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

Summary:

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

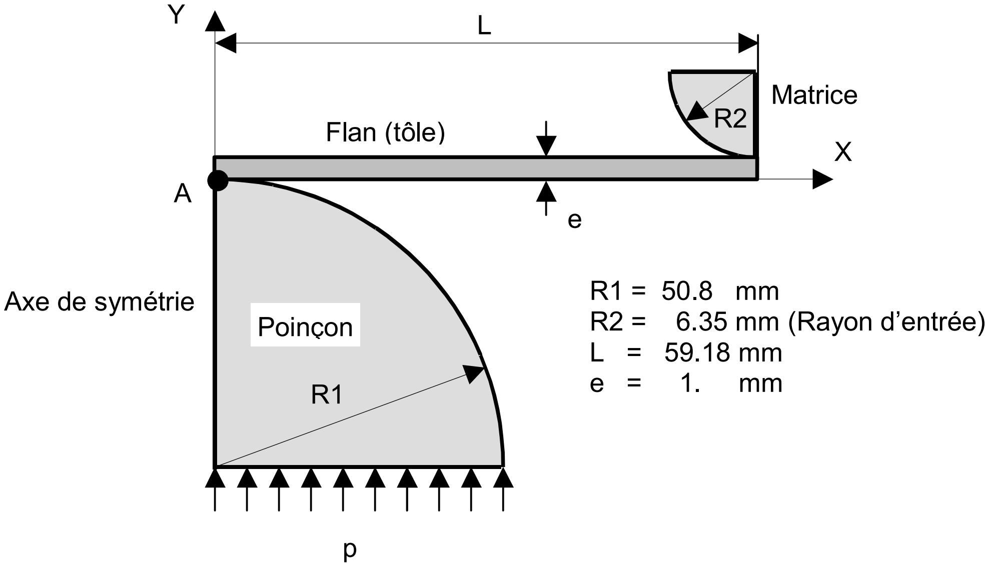
The analyzed results are the vertical displacement of the punch according to the imposed force. They are compared with a digital reference solution.

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

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

1 Problem of reference

1.1 Geometry



1.2 Properties of material

Blank:

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

Punch, die

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

Zones of contact: punch/blank, die/blank

$\mu=0.15$	Coefficient of friction

1.3 Boundary conditions and loadings

Boundary conditions:

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

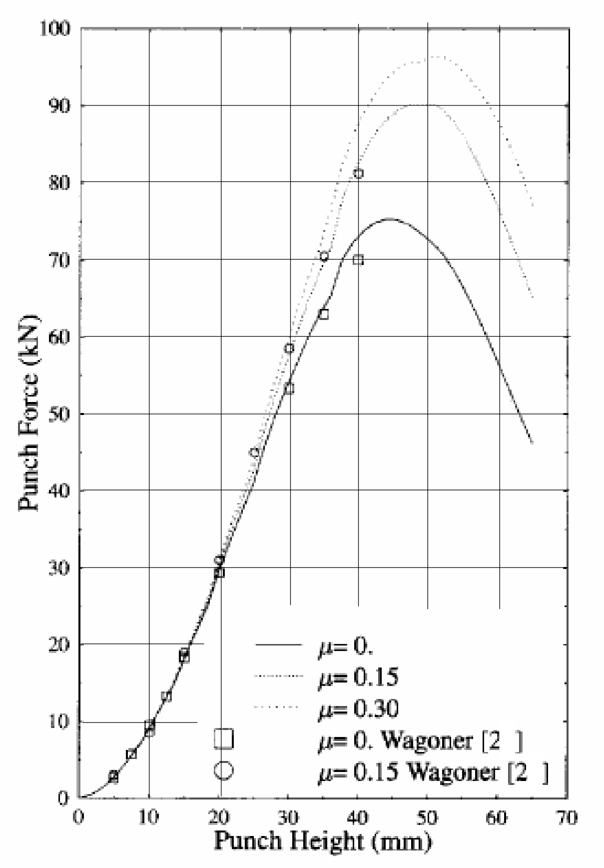
Loading: pressure $p=12.33\mathrm{N}/mm^2$ that is to say force of stamping of $100\,kN$

