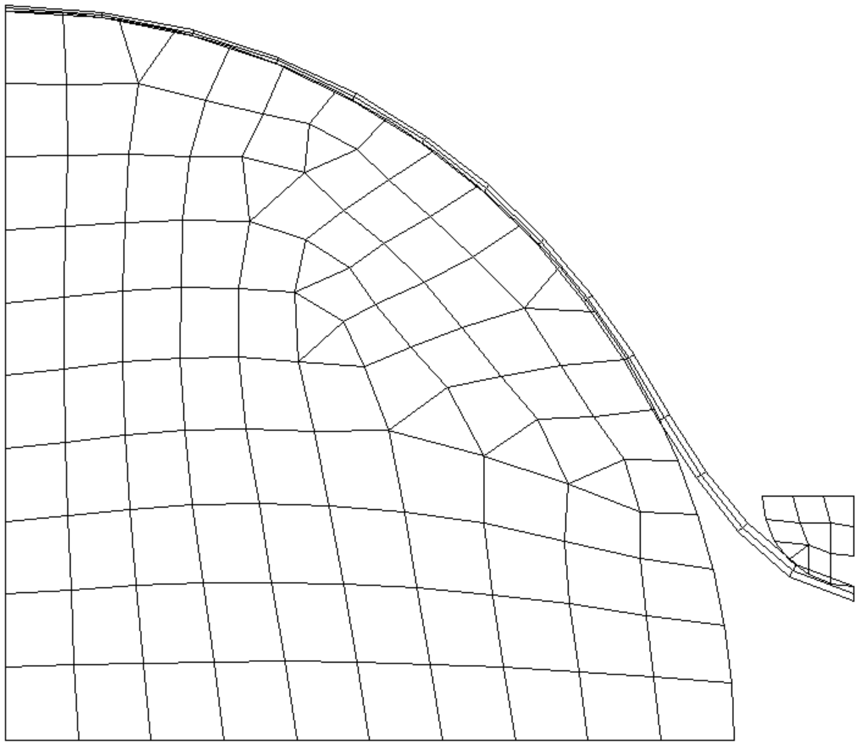
Identification (Displacement)	Loading ($\times 10^4 N$)	Standard	Reference of reference	Tolerance
DX ($N87$)	1.	10.6	"SOURCE_EXTERNE"	25,00%
DX ($N87$)	2.	15.4	"SOURCE_EXTERNE"	10.00%
DX ($N87$)	3.	20.0	"SOURCE_EXTERNE"	10.00%
DX ($N87$)	4.	24.7	"SOURCE_EXTERNE"	10.00%
DX ($N87$)	5.	28.2	"SOURCE_EXTERNE"	10.00%
DX ($N87$)	6.	33.0	"SOURCE_EXTERNE"	10.00%
DX ($N87$)	7.	37.4	"SOURCE_EXTERNE"	10.00%
DX ($N87$)	7.5	44.0	"SOURCE_EXTERNE"	10.00%
DX ($N87$)	1.	10.6	"NON_REGRESSION"	0.10%
DX ($N87$)	2.	15.4	"NON_REGRESSION"	0.10%
DX ($N87$)	3.	20.0	"NON_REGRESSION"	0.10%
DX ($N87$)	4.	24.7	"NON_REGRESSION"	0.10%
DX ($N87$)	5.	28.2	"NON_REGRESSION"	0.10%
DX ($N87$)	6.	33.0	"NON_REGRESSION"	0.10%
DX ($N87$)	7.	37.4	"NON_REGRESSION"	0.10%
DX ($N87$)	7.5	44.0	"NON_REGRESSION"	0.10%

5.4 Remarks

the constitutive law of the material constituting sheet is given linearized under-form.
The computation does not converge any more beyond 75% of the total load.

6 Summary of the results

On the figure below we present, for the modelization A, the deformed shape of the blank, the position of the die and the punch for a loading of $75\,kN$.



One notes a variation compared to the references [bib1] and [bib2]. For a loading reaching 75% of the total specified in these references, we have:

1) for A, 7,5% of error on displacement,
2) for C, 9,7% of error on displacement.

For the modelization B (with friction), the error with 75% of the load given by the references [bib1] and [bib2] is of 6%.