ZZZZ120 - Calculation of an assembly pin-attaches

Summary:

The purpose of these two tests are to validate the two macro-orders MACR_GOUJ2E_MAIL and MACR_GOUJ2E_CALC as well as order POST_GOUJ2E. In modeling A we calculate in a total way an assembly pin-attaches whose support comprises a top of support. Modeling B differs from modeling A by the fact that the support does not have top of support. In two modelings we calculate the shearing forces of each net.
It is about a problem of stationary mechanics nonlinear modelled in $2D$ axisymmetric for the support and in $3D$ (elements of beam) for the pin.
The reference solution is digital, it was obtained with the tool trade GOUJ2ECH.

The tests are of following interests:

- macro-orders MACR_GOUJ2E_MAIL and MACR_GOUJ2E_CALC as well as order POST_GOUJ2E are validated,
- some of the nets are missing,
- two types of support (with and without top of support) are tested.

1 Problem of reference

1.1 Geometry

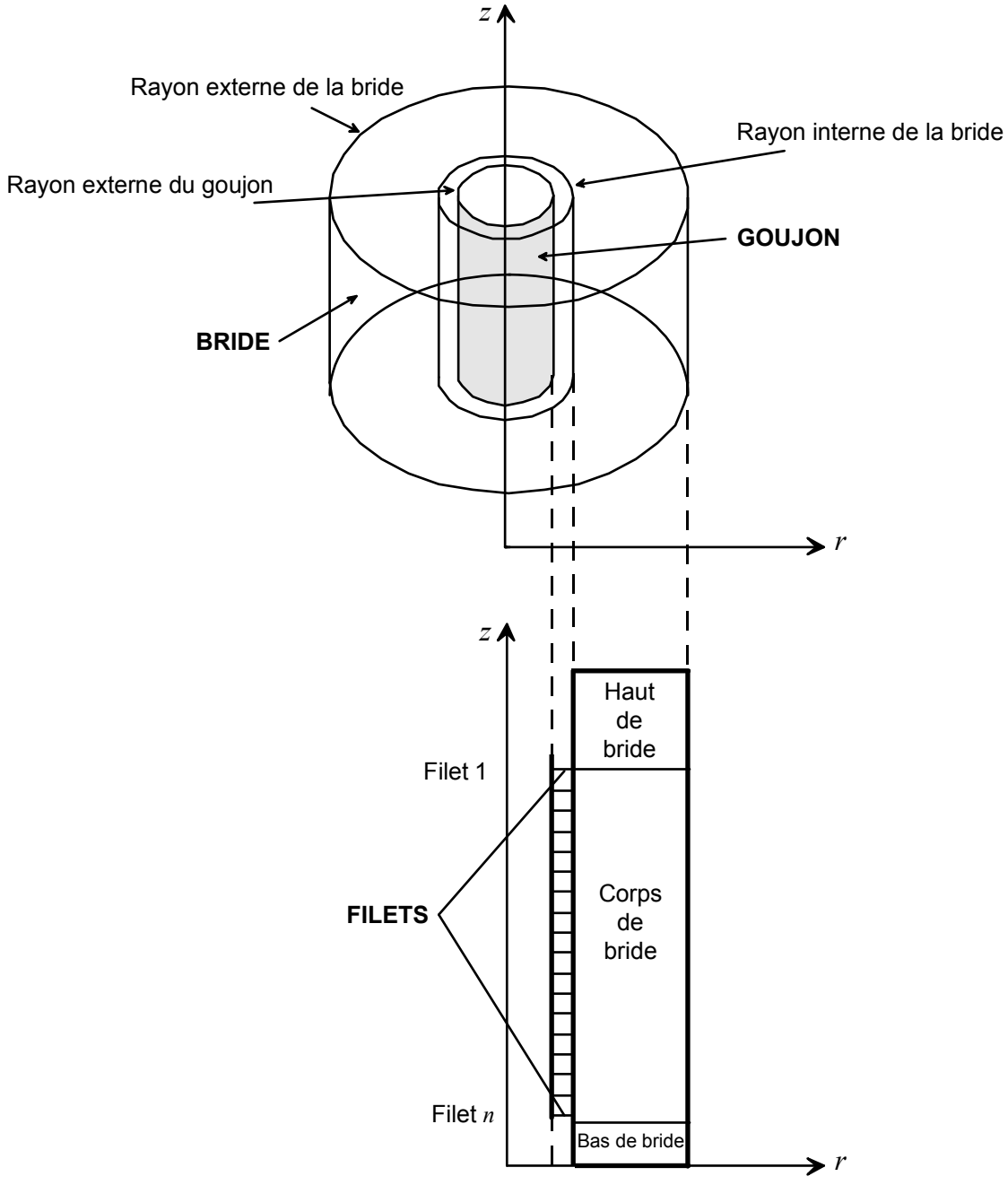


Figure 1.1-a

1.2 Properties of materials

	Material	Young modulus	Poisson's ratio
Pin	40NCDV	$E = 191139\ MPa$	$\nu = 0,3$
Attach	16MND5	$E = 190000\ MPa$	$\nu = 0,3$

