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Accounting for large membrane strains in Q4GS and T3GS elements in EUROPLEXUS

Folco Casadei
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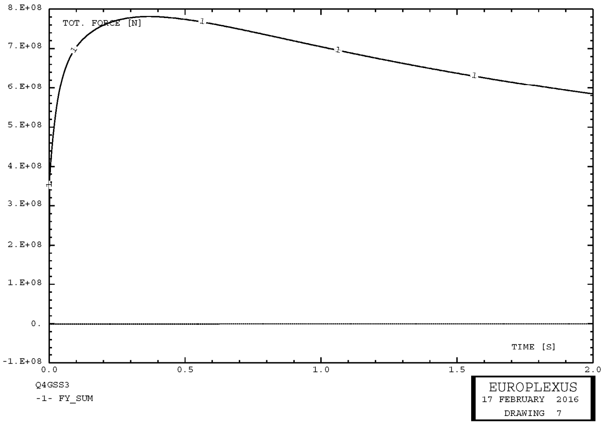
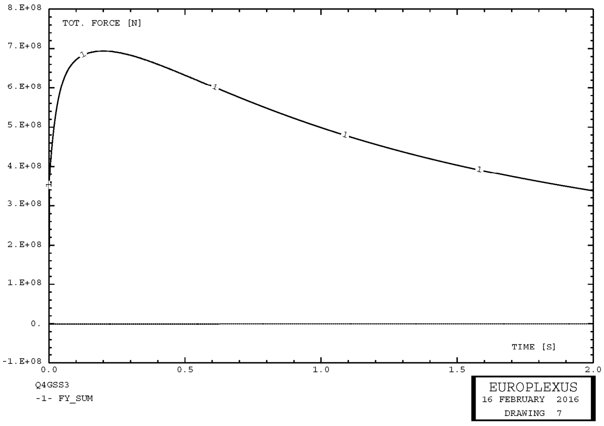
2016





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Accounting for large membrane strains in Q4GS and T3GS elements in EUROPLEXUS

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February 19, 2016

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1 Introduction

This short note presents the updating of element thickness due to large membrane strains recently introduced in some shell elements (Q4GS and T3GS) of the EUROPLEXUS code (EPX).

EUROPLEXUS [1] is a computer code jointly developed by the French Commissariat à l'Energie Atomique (CEA DMT Saclay) and by EC-JRC. The code application domain is the numerical simulation of fast transient phenomena such as explosions, crashes and impacts in complex three-dimensional fluid-structure systems.

The Cast3m [2] software from CEA is used as a pre-processor to EPX when it is necessary to generate complex meshes.

The development proposed here solves a problem highlighted in a previous report, see [3], where it had been noted that some of EPX's shell elements do not update the thickness when the element is subjected to large membrane strains. As a consequence, membrane forces (but also bending and transverse shear components) are incorrectly evaluated when large membrane strains are present.

2 Updating the shell element thickness

In reference [3] the implementation of the VPJC modified Johnson-Cook material model described in [4] was checked by simple displacement-driven one-element tests. The imposed diplacements were such that (very) large membrane strains were induced in the elements.

It was noted that some shell elements failed (at least partly) to give the expected (analytical) solution. The computed stresses and strains were correct, but the nodal forces were wrong due to the fact that the element thickness was not updated as a consequence of the large membrane deformations.

For one of these elements (JRC's COQI triangular plate/shell) the problem was identified in the element formulation itself. Although the thickness of this element is updated as a consequence of large membrane strains, the element formulation *itself* is such that large membrane strains are not properly accounted for. Therefore, it was concluded that COQI elements should not be used whenever the expected membrane strains exceed a few percent.

For another set of elements (CEA's Q4GS, T3GS, Q4GR, QPPS, DKT3 and DST3) the problem consists in the fact that the update of element thickness was not implemented in the element routine (with the notable exception of Q4GS when used in conjunction with the hyperelastic material HYPE).

The existing bibliography on these elements formulation was then inspected in order to devise a possible solution. It turns out that the DKT3 and DST3 elements are not really suited to be used in conjunction with non-linear materials, see e.g. reference [6], and this despite the fact that EPX does allow their use with materials such as VMIS ISOT (elasto-plastic). Since large (membrane) strains are almost necessarily accompanied by non-linear material behaviour in practical applications, it was decided not to update these element routines.

The same conclusion was applied to the QPPS element (because it is rarely used) and to the Q4GR (this element is underintegrated and necessitates of anti-hourglass treatment by means of empirical parameters, therefore its use is discouraged in recent applications, in favour of Q4GS).

The two remaining elements, Q4GS and T3GS, are the most general and most frequently used shell elements of EPX, for the quadrilateral and triangular shape, respectively, and can be used in mixed meshes being fully compatible with each other. Therefore, it was considered essential to extend at least these two heavy-duty shell elements to the treatment of large membrane strains.

The existing documentation for the Q4GS is reference [5], and for T3GS it is reference [6].

2.1 Calculating the new thickness

For the two shell elements considered here (Q4GS and T3GS), the element thickness is contained in the global array TH(1), while the element excentricity is contained in TH(2).

These values are always the *initial* values, as provided by the user in the input file, with the only exception of the Q4GS element used in conjunction with the HYPE (hyperelastic) material, where the value of TH(1) (but curiously not TH(2)) is updated as a consequence of through-the-thickness strain. In the modifications prepared in the present work, care has been taken so as not to modify the behaviour of Q4GS when used in conjunction with HYPE.

When a shell undergoes large membrane strains, its thickness varies in general. The new thickness can be computed from the through-the-thickness total strain ϵ_z, whose value is computed and returned by (most) material routines as a consequence of imposing a zero-stress condition along the thickness ($\sigma_z = 0$). Of course, the change in shell thickness has an influence on membrane, bending and transverse shear forces.