2 Reference solution

2.1 Method of calculating used for the reference solution

The method of calculating used to simulate the behavior in the zone of contact 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

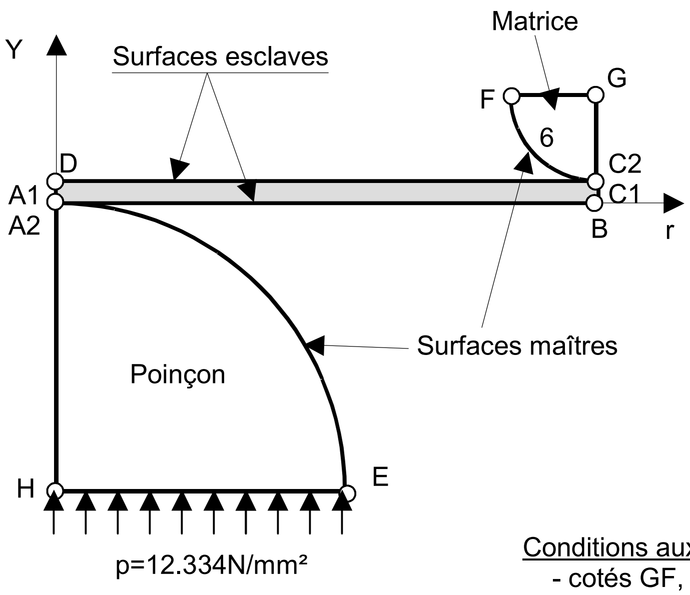
1) P. CHABRAND, F. DUBOIS, J.C. GELIN: “Modelling drawbeads in sheet metal forming”, Int. J. Mechanics, flight 38 n°1 pp 99-77 (1996)

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

3 Modeling A

3.1 Characteristics of modeling

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



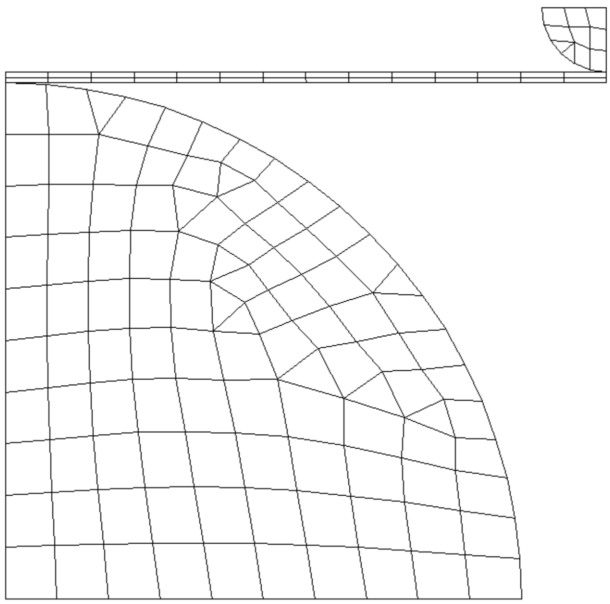
Mailles solides
- Flan
  . 2 éléments dans l'épaisseur
  . 14 éléments suivant le rayon
- Poinçon
  . 20 éléments sur AE
- Matrice
  . 6 éléments sur CF

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 the rigid movements of body, one forces that displacements DY points $A1$ (pertaining to the blank) and $A2$ (pertaining to the punch) are identical.