For the nets one has six traction diagrams, three curves corresponding to modeling A (with a top of support):

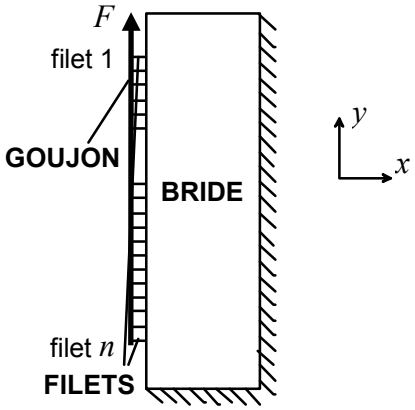
First net		Second net		Current net	
$u - v$ (m)	$q = f(u - v)$ (MN/m)	$u - v$ (m)	$q = f(u - v)$ (MN/m)	$u - v$ (m)	$q = f(u - v)$ (MN/m)
0.0	0.0	0.0	0.0	0.0	0.0
1.6497D-05	2.6890D+01	1.6010D-05	2.5140D+01	1.6010D-05	2.5140D+01
2.3835D-05	3.8844D+01	2.3133D-05	3.6324D+01	2.3133D-05	3.6324D+01
3.1201D-05	5.0755D+01	3.0284D-05	4.7569D+01	3.0284D-05	4.7569D+01
3.8721D-05	6.2433D+01	3.7597D-05	5.9212D+01	3.7597D-05	5.9212D+01
4.6847D-05	7.3269D+01	4.5542D-05	7.1024D+01	4.5542D-05	7.1024D+01
5.8812D-05	8.4467D+01	5.7342D-05	8.3503D+01	5.7342D-05	8.3503D+01
7.3112D-05	9.2437D+01	7.1528D-05	9.1787D+01	7.1528D-05	9.1787D+01
8.8706D-05	9.8271D+01	8.7040D-05	9.8055D+01	8.7040D-05	9.8055D+01
9.6809D-05	1.0075D+02	9.5114D-05	1.0075D+02	9.5114D-05	1.0075D+02
1.0511D-04	1.0299D+02	1.0338D-04	1.0315D+02	1.0338D-04	1.0315D+02

and three partners with modeling B (without top of support):

First net		Second net		Current net	
$u - v$ (m)	$q = f(u - v)$ (MN/m)	$u - v$ (m)	$q = f(u - v)$ (MN/m)	$u - v$ (m)	$q = f(u - v)$ (MN/m)
0.0	0.0	0.0	0.0	0.0	0.0
1.4119D-05	13.6330	1.4281D-05	19.8762	1.67633D-05	29.78608
1.8273D-05	17.6418	1.8482D-05	25.7282	2.51686D-05	43.54046
2.6426D-05	25.5596	2.6733D-05	37.2252	3.37170D-05	58.44226
3.4650D-05	33.6343	3.5071D-05	49.0023	4.31017D-05	74.31599
4.3138D-05	42.4594	4.3757D-05	61.6887	5.46760D-05	87.81715
5.2080D-05	52.4101	5.3010D-05	73.9464	6.87233D-05	96.55312
6.1709D-05	63.4097	6.3161D-05	83.5238	8.39777D-05	103.21506
7.2109D-05	73.9736	7.4294D-05	90.6382	1.00084D-04	108.63585
8.3500D-05	82.0174	8.6551D-05	96.1680	1.16889D-04	113.05545
9.5698D-05	87.6548	9.9798D-05	100.7534		
1.0908D-04	91.0197				

1.3 Boundary conditions and loading

The boundary conditions are of type: blocking of displacements according to x and y on the side external and with the base of the support.



Conditions aux limites 2

The force of total traction F, which is exerted on the pin is of 5 MN. This one is applied in five increments of 1 MN.

1.4 Characteristics of the assembly pin-attaches

The tool trade GOUJ2ECH, the data entered via a data file which is presented in the following form:

Many nets in catch	56
Height of support (in m):	0,225
Ray ext. embroiders (in m):	0,140
Force applied (out of mn, traction > 0):	5.0
Many increments of load:	5
Assembly (Nominal, Helicoil,…):	nominal
Geometry (M64, M155, M180,…):	M155
High of support (with, without):	with (modeling A), without (modeling B)
Game (Maximum, Mini,…):	maximum
Behavior (elastic, elastoplastic,…):	elastoplastic
Material pin (40NCDV,…):	40NCDV
Material attaches (16MND5,…):	16MND5
Section of the pin (M^2):	0.01704
Ray external of the pin (M):	0.0736478
Thickness (M):	0,004
Interior ray of the support (M):	0,080
Zones and characteristics of the nets	3 4
	lack

Note:

In the example above nets 3 and 4 are missing.