Shell elements possess a number of Gauss integration points, which are located on *laminas* (surfaces parallel to the mean surface of the shell). When non-linear materials are used, several laminas and therefore several Gauss points through the thickness are used to achieve accurate numerical integration, because the stress profile through the thickness is non-linear in general. A *fiber* is defined as a straight line, initially normal to the shell mid-surface (lamina). As a consequence of deformation, the fiber is assumed to remain straight (so that the strain profile along a fiber is linear), but it may become no longer normal to the laminas if Reissner-Mindlin shell theory (thick shells) is adopted (this is the case for Q4GS and T3GS), as opposed to Poisson-Kirchhoff (thin shells) theory.

Note incidentally that in EPX stress and strain values for shells may be organized either fiber-first, or lamina-first (the latter is the case for both Q4GS and T3GS), depending on element type.

As concerns lamina integration, the Q4GS adopts a 2×2 (i.e., 4 points) rule in each lamina, while the T3GS uses a single point in each lamina. The number of Gauss points through the thickness (i.e along a fiber) depends upon the material. A single point (analytical integration) is used with "linear" materials (e.g. the linear elastic material LINE or a global formulation such as GLRC), while several points (5 by default, but their number can be varied by the user) are used if a non-linear material (and/or a layered shell model with varying material layer by layer) is adopted. Each Gauss point has its own set of stress, strain and hardening variable components.

At the beginning of the element routine, in order to update the element thickness, a weighted average $\bar{\epsilon}_z$ of the through-the-thickness strain ϵ_z is evaluated along each fiber i:

$$\bar{\epsilon}_{zi} = \frac{\sum_{f=1}^{n_f} \epsilon_{zif} W_f}{\sum_{f=1}^{n_f} W_f} \tag{1}$$

where i indicates the particular fiber chosen, f are the integration points (from 1 to n_f) along the fiber (i.e., through the thickness) and W_f is the integration weight associated with each integration point.

By denoting h_0 the initial thickness of the element (as provided by the user), the current thickness h_i of the fiber i under consideration is is estimated as:

$$h_i = h_0 \exp(\bar{\epsilon}_{zi}) \tag{2}$$

From this, an average current thickness h for the whole element is estimated, according to:

$$h = \frac{1}{n_l} \sum_{l=1}^{n_l} h_l \tag{3}$$

where l are the integration points (from 1 to n_l) over the lamina (i.e. in the element plane).

The element excentricity κ is scaled in the same proportion as the thickness:

$$\kappa = \frac{h}{h_0} \kappa_0 \tag{4}$$

where κ_0 indicates the initial element excentricity as provided by the user.

The estimated current thickness h and current excentricity κ are then used in the rest of the routine instead of the initial ones in order to compute the element strain increments, new stresses and nodal forces. Note, however, that the values of thickness and excentricity in the TH array are never modified (except in the case of HYPE material already noted above) and remain therefore the initial values provided by the user.

2.2 Implementation notes

The thickness (and excentricity) update proposed in the previos Section is applied in the Q4GS and T3GS elements only when the element is integrated through the thickness, i.e. when more than one Gauss point is used along a fiber. Recall that this is the case for non-linear materials. In fact, for linear materials it would probably not make sense to update the thickness, since in such cases the membrane strains should be small anyway.

With the proposed modification, all standard benchmark tests pass for the T3GS element, while for Q4GS (which is used much more frequently) some benchmarks do not pass the qualification (this is perhaps normal, if non-negligible membrane strains occur in such cases).

In order to avoid perturbing the results of existing tests and applications, it has been decided to implement the proposed modification in the form of an option. A new optional keyword `OPTI LMST` (for Large Menbrane STrains) is implemented. This option activates the thickness update in elements Q4GS and T3GS, provided these elements use a non-linear material. In case of linear material (and also in case of the HYPE material, for the Q4GS), the option has no effect and the results obtained should be identical to previous solutions (without the option).

3 Numerical examples

3.1 Test cases with VPJC material

We first check the problematic cases of reference [3] with Q4GS and T3GS by adding the new option to see whether the results in terms of nodal forces are correct. All such tests use the VPJC material.

The performed tests are summarized in Table 1. Two sets of cases were considered, one involving linear elastic material and the other involving elastic perfectly-plastic material. The test geometry is similar to the one considered in the previous section (a single 4-node shell element subjected to imposed displacements) but the final length of the element is twice the initial one (instead of three times the initial one).

Case	Mesh	ϵ_x	ϵ_y	ϵ_z	σ_y	F_y
Analytical	—	-0.54931	1.0986	-0.54931	10.116×10^8	3.3720×10^8
Q4GSS3	Q4GS	-0.54894	1.0986	-0.54025	10.116×10^8	3.3777×10^8
T3GSS3	T3GS	-0.54894	1.0986	-0.54025	10.116×10^8	3.3777×10^8

Table 1: Calculations with 3D shell elements and VPJC material.

3.1.1 Q4GSS3

This test is similar to the homonymous case of reference [3] but the `OPTI LMST` is added. As shown in Table 1, the total driving force F_y resulting from the imposed displacement is now correct.

The time variation of the driving force is depicted in Figure 1(a).