3.2 Characteristics of the grid

Many nodes: 182

Many meshs: 131 QUAD4, 12 TRIA3 and 84 SEG2

3.3 Sizes tested and results

Identification (Displacement)	Loading ($\times 10^3 N$)	Reference	Type 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%

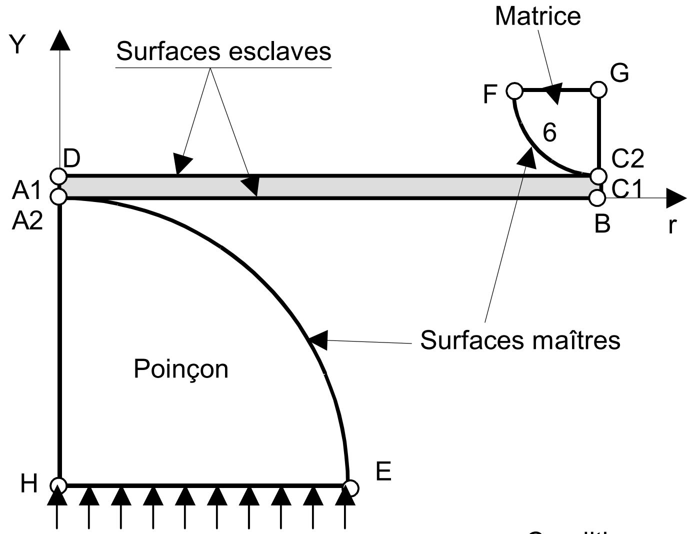
3.4 Remarks

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

4 Modeling B

4.1 Characteristics of modeling

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



p=12.334N/mm²

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 the rigid movements of body, one forces that displacements DY points $A1$ (pertaining to the blank) and $A2$ (pertaining to the punch) are identical.

4.2 Characteristics of the grid

Many nodes: 182
Many meshs: 131 QUAD4, 12 TRIA3 and 84 SEG2

4.3 Sizes tested and results

Identification (Displacement)	Loading ($\times 10^4 N$)	Reference	Type 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%

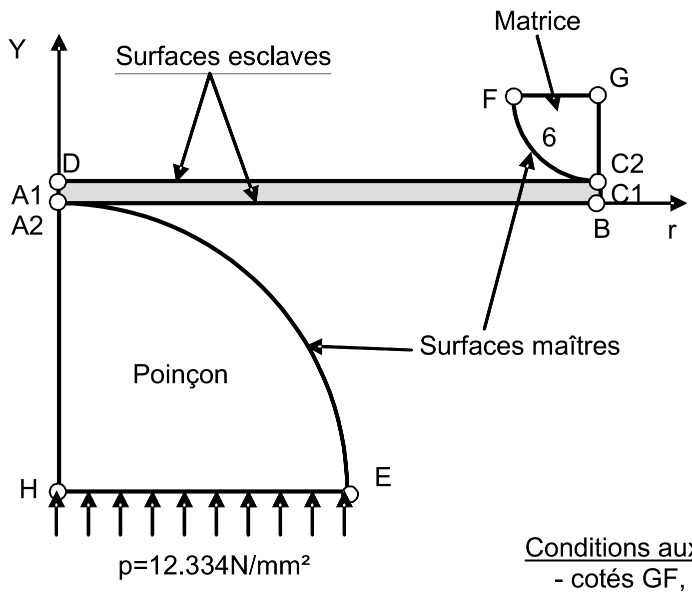
4.4 Remarks

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

5 Modeling C

5.1 Characteristics of modeling

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



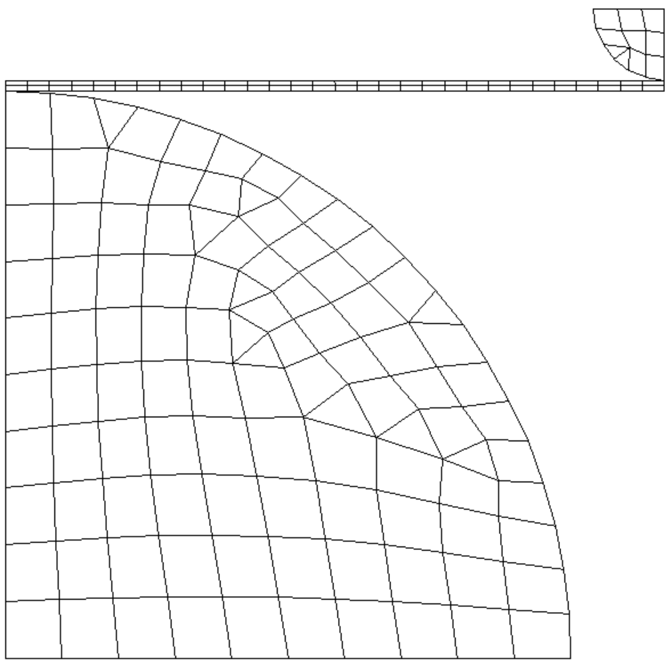
Mailles solides
- Flan
  . 2 éléments dans l'épaisseur
  . 30 éléments suivant le rayon
- Poinçon
  . 20 éléments sur AE
- Rayon entrée/matrice
  . 6 éléments sur CF