2 Reference solution

2.1 Method of calculating used for the reference solution

The procedure of calculation of the pins is described in [bib1] and it is established in software GOUJ2ECH [bib2]. This procedure consists of two principal parts:

- Local calculation by finite elements ($2D$ axisymmetric) net by net
  On [Figure 1.1-a] one represented a net where u corresponds to the displacement of the pin, v with the displacement of the support and q with the shearing supported by the net.

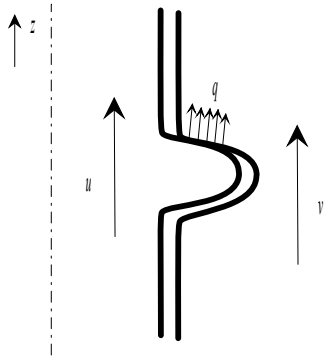


Figure 2.1-a: Calculation of a net

For each net one calculates $q = f(u - v)$ where f is a nonlinear function for a monotonous loading. One considers several types of net and thus one obtains several types of curves q : 1 q first net, 2 q second net, 3 q net running, 4 q missing net, 5 q truncated net, 6 q net except tolerance.
For each calculated type of pin curves q are stored in a database. This database feeds the software which allows the total calculation of the pin.

- Total calculation of the pin with the method of the stepladder with the software **GOUJ2ECH**
  On Figure 1.2 one represented the total modeling of the structure, it acts of a modeling $1D$. They are two beams in vertical shearing and which are connected between them by springs which have as a behavior the various curves q. Software **GOUJ2ECH** current solves the following problem:

poutre $\int_0^{L_g} \left(E S u' w' + f(u - v) w \right) dz = F w(0)$

massif $\int_0^{L_b} \left(A v' w' + B v w - f(u - v) w \right) dz = 0 \quad + C.L. \quad \forall w$

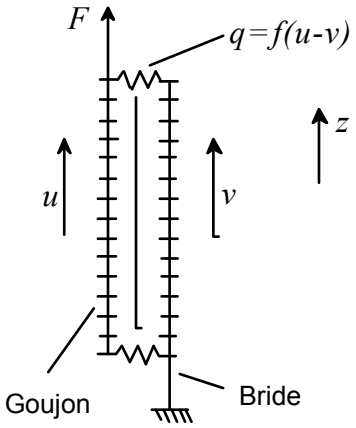


Figure 2.1-b - Modeling of the pin and the support.

The boundary conditions of the support can vary. It is the term $B v w$ variational formulation of the solid mass which varies according to the boundary conditions, [bib2].
Software **GOUJ2ECH** (via the Anthemix environment) the effort undergone by each net calculates, [bib2].

2.2 Results of reference

Reaction exerted on the nets numbers 1,2,5,6,7,28,55,56 when the force of traction exerted on the pin is of $1 MN$ and $5 MN$.

Curves Reaction of the nets according to the numbers of the nets when the force of traction exerted on the pin is of $1 MN$ and $5 MN$.

Curves Reaction cumulated of the nets divided by the force of traction exerted according to the numbers of the nets when the force of traction exerted on the pin is of $1 MN$ and $5 MN$.

2.3 Uncertainty on the solution

Digital solution obtained with the software **GOUJ2ECH**.
There is no analytical solution.

2.4 Bibliographical references

1) S. ANDRIEUX, LIGHT A., Y. WADIER: A method on two scales for calculation of the threaded assemblies. Note interns EDF HI-73/5825, 1987