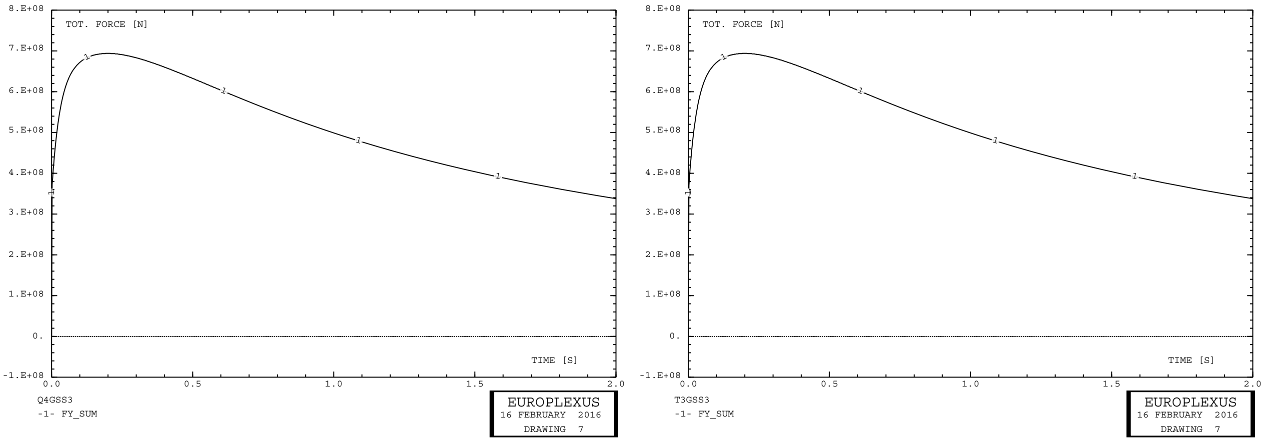
3.1.2 T3GSS3

This test is similar to the homonymous case of reference [3] but the `OPTI LMST` is added. As shown in Table 1, the total driving force F_y resulting from the imposed displacement is now correct.

The time variation of the driving force is depicted in Figure 1(b).

3.2 Test cases with linear material

Next, we check the Q4GS element in conjunction with other materials. In particular, we refer to the tests already considered, and which failed at least partially, in reference [7]. In all such tests, the new option `OPTI LMST` is added.



(a) Case Q4GSS3

(b) Case T3GSS3

Figure 1: Total driving force in cases Q4GSS3 and T3GSS3.

The test geometry is similar to the one considered in the previous section (a single 4-node quadrilateral subjected to imposed displacements), but the final length of the element is only twice instead of three times the initial one.

Two sets of tests are considered, one involving linear elastic material and the other involving elastic perfectly-plastic material. The performed tests for the first set are summarized in Table 2.

`Case`	Element	Material	Comments	ϵ_x	ϵ_y	ϵ_z	σ_x	F_x
Analytical	N/A	N/A	Static solution	0.69315	-0.20794	-0.20794	1.3863×10^{11}	9.1461×10^{10}
Q4GSS1	Q4GS	VM23 (elastic)		0.69314	-0.20793	-0.20795	1.3863×10^{11}	9.1462×10^{10}
Q4GSS3	Q4GS	LINE	'Linear' case	0.69314	-0.20791	N/A (0.0)	1.3863×10^{11}	11.261×10^{10}
Q4GSS4	Q4GS	VMIS PARF (elastic)		0.69314	-0.20791	-4.0×10^{-15}	1.3863×10^{11}	11.261×10^{10}

Table 2: Solutions of the uniaxial stress problem with elastic material

3.2.1 Q4GSS1

This test is similar to the homonymous case of reference [7] but the `OPTI LMST` is added. As shown in Table 2, the total driving force F_x resulting from the imposed displacement is now correct.

This is due to the fact that the used material model to represent an elastic behaviour is VM23 (a nominally an elasto-plastic law), with parameters set in such a way that the elastic limit is not exceeded. In this way, the code does perform numerical integration through the element thickness and the `LMST` option has a chance to work (as it does, indeed).

This is a useful practical "trick" in order to perform an elastic (but large strain) calculation with Q4GS.

3.2.2 Q4GSS3

This test is similar to the homonymous case of reference [7] but the `OPTI LMST` is added. Note that this case is *different* from case Q4GSS3 (actually, BM_STR_VPJC_Q4GSS3) presented in the previous Section, although they have the same "short" name. The material for this test is the LINE material. Therefore, as already mentioned in the previous Sections, the element is *not* integrated through the thickness and the `LMST` option should have no effect.

Indeed, the results of the calculation in terms of driving force are as false as in reference [7]. Note also that the through-the-thickness strain ϵ_z is *not* computed by the LINE material routine (it is zero). Therefore, the result would be wrong anyway, even if the code would take into account the `LMST` option for this material.

3.2.3 Q4GSS4

This test is similar to the homonymous case of reference [7] but the `OPTI LMST` is added. The material for this test is the VMIS PARF material, i.e. an elastic perfectly-plastic law, but with an elastic limit high enough so that it is never reached during this test (so that the law is elastic in practice). The shell element routine does integrate the element through the thickness in this case, so the `LMST` option has a chance to work.

Nevertheless, the results of the calculation in terms of driving force are as false as in reference [7]. This is due to the fact that the through-the-thickness strain ϵ_z is *not* correctly computed by the VMIS PARF material routine (it is practically zero). However, this is a problem of the material routine and not of the shell element routine.

3.3 Test cases with elsastic perfectly-plastic material

The performed tests for the second set of tests from reference [7] (i.e. those assuming an elastic perfectly-plastic material model) are summarized in Table 3.

`Case`	Element	Material	Comments	ϵ_x	ϵ_y	ϵ_z	σ_x	F_x
Analytical	N/A	N/A	Static solution	0.69315	-0.34657	-0.34657	4.0000×10^8	2.0000×10^8
Q4GSS2	Q4GS	VM23		0.69314	-0.34699	-0.14835	4.0000×10^8	2.4375×10^8
Q4GSS5	Q4GS	VMIS PARF		0.69314	-0.34699	-1.8×10^{-14}	4.0000×10^8	2.8273×10^8

Table 3: Solutions of the uniaxial stress problem with elastic perfectly plastic material

3.3.1 Q4GSS2

This test is similar to the homonymous case of reference [7] but the `OPTI LMST` is added. The VM23 material model is used with suitably chosen parameters to represent an elastic perfectly-plastic material behaviour.

As it can be seen from Table 3, the computed driving force is still false (although the found value is different from the one in reference [7], which did not use the `LMST` option). This seems to be due to the fact that the through-the-thickness strain ϵ_z is wrongly computed by the routine SGDI in these circumstances. The value of this strain is largely underestimated, as it appears from Table 3.

This problem will have to be further investigated.

3.3.2 Q4GSS5

This test is similar to the homonymous case of reference [7] but the `OPTI LMST` is added. The VMIS PARF material model is used, which would be the obvious choice in this case.