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 the rigid movements of body, one forces that displacements DY points $A1$ (pertaining to the blank) and $A2$ (pertaining to the punch) are identical.



5.2 Characteristics of the grid

Many nodes: 230
Many meshs: 291 meshs (163 QUAD4, 12 TRIA3 and 116 SEG2)

5.3 Sizes tested and results

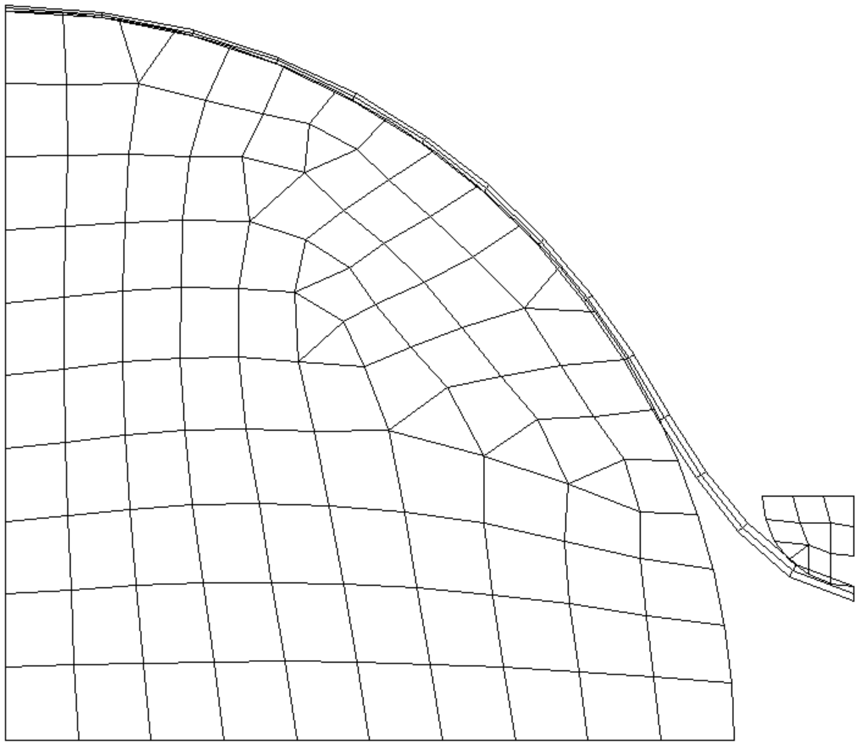
Identification (Displacement)	**Loading** ($\times 10^4 N$)	**Reference**	**Type of reference**	**Tolerance**
DX ($N87$)	1.	10.6	'SOURCE_EXTERNE'	25.00%
DX ($N87$)	2.	15.4	'SOURCE_EXTERNE'	10,00%
DX ($N87$)	3.	20.0	'SOURCE_EXTERNE'	10,00%
DX ($N87$)	4.	24.7	'SOURCE_EXTERNE'	10,00%
DX ($N87$)	5.	28.2	'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 law of behavior of material constituting sheet is given linearized under-form.
Calculation does not converge any more beyond 75% of the total load.

6 Summary of the results

On the figure below we present, for modeling A, the deformation 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 modeling B (with friction), the error with 75% of the load given by the references [bib1] and [bib2] is of 6%.