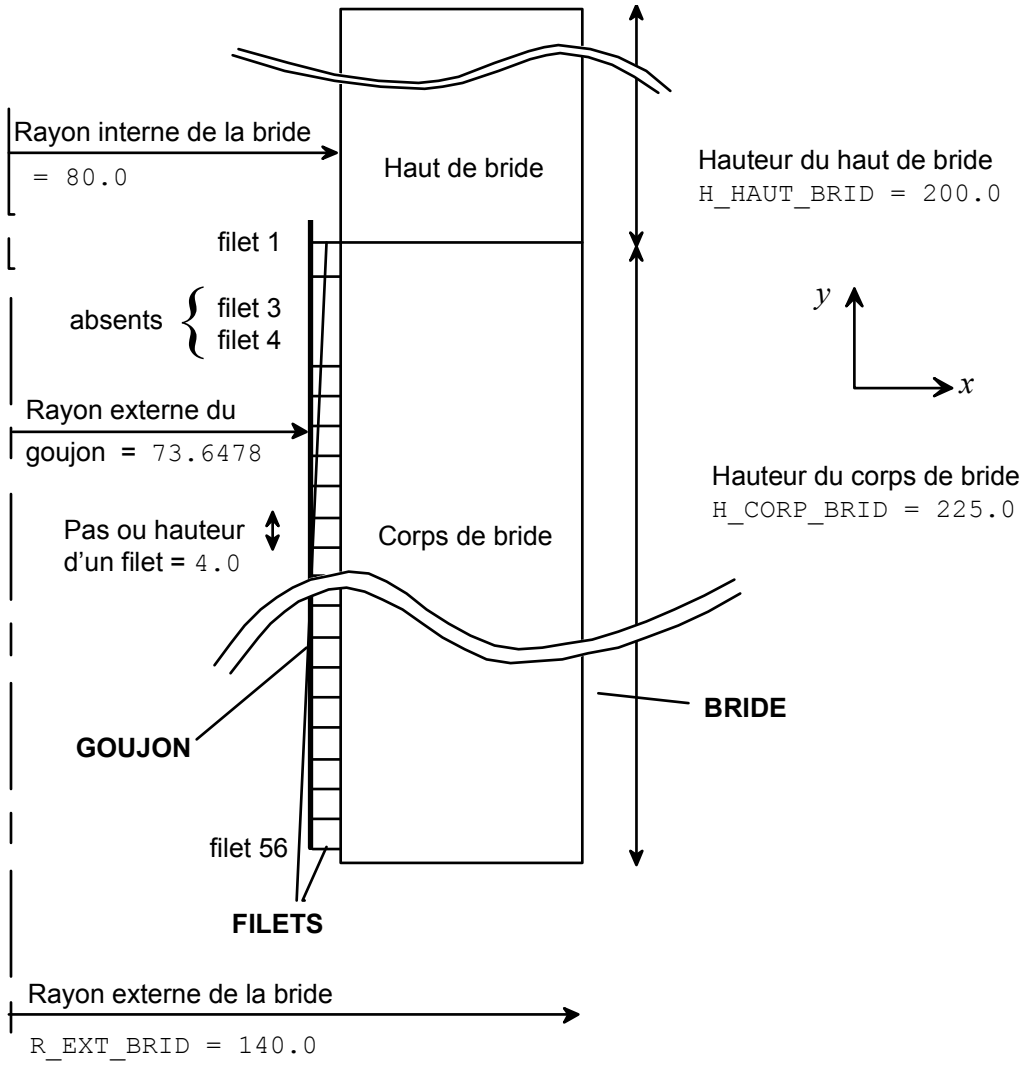
2) S. ANDRIEUX, LIGHT A., S. GEISSEL, F. VOLDOIRE: GOUJ2ECH - Method on two scales of calculation of threaded assemblies, Note of use. Note interns EDF, HI-73-6241 index C, 1994

3 Modeling A

3.1 Characteristic of modeling

This calculation is carried out in $2D$ axisymmetric, contrary to the reference solution which is it in $1D$.

axis (SEG2, SEG3, TRIA6, QUAD8)



Numbers of the nets	X	Y	
1	73.6478	220.00	N1954
2	73.6478	216.00	N1953
5	73.6478	204.00	N1950
6	73.6478	200.00	N1949
7	73.6478	196.00	N1948
28	73.6478	112.00	N1927
55	73.6478	4.00	N1900
56	73.6478	0.00	N1899

3.2 Characteristics of the grid

Many nodes: 1962.

Many meshs and types: 110 SEG2, 109 SEG3, 154 TRIA6, 487 QUAD8.

3.3 Properties of materials

For the pin, material 40NCDV:
$E = 191139\ MPa$; $\nu = 0{,}3$.

For the support, material 16MND5:
The Young modulus of material constituting the support must be multiplied by 2π. This is due to the fact that the support is modelled in $2D$ axis whereas the pin is in 3D (modelled in beam).
$E = 1193800\ MPa$; $\nu = 0{,}3$.

For the nets one has three traction diagrams:

First net		Second net		Current net	
$u - v$ (mm)	$q = f(u - v)$ (N)	$u - v$ (mm)	$q = f(u - v)$ (N)	$u - v$ (mm)	$q = f(u - v)$ (N)
1.6497D-02	107.560E+03	1.6010D-02	100.560E+03	1.6010D-02	100.560E+03
2.3835D-02	155.376E+03	2.3133D-02	145.296E+03	2.3133D-02	145.296E+03
3.1201D-02	203.020E+03	3.0284D-02	190.208E+03	3.0284D-02	190.208E+03
3.8721D-02	249.732E+03	3.7597D-02	236.140E+03	3.7597D-02	236.140E+03
4.6847D-02	293.076E+03	4.5542D-02	284.096E+03	4.5542D-02	284.096E+03
5.8812D-02	337.868E+03	5.7342D-02	334.012E+03	5.7342D-02	334.012E+03
7.3112D-02	369.748E+03	7.1528D-02	367.148E+03	7.1528D-02	367.148E+03
8.8706D-02	393.084E+03	8.7040D-02	392.220E+03	8.7040D-02	392.220E+03
9.6809D-02	403.000E+03	9.5114D-02	403.000E+03	9.5114D-02	403.000E+03
1.0511D-01	411.960E+03	1.0338D-01	412.600E+03	1.0338D-01	412.600E+03

Note:

Relative displacement between the pin and the support is indicated here in millimetre, whereas in the problem of reference it is it in meter.
The unit of the shearing force is Newton here, whereas in the problem of reference the shearing force is given in MN/m , [bib1], [bib2].