As seen in Table 3, the computed value of the driving force is wrong. This is because, as already noted in test Q4GSS4 commented above, the VMIS PARF routine fails to compute the correct value of ϵ_z (which is returned as nearly zero).

4 Conclusions and future work

The new option `LMST` allows to to update the element thickness in Q4GS and T3GS shell elements whenever a non-linear material model is used.

This works if the material routine correctly estimates the through-the-thickness strain ϵ_z resulting from the plane stress assumption in the shell element formulation.

The problems observed in a previous report with the VPJC material model are corrected by the new option.

For other material models such as VM23 and VMIS, some problems persist (and will have to be corrected in a fortcoming development) but these are due to the material routine and not to the shell element routine.

References

[1] EUROPLEXUS User's Manual, on-line version: http://europlexus.jrc.ec.europa.eu.

[2] Cast3m Software: http://www-cast3m.cea.fr/.

[3] F. Casadei, V. Aune, G. Valsamos, M. Larcher. *Testing of the Johnson-Cook material model VPJC in EUROPLEXUS.* JRC Technical Report, PUBSY No. JRC98848, EUR Report 27594 EN, in publication, 2016.

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[6] D. Markovic. *Implementation d'un nouvel élément fini de coque épaisse (T3GS) dans Europlexus.* EDF Report H-T62-2008-00080-FR, 2008.

[7] F. Casadei, V. Aune, G. Valsamos, M. Larcher. *Description of the elasto-plastic material routine SGDI.* JRC Technical Report, PUBSY No. JRC97557, EUR Report 27434 EN, 2015.

Appendix — Input files

All the input files used in the previous Sections are listed below.

bm_str_vpjc_q4gss3.epx

```
$  BM_STR_VPJC_Q4GSS3         TOUS GVALSAMOS 15/12/10 20:09:15 #2978
Q4GSS3
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 4 Q4GS 1 TERM
 -0.5 -0.5  0.0     0.5 -0.5  0.0     0.5  0.5  0.0    -0.5  0.5  0.0
 1 2 3 4
COMP EPAI 1.0 LECT 1 TERM
MATE VPJC RO   7850.0
          YOUN 2.1E11
          NU   0.33
          ELAS 3.70E8
          QR1  2.364E8
          CR1  39.3
          QR2  4.081E8
          CR2  4.5
          PDOT 5.E-4
          C    0.0
          TQ   0.9     ! We assume adiabatic conditions
          CP   452.0
          TM   1800.0
          M    0.0     ! Zero M : no temperature-induced softening
          DC   1.0
          WC   15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
     LECT 1 TERM
FONC NUM 1 TABL 2 0.0 1.0  ! Constant function in time
                  2.0 1.0
LINK COUP
     VITE 2 -0.5 FONC 1 LECT 1 2 TERM ! Relative velocity 1 m/s
     VITE 2  0.5 FONC 1 LECT 3 4 TERM
INIT VITE 2 -0.5 LECT 1 2 TERM
     VITE 2  0.5 LECT 3 4 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
     FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
     LMST ! To activate thickness update in Q4GS element with VPJC material
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 ’Time [s]’
COUR  1 ’dy_1’ DEPL COMP 2 NOEU LECT 1 TERM
COUR  2 ’dy_2’ DEPL COMP 2 NOEU LECT 2 TERM
COUR  3 ’dy_3’ DEPL COMP 2 NOEU LECT 3 TERM
COUR  4 ’dy_4’ DEPL COMP 2 NOEU LECT 4 TERM
COUR  5 ’fy_1’ FLIA COMP 2 NOEU LECT 1 TERM
COUR  6 ’fy_2’ FLIA COMP 2 NOEU LECT 2 TERM
COUR  7 ’fy_3’ FLIA COMP 2 NOEU LECT 3 TERM
COUR  8 ’fy_4’ FLIA COMP 2 NOEU LECT 4 TERM
COUR 11 ’s1_1’ CONT COMP 1 ELEM LECT 1 TERM
COUR 12 ’s2_1’ CONT COMP 2 ELEM LECT 1 TERM
COUR 13 ’s3_1’ CONT COMP 3 ELEM LECT 1 TERM
COUR 14 ’s4_1’ CONT COMP 4 ELEM LECT 1 TERM
COUR 15 ’s5_1’ CONT COMP 5 ELEM LECT 1 TERM
COUR 16 ’s6_1’ CONT COMP 6 ELEM LECT 1 TERM
COUR 21 ’e1_1’ EPST COMP 1 ELEM LECT 1 TERM
COUR 22 ’e2_1’ EPST COMP 2 ELEM LECT 1 TERM
COUR 23 ’e3_1’ EPST COMP 3 ELEM LECT 1 TERM
COUR 24 ’e4_1’ EPST COMP 4 ELEM LECT 1 TERM
COUR 25 ’e5_1’ EPST COMP 5 ELEM LECT 1 TERM
COUR 26 ’e6_1’ EPST COMP 6 ELEM LECT 1 TERM
COUR 32 ’se_1’ ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 ’ep_1’ ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 ’fy_sum’ FLIA COMP 2 ZONE LECT 3 4 TERM
TRAC 1 2 3 4 AXES 1.0 ’DISPL. [M]’ YZER
TRAC 5 6 7 8 AXES 1.0 ’FORCE [N]’ YZER
TRAC 11 12 13 14 15 16 AXES 1.0 ’STRESS [PA]’ YZER
TRAC 21 22 23 24 25 26 AXES 1.0 ’STRAIN [-]’ YZER
TRAC 14 AXES 1.0 ’STRESS [PA]’ XAXE 24 1.0 ’STRAIN [-]’ YZER
TRAC 32 AXES 1.0 ’EQ. STRESS [PA]’ XAXE 33 1.0 ’EQ PL STRAIN [-]’ YZER
TRAC 50 AXES 1.0 ’TOT. FORCE [N]’ YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-XX
     EPST COMP 2 LECT 1 TERM REFE  0.10986E+01 TOLE 1.E-3 ! EPS-YY
     EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-ZZ
     CONT COMP 2 LECT 1 TERM REFE  0.10116E+10 TOLE 1.E-2 ! SIG-YY
     COUR 50                REFE  0.33720E+09 TOLE 1.E-2 ! FY-SUM
SUIT
Q4GSS3A
ECHO
 CONV WIN
OPTI PRIN
RESU ALIC GARD PSCR
SORT VISU NSTO 1
PLAY
CAME   1 EYE   0.00000E+00  0.00000E+00  7.90569E+00
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  0.00000E+00
!RSPHERE:  1.58114E+00
!RADIUS :  7.90569E+00
!ASPECT :  1.00000E+00
!NEAR   :  6.16644E+00
!FAR    :  1.10680E+01
SCEN GEOM NAVI FREE
          REFE FRAM
          INIT WIRE
     VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI  NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

BEGIN DESCRIPTION

A bi-unit quadrilateral shell is subjected to an imposed elongation up to 3
times the initial length along one of the axes (by an imposed
constant velocity).

The material is VPJC and the purpose is to test the material model
under large strains. The effects of strain rate and of
temperature are neglected (m=0, C=0).

The result is compared with an analytical solution, showing
good agreement.

END DESCRIPTION
```