3.4 Sizes tested and results

Shearing force in Newton to the first step of load

Identification	Reference	Code_Aster	% difference
reaction on net 1	0.920783E+05	0.935989E+05	1,651
reaction on net 2	0.818096E+05	0.882044E+05	0,287
reaction on net 5	0.632683E+05	0.613744E+05	– 2,993
reaction on net 6	0.576444E+05	0.544912E+05	– 5,470
reaction on net 7	0.525322E+05	0.489092E+05	– 6,897
reaction on net 28	0.852649E+04	0.103178E+05	21,009
reaction on net 55	0.954627E+04	0.844846E+04	– 11,500
reaction on net 56	0.103622E+05	0.956714E+04	– 7,673

Shearing force in Newton to the fifth and the last not of load

Identification	Reference	Code_Aster	% difference
reaction on net 1	3.70668E+05	3.75966E+05	1,429
reaction on net 2	3.59170E+05	3.63799E+05	1,289
reaction on net 5	3.14594E+05	3.09596E+05	– 1,589
reaction on net 6	2.94781E+05	2.84261E+05	– 3,569
reaction on net 7	2.73743E+05	2.55513E+05	– 6,660
reaction on net 28	4.43446E+04	5.31170E+04	19,782
reaction on net 55	4.80746E+04	4.31747E+04	– 11,500
reaction on net 56	5.21624E+04	4.88871E+04	– 6,279

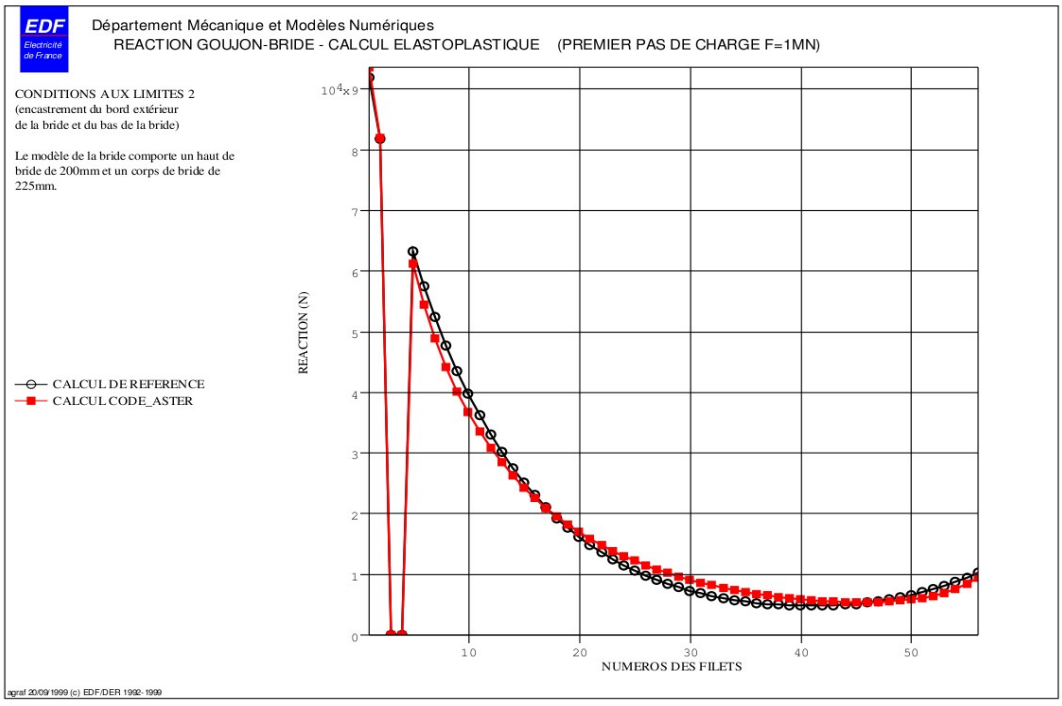


Figure 4.1-a: Reaction pin-attaches with the first step of load

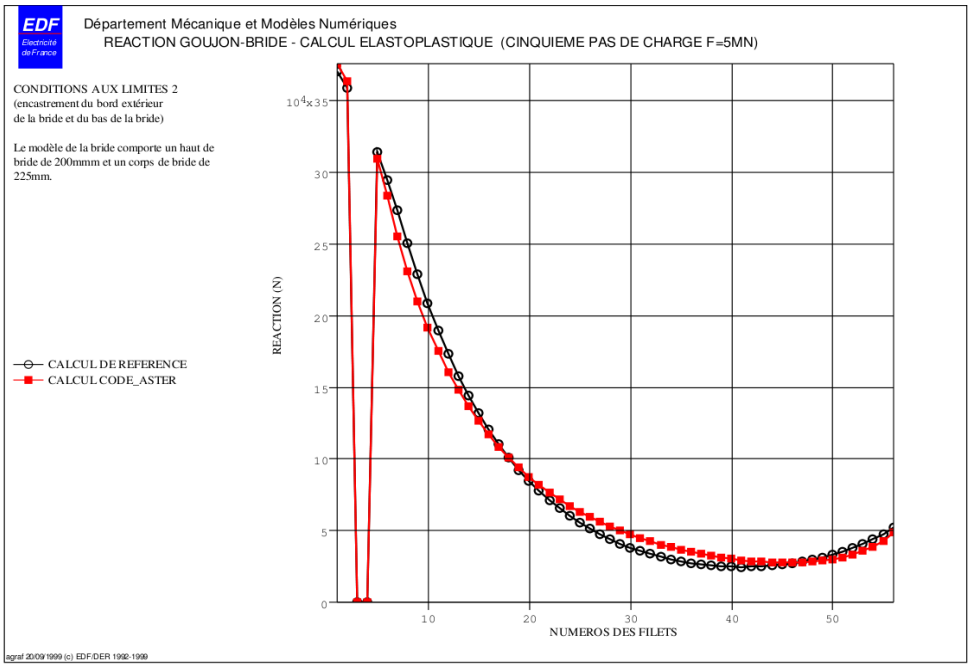


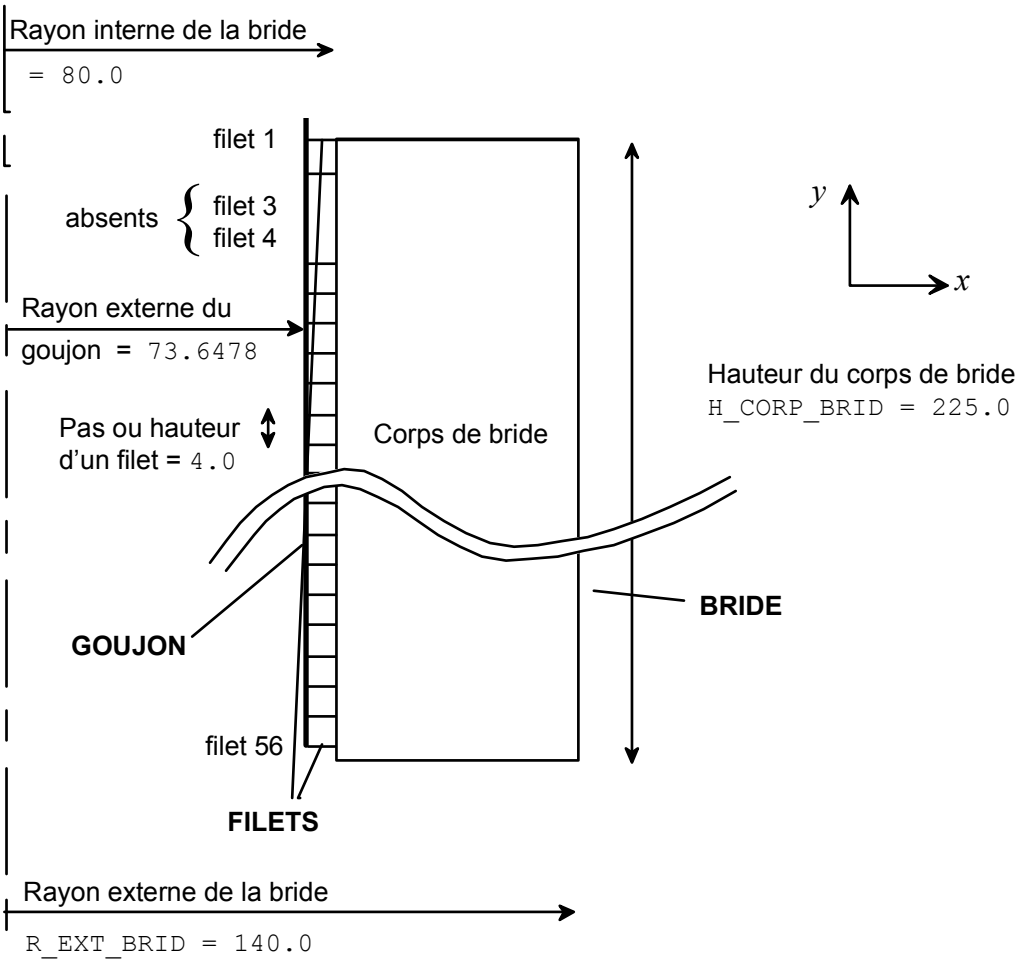
Figure 4.1-b: Reaction pin-attaches with the fifth step of load

4 Modeling B

4.1 Characteristic of modeling

Idem modeling A, without top of support.

axis (SEG2, SEG3, TRIA6, QUAD8)



Numbers of the nets	X	Y	
1	73.6478	220.00	N1469
2	73.6478	216.00	N1468
5	73.6478	204.00	N1465
6	73.6478	200.00	N1464
7	73.6478	196.00	N1463
28	73.6478	112.00	N1442
55	73.6478	4.00	N1415
56	73.6478	0.00	N1414

4.2 Characteristics of the grid

Many nodes: 1477.

Many meshs and types: 110 SEG2, 170 SEG3, 130 TRIA6, 352 QUAD8.

4.3 Properties of materials

For the pin, material 40NCDV:
$E = 191139\ MPa$; $\nu = 0{,}3$.

For the support, material 16MND5:
The Young modulus of material constituting the support must be multiplied by 2π. This is due to the fact that the support is modelled in 2D axis whereas the pin is in 3D (modelled in beam).
$E = 1193800\ MPa$; $\nu = 0{,}3$.

For the nets one has three traction diagrams:

First net		Second net		Current net	
$u - v$ (mm)	$q = f(u - v)$ (NR)	$u - v$ (mm)	$q = f(u - v)$ (NR)	$u - v$ (mm)	$q = f(u - v)$ (NR)
1.4119E-02	64.5154E+03	1.4281E-02	79.5058E+03	1.67633E-02	119.14432E+03
1.8273E-02	83.4966E+03	1.8482E-02	102.8924E+03	2.51686E-02	174.16184E+03
2.6426E-02	120.7508E+03	2.6733E-02	148.8272E+03	3.37170E-02	233.76904E+03
3.4650E-02	158.3295E+03	3.5071E-02	195.2463E+03	4.31017E-02	297.26396E+03
4.3138E-02	197.1145E+03	4.3757E-02	243.6027E+03	5.46760E-02	351.26860E+03
5.2080E-02	237.9740E+03	5.3010E-02	295.1158E+03	6.87233E-02	386.21248E+03
6.1709E-02	253.6388E+03	6.3161E-02	334.0952E+03	8.39777E-02	412.86024E+03
7.2109E-02	295.8944E+03	7.4294E-02	362.5528E+03	10.00835E-02	434.54340E+03
8.3500E-02	328.0696E+03	8.6551E-02	384.6720E+03	11.68892E-02	452.22180E+03
9.5698E-02	350.6192E+03	9.9798E-02	403.0136E+03		
10.9076E-02	364.0788E+03				

Note:

Relative displacement between the pin and the support is indicated here in millimetre, whereas in the problem of reference it is it in meter.
The unit of the shearing force is Newton here, whereas in the problem of reference the shearing force is given in MN/m , [bib1], [bib2].

4.4 Sizes tested and results

Shearing force in Newton to the first step of load

Identification	Reference	Code_Aster	% difference
reaction on net 1	5.53271E+04	5.55046E+04	0,321
reaction on net 2	7.33944E+04	6.48494E+04	– 11,643
reaction on net 5	7.13611E+04	6.25512E+04	– 12,346
reaction on net 6	6.46135E+04	5.56557E+04	– 13,864
reaction on net 7	5.85172E+04	5.00993E+04	– 14,385
reaction on net 28	8.35972E+03	1.12944E+04	35,105
reaction on net 55	1.00588E+04	1.02133E+04	1,536
reaction on net 56	1.10041E+04	1.17140E+04	6,451

Shearing force in Newton to the fifth and the last not of load

Identification	Reference	Code_Aster	% difference
reaction on net 1	2.97536E+05	2.57685E+05	– 13,394
reaction on net 2	3.43887E+05	3.20998E+05	– 6,656
reaction on net 5	3.35310E+05	3.07108E+05	– 8,411
reaction on net 6	3.12992E+05	2.77724E+05	– 11,268
reaction on net 7	2.90708E+05	2.50588E+05	– 13,801
reaction on net 28	4.27787E+04	5.70916E+04	33,458
reaction on net 55	5.04395E+04	5.13517E+04	1,808
reaction on net 56	5.51691E+04	5.88938E+04	6,751

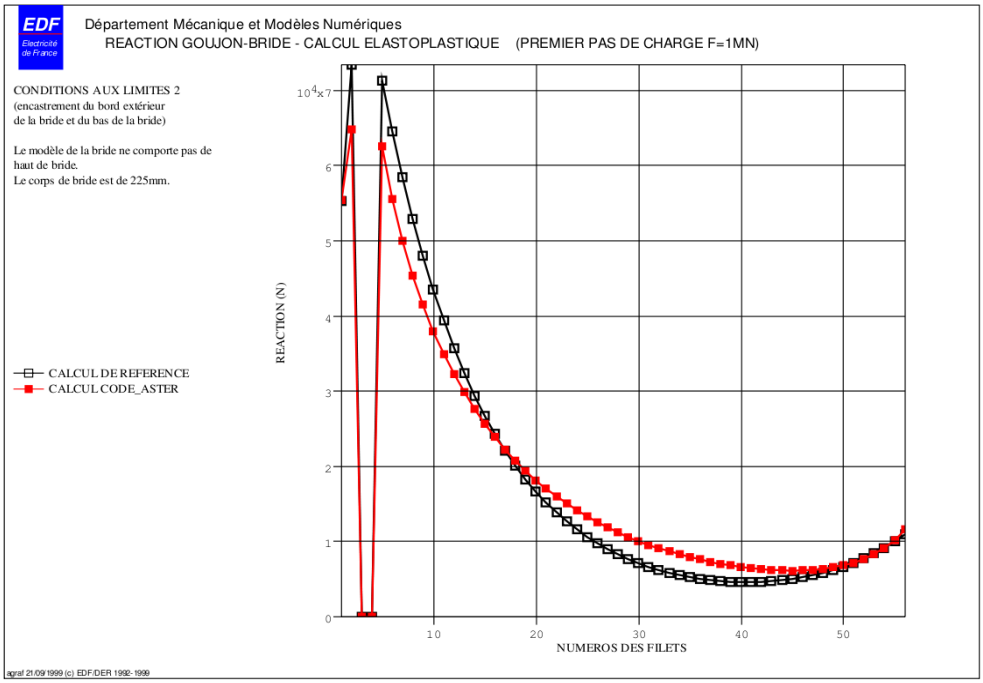


Figure 6.1-a: Reaction pin-attaches with the first step of load

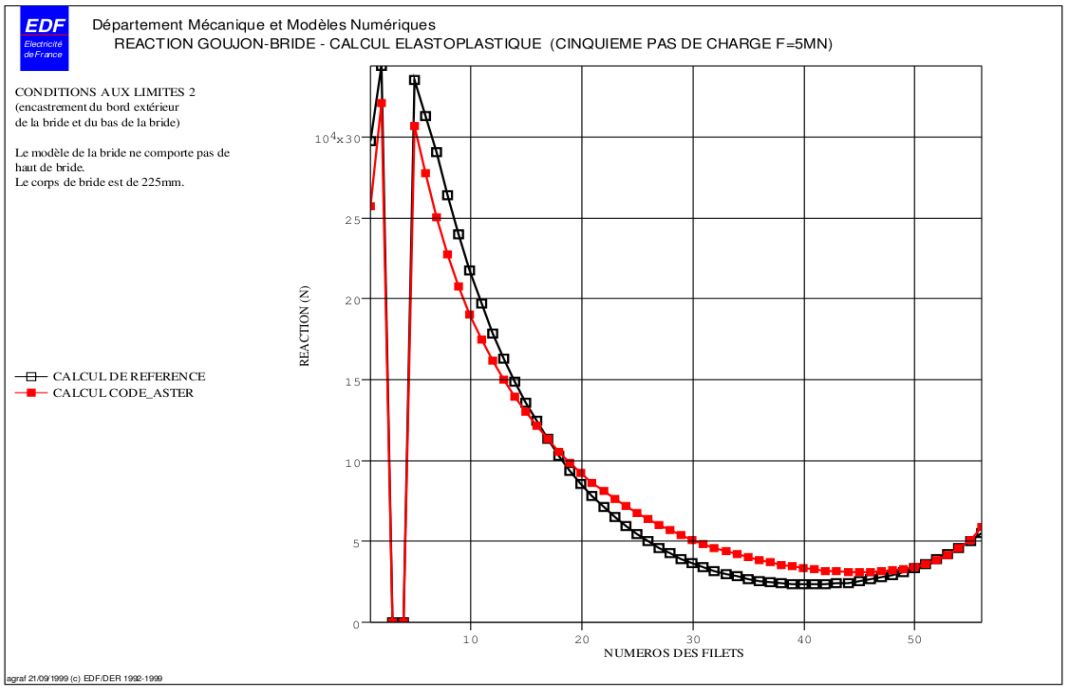


Figure 6.1-b: Reaction pin-attaches with the fifth step of load

5 Summary of the results

Taking into account the differences in modeling between the problem of reference and modeling A, the results of this one are very satisfactory.

The results of modeling B are a little less close, but remain satisfactory. In this last case the variations are explained by the fact why in the method of reference, the transverse distribution of the axial component of displacements in the support is projected on the solutions of an infinite beam in traction and an infinite beam in shearing. However at the top of the support, this assumption is not checked when there is no top of support.