bm_str_vpjc_t3gss3.epx

```
$  BM_STR_VPJC_T3GSS3         TOUS GVALSAMOS 15/12/10 20:09:15 #2978
T3GSS3
ECHO
!CONV WIN
LAGR TRID
GEOM LIBR POIN 4 T3GS 2 TERM
 -0.5 -0.5  0.0     0.5 -0.5  0.0     0.5  0.5  0.0    -0.5  0.5  0.0
 1 2 3
 3 4 1
COMP EPAI 1.0 LECT 1 2 TERM
MATE VPJC RO   7850.0
          YOUN 2.1E11
          NU   0.33
          ELAS 3.70E8
          QR1  2.364E8
          CR1  39.3
          QR2  4.081E8
          CR2  4.5
          PDOT 5.E-4
          C    0.0
          TQ   0.9     ! We assume adiabatic conditions
          CP   452.0
          TM   1800.0
          M    0.0     ! Zero M : no temperature-induced softening
          DC   1.0
          WC   15.95E8 ! Large WC : no failure (realistic value is 4.73E8)
     LECT 1 2 TERM
FONC NUM 1 TABL 2 0.0 1.0  ! Constant function in time
                  2.0 1.0
LINK COUP
     VITE 2 -0.5 FONC 1 LECT 1 2 TERM ! Relative velocity 1 m/s
     VITE 2  0.5 FONC 1 LECT 3 4 TERM
INIT VITE 2 -0.5 LECT 1 2 TERM
     VITE 2  0.5 LECT 3 4 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 10000
     FICH ALIC FREQ 100
OPTI NOTE PAS UTIL LOG 1000
     LMST ! To activate thickness update in T3GS element with VPJC material
CALC TINI 0 TFIN 2.0 PASF 2.E-5 NMAX 100000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 ’Time [s]’
COUR  1 ’dy_1’ DEPL COMP 2 NOEU LECT 1 TERM
COUR  2 ’dy_2’ DEPL COMP 2 NOEU LECT 2 TERM
COUR  3 ’dy_3’ DEPL COMP 2 NOEU LECT 3 TERM
COUR  4 ’dy_4’ DEPL COMP 2 NOEU LECT 4 TERM
COUR  5 ’fy_1’ FLIA COMP 2 NOEU LECT 1 TERM
COUR  6 ’fy_2’ FLIA COMP 2 NOEU LECT 2 TERM
COUR  7 ’fy_3’ FLIA COMP 2 NOEU LECT 3 TERM
COUR  8 ’fy_4’ FLIA COMP 2 NOEU LECT 4 TERM
COUR 11 ’s1_1’ CONT COMP 1 ELEM LECT 1 TERM
COUR 12 ’s2_1’ CONT COMP 2 ELEM LECT 1 TERM
COUR 13 ’s3_1’ CONT COMP 3 ELEM LECT 1 TERM
```

```
COUR 14 ’s4_1’ CONT COMP 4 ELEM LECT 1 TERM
COUR 15 ’s5_1’ CONT COMP 5 ELEM LECT 1 TERM
COUR 16 ’s6_1’ CONT COMP 6 ELEM LECT 1 TERM
COUR 21 ’e1_1’ EPST COMP 1 ELEM LECT 1 TERM
COUR 22 ’e2_1’ EPST COMP 2 ELEM LECT 1 TERM
COUR 23 ’e3_1’ EPST COMP 3 ELEM LECT 1 TERM
COUR 24 ’e4_1’ EPST COMP 4 ELEM LECT 1 TERM
COUR 25 ’e5_1’ EPST COMP 5 ELEM LECT 1 TERM
COUR 26 ’e6_1’ EPST COMP 6 ELEM LECT 1 TERM
COUR 32 ’se_1’ ECRO COMP 2 ELEM LECT 1 TERM
COUR 33 ’ep_1’ ECRO COMP 3 ELEM LECT 1 TERM
COUR 50 ’fy_sum’ FLIA COMP 2 ZONE LECT 3 4 TERM
TRAC 1 2 3 4 AXES 1.0 ’DISPL. [M]’ YZER
TRAC 5 6 7 8 AXES 1.0 ’FORCE [N]’ YZER
TRAC 11 12 13 14 15 16 AXES 1.0 ’STRESS [PA]’ YZER
TRAC 21 22 23 24 25 26 AXES 1.0 ’STRAIN [-]’ YZER
TRAC 14 AXES 1.0 ’STRESS [PA]’ XAXE 24 1.0 ’STRAIN [-]’ YZER
TRAC 32 AXES 1.0 ’EQ. STRESS [PA]’ XAXE 33 1.0 ’EQ PL STRAIN [-]’ YZER
TRAC 50 AXES 1.0 ’TOT. FORCE [N]’ YZER
QUAL EPST COMP 1 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-XX
     EPST COMP 2 LECT 1 TERM REFE  0.10986E+01 TOLE 1.E-3 ! EPS-YY
     EPST COMP 4 LECT 1 TERM REFE -0.54931E+00 TOLE 1.E-2 ! EPS-ZZ
     CONT COMP 2 LECT 1 TERM REFE  0.10116E+10 TOLE 1.E-2 ! SIG-YY
     COUR 50                 REFE  0.33720E+09 TOLE 1.E-2 ! FY-SUM
SUIT
T3GSS3A
ECHO
 CONV WIN
OPTI PRIN
RESU ALIC GARD PSCR
SORT VISU NSTO 1
PLAY
CAME   1 EYE   0.00000E+00  0.00000E+00  7.90569E+00
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  0.00000E+00  0.00000E+00
!RSPHERE:  1.58114E+00
!RADIUS :  7.90569E+00
!ASPECT :  1.00000E+00
!NEAR   :  6.16644E+00
!FAR    :  1.10680E+01
SCEN GEOM NAVI FREE
          REFE FRAM
          INIT WIRE
     VECT SCCO FIEL VITE SCAL USER PROG 0.035 PAS 0.035 0.49 TERM
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
FREQ 10
TRAC OFFS FICH AVI  NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL DEFO REND
GO
TRAC OFFS FICH AVI CONT DEFO REND
ENDPLAY
FIN

BEGIN DESCRIPTION

A bi-unit quadrilateral shell is subjected to an imposed elongation up to 3
times the initial length along one of the axes (by an imposed
constant velocity).

The material is VPJC and the purpose is to test the material model
under large strains. The effects of strain rate and of
temperature are neglected (m=0, C=0).

The result is compared with an analytical solution, showing
good agreement.

END DESCRIPTION
```

q4gss1.epx

```
Q4GSS1
ECHO
!CONV WIN
TRID LAGR
GEOM LIBR POIN 4 Q4GS 1 TERM
 0 0 0  1 0 0  1 1 0  0 1 0
 1 2 3 4
COMP EPAI 1.0 LECT 1 TERM
MATE VM23 RO 8000 YOUN 2.E11 NU 0.3 ELAS 2.E11
          TRAC 1 2.E11 1.0
          LECT 1 TERM
LINK COUP BLOQ 1 LECT 1 4 TERM
          VITE 1 1.0 FONC 1 LECT 2 3 TERM
FONC NUM 1 TABL 2 0.0 1.0
                  1.0 1.0
INIT VITE 1 1.0 LECT 2 3 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 5000
     FICH ALIC FREQ 50
OPTI NOTE PAS UTIL CSTA 0.5E0
     LMST
CALC TINI 0 TFIN 1.0 PASF 2.E-5 NMAX 50000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 ’Time [s]’
COUR  1 ’dx_1’ DEPL COMP 1 NOEU LECT 1 TERM
COUR  2 ’dx_2’ DEPL COMP 1 NOEU LECT 2 TERM
COUR  3 ’dx_3’ DEPL COMP 1 NOEU LECT 3 TERM
COUR  4 ’dx_4’ DEPL COMP 1 NOEU LECT 4 TERM
COUR  5 ’fx_1’ FLIA COMP 1 NOEU LECT 1 TERM
COUR  6 ’fx_2’ FLIA COMP 1 NOEU LECT 2 TERM
COUR  7 ’fx_3’ FLIA COMP 1 NOEU LECT 3 TERM
COUR  8 ’fx_4’ FLIA COMP 1 NOEU LECT 4 TERM
COUR 11 ’s1_1’ CONT COMP 1 ELEM LECT 1 TERM
COUR 12 ’s2_1’ CONT COMP 2 ELEM LECT 1 TERM
COUR 13 ’s3_1’ CONT COMP 3 ELEM LECT 1 TERM
COUR 14 ’s4_1’ CONT COMP 4 ELEM LECT 1 TERM
COUR 15 ’s5_1’ CONT COMP 5 ELEM LECT 1 TERM
COUR 16 ’s6_1’ CONT COMP 6 ELEM LECT 1 TERM
COUR 21 ’e1_1’ EPST COMP 1 ELEM LECT 1 TERM
COUR 22 ’e2_1’ EPST COMP 2 ELEM LECT 1 TERM
COUR 23 ’e3_1’ EPST COMP 3 ELEM LECT 1 TERM
COUR 24 ’e4_1’ EPST COMP 4 ELEM LECT 1 TERM
COUR 25 ’e5_1’ EPST COMP 5 ELEM LECT 1 TERM
COUR 26 ’e6_1’ EPST COMP 6 ELEM LECT 1 TERM
COUR 50 ’fx_sum’ FLIA COMP 1 ZONE LECT 2 3 TERM
TRAC 1 2 3 4 AXES 1.0 ’DISPL. [M]’ YZER
TRAC 5 6 7 8 AXES 1.0 ’FORCE [N]’ YZER
TRAC 11 12 13 14 15 16 AXES 1.0 ’STRESS [PA]’ YZER
TRAC 21 22 23 24 25 26 AXES 1.0 ’STRAIN [-]’ YZER
TRAC 11 AXES 1.0 ’STRESS [PA]’ XAXE 21 1.0 ’STRAIN [-]’ YZER
QUAL EPST COMP 1 LECT 1 TERM REFE  0.69315E+00 TOLE 1.E-2 ! EPS-XX
     EPST COMP 2 LECT 1 TERM REFE -0.20794E+00 TOLE 1.E-3 ! EPS-YY
     EPST COMP 4 LECT 1 TERM REFE -0.20794E+00 TOLE 1.E-2 ! EPS-ZZ
     CONT COMP 1 LECT 1 TERM REFE  0.13863E+12 TOLE 1.E-2 ! SIG-XX
     COUR 50                 REFE  0.91461E+11 TOLE 1.E-2 ! FX-SUM
FIN
```

q4gss2.epx

```
Q4GSS2
ECHO
!CONV WIN
TRID LAGR
GEOM LIBR POIN 4 Q4GS 1 TERM
 0 0 0  1 0 0  1 1 0  0 1 0
 1 2 3 4
COMP EPAI 1.0 LECT 1 TERM
MATE VM23 RO 8000 YOUN 2.E11 NU 0.3 ELAS 4.E8
          TRAC 2 4.E8 2.E-3
                 4.E8 1.E0
          LECT 1 TERM
LINK COUP BLOQ 1 LECT 1 4 TERM
          VITE 1 1.0 FONC 1 LECT 2 3 TERM
FONC NUM 1 TABL 2 0.0 1.0
                  1.0 1.0
INIT VITE 1 1.0 LECT 2 3 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 5000
     FICH ALIC FREQ 50
OPTI NOTE PAS UTIL CSTA 0.5E0
     LMST
CALC TINI 0 TFIN 1.0 PASF 2.E-5 NMAX 50000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 ’Time [s]’
COUR  1 ’dx_1’ DEPL COMP 1 NOEU LECT 1 TERM
COUR  2 ’dx_2’ DEPL COMP 1 NOEU LECT 2 TERM
COUR  3 ’dx_3’ DEPL COMP 1 NOEU LECT 3 TERM
COUR  4 ’dx_4’ DEPL COMP 1 NOEU LECT 4 TERM
COUR  5 ’fx_1’ FLIA COMP 1 NOEU LECT 1 TERM
COUR  6 ’fx_2’ FLIA COMP 1 NOEU LECT 2 TERM
COUR  7 ’fx_3’ FLIA COMP 1 NOEU LECT 3 TERM
COUR  8 ’fx_4’ FLIA COMP 1 NOEU LECT 4 TERM
COUR 11 ’s1_1’ CONT COMP 1 ELEM LECT 1 TERM
COUR 12 ’s2_1’ CONT COMP 2 ELEM LECT 1 TERM
COUR 13 ’s3_1’ CONT COMP 3 ELEM LECT 1 TERM
COUR 14 ’s4_1’ CONT COMP 4 ELEM LECT 1 TERM
COUR 15 ’s5_1’ CONT COMP 5 ELEM LECT 1 TERM
COUR 16 ’s6_1’ CONT COMP 6 ELEM LECT 1 TERM
COUR 21 ’e1_1’ EPST COMP 1 ELEM LECT 1 TERM
COUR 22 ’e2_1’ EPST COMP 2 ELEM LECT 1 TERM
COUR 23 ’e3_1’ EPST COMP 3 ELEM LECT 1 TERM
COUR 24 ’e4_1’ EPST COMP 4 ELEM LECT 1 TERM
COUR 25 ’e5_1’ EPST COMP 5 ELEM LECT 1 TERM
COUR 26 ’e6_1’ EPST COMP 6 ELEM LECT 1 TERM
COUR 50 ’fx_sum’ FLIA COMP 1 ZONE LECT 2 3 TERM
TRAC 1 2 3 4 AXES 1.0 ’DISPL. [M]’ YZER
TRAC 5 6 7 8 AXES 1.0 ’FORCE [N]’ YZER
TRAC 11 12 13 14 15 16 AXES 1.0 ’STRESS [PA]’ YZER
TRAC 21 22 23 24 25 26 AXES 1.0 ’STRAIN [-]’ YZER
TRAC 11 AXES 1.0 ’STRESS [PA]’ XAXE 21 1.0 ’STRAIN [-]’ YZER
QUAL EPST COMP 1 LECT 1 TERM REFE  0.69315E+00 TOLE 1.E-2 ! EPS-XX
     EPST COMP 2 LECT 1 TERM REFE -0.34657E+00 TOLE 1.E-3 ! EPS-YY
     EPST COMP 4 LECT 1 TERM REFE -0.34657E+00 TOLE 1.E-2 ! EPS-ZZ
     CONT COMP 1 LECT 1 TERM REFE  0.40000E+09 TOLE 1.E-2 ! SIG-XX
     COUR 50                 REFE  0.20000E+08 TOLE 1.E-2 ! FX-SUM
FIN
```

q4gss3.epx

```
Q4GSS3
ECHO
!CONV WIN
TRID LAGR
GEOM LIBR POIN 4 Q4GS 1 TERM
 0 0 0  1 0 0  1 1 0  0 1 0
 1 2 3 4
COMP EPAI 1.0 LECT 1 TERM
MATE LINE RO 8000 YOUN 2.E11 NU 0.3
          LECT 1 TERM
LINK COUP BLOQ 1 LECT 1 4 TERM
          VITE 1 1.0 FONC 1 LECT 2 3 TERM
FONC NUM 1 TABL 2 0.0 1.0
                  1.0 1.0
INIT VITE 1 1.0 LECT 2 3 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 5000
     FICH ALIC FREQ 50
OPTI NOTE PAS UTIL CSTA 0.5E0
     LMST ! This should have no effect with LINE material ...
CALC TINI 0 TFIN 1.0 PASF 2.E-5 NMAX 50000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 ’Time [s]’
COUR  1 ’dx_1’ DEPL COMP 1 NOEU LECT 1 TERM
COUR  2 ’dx_2’ DEPL COMP 1 NOEU LECT 2 TERM
COUR  3 ’dx_3’ DEPL COMP 1 NOEU LECT 3 TERM
COUR  4 ’dx_4’ DEPL COMP 1 NOEU LECT 4 TERM
COUR  5 ’fx_1’ FLIA COMP 1 NOEU LECT 1 TERM
COUR  6 ’fx_2’ FLIA COMP 1 NOEU LECT 2 TERM
COUR  7 ’fx_3’ FLIA COMP 1 NOEU LECT 3 TERM
COUR  8 ’fx_4’ FLIA COMP 1 NOEU LECT 4 TERM
COUR 11 ’s1_1’ CONT COMP 1 ELEM LECT 1 TERM
COUR 12 ’s2_1’ CONT COMP 2 ELEM LECT 1 TERM
COUR 13 ’s3_1’ CONT COMP 3 ELEM LECT 1 TERM
COUR 14 ’s4_1’ CONT COMP 4 ELEM LECT 1 TERM
COUR 15 ’s5_1’ CONT COMP 5 ELEM LECT 1 TERM
COUR 16 ’s6_1’ CONT COMP 6 ELEM LECT 1 TERM
COUR 21 ’e1_1’ EPST COMP 1 ELEM LECT 1 TERM
COUR 22 ’e2_1’ EPST COMP 2 ELEM LECT 1 TERM
COUR 23 ’e3_1’ EPST COMP 3 ELEM LECT 1 TERM
COUR 24 ’e4_1’ EPST COMP 4 ELEM LECT 1 TERM
COUR 25 ’e5_1’ EPST COMP 5 ELEM LECT 1 TERM
COUR 26 ’e6_1’ EPST COMP 6 ELEM LECT 1 TERM
COUR 50 ’fx_sum’ FLIA COMP 1 ZONE LECT 2 3 TERM
TRAC 1 2 3 4 AXES 1.0 ’DISPL. [M]’ YZER
TRAC 5 6 7 8 AXES 1.0 ’FORCE [N]’ YZER
TRAC 11 12 13 14 15 16 AXES 1.0 ’STRESS [PA]’ YZER
TRAC 21 22 23 24 25 26 AXES 1.0 ’STRAIN [-]’ YZER
TRAC 11 AXES 1.0 ’STRESS [PA]’ XAXE 21 1.0 ’STRAIN [-]’ YZER
TRAC 50 AXES 1.0 ’TOT. FORCE [N]’ YZER
QUAL EPST COMP 1 LECT 1 TERM REFE  0.69315E+00 TOLE 1.E-2 ! EPS-XX
     EPST COMP 2 LECT 1 TERM REFE -0.20794E+00 TOLE 1.E-3 ! EPS-YY
!    EPST COMP 4 LECT 1 TERM REFE -0.20794E+00 TOLE 1.E-2 ! EPS-ZZ
     EPST COMP 4 LECT 1 TERM REFE  0.00000E+00 TOLE 1.E-2 ! EPS-ZZ
     CONT COMP 1 LECT 1 TERM REFE  0.13863E+12 TOLE 1.E-2 ! SIG-XX
     COUR 50                 REFE  0.91461E+11 TOLE 1.E-2 ! FX-SUM
FIN
```

q4gss4.epx

```
Q4GSS4
ECHO
!CONV WIN
TRID LAGR
GEOM LIBR POIN 4 Q4GS 1 TERM
 0 0 0  1 0 0  1 1 0  0 1 0
 1 2 3 4
COMP EPAI 1.0 LECT 1 TERM
MATE VMIS PARF RO 8000 YOUN 2.E11 NU 0.3 ELAS 2.E11
          LECT 1 TERM
LINK COUP BLOQ 1 LECT 1 4 TERM
          VITE 1 1.0 FONC 1 LECT 2 3 TERM
FONC NUM 1 TABL 2 0.0 1.0
                  1.0 1.0
INIT VITE 1 1.0 LECT 2 3 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 5000
     FICH ALIC FREQ 50
OPTI NOTE PAS UTIL CSTA 0.5E0
     LMST
CALC TINI 0 TFIN 1.0 PASF 2.E-5 NMAX 50000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 ’Time [s]’
COUR  1 ’dx_1’ DEPL COMP 1 NOEU LECT 1 TERM
COUR  2 ’dx_2’ DEPL COMP 1 NOEU LECT 2 TERM
COUR  3 ’dx_3’ DEPL COMP 1 NOEU LECT 3 TERM
COUR  4 ’dx_4’ DEPL COMP 1 NOEU LECT 4 TERM
COUR  5 ’fx_1’ FLIA COMP 1 NOEU LECT 1 TERM
COUR  6 ’fx_2’ FLIA COMP 1 NOEU LECT 2 TERM
COUR  7 ’fx_3’ FLIA COMP 1 NOEU LECT 3 TERM
COUR  8 ’fx_4’ FLIA COMP 1 NOEU LECT 4 TERM
COUR 11 ’s1_1’ CONT COMP 1 ELEM LECT 1 TERM
COUR 12 ’s2_1’ CONT COMP 2 ELEM LECT 1 TERM
COUR 13 ’s3_1’ CONT COMP 3 ELEM LECT 1 TERM
COUR 14 ’s4_1’ CONT COMP 4 ELEM LECT 1 TERM
COUR 15 ’s5_1’ CONT COMP 5 ELEM LECT 1 TERM
COUR 16 ’s6_1’ CONT COMP 6 ELEM LECT 1 TERM
COUR 21 ’e1_1’ EPST COMP 1 ELEM LECT 1 TERM
COUR 22 ’e2_1’ EPST COMP 2 ELEM LECT 1 TERM
COUR 23 ’e3_1’ EPST COMP 3 ELEM LECT 1 TERM
COUR 24 ’e4_1’ EPST COMP 4 ELEM LECT 1 TERM
COUR 25 ’e5_1’ EPST COMP 5 ELEM LECT 1 TERM
COUR 26 ’e6_1’ EPST COMP 6 ELEM LECT 1 TERM
COUR 50 ’fx_sum’ FLIA COMP 1 ZONE LECT 2 3 TERM
TRAC 1 2 3 4 AXES 1.0 ’DISPL. [M]’ YZER
TRAC 5 6 7 8 AXES 1.0 ’FORCE [N]’ YZER
TRAC 11 12 13 14 15 16 AXES 1.0 ’STRESS [PA]’ YZER
TRAC 21 22 23 24 25 26 AXES 1.0 ’STRAIN [-]’ YZER
TRAC 11 AXES 1.0 ’STRESS [PA]’ XAXE 21 1.0 ’STRAIN [-]’ YZER
QUAL EPST COMP 1 LECT 1 TERM REFE  0.69315E+00 TOLE 1.E-2 ! EPS-XX
     EPST COMP 2 LECT 1 TERM REFE -0.20794E+00 TOLE 1.E-3 ! EPS-YY
     EPST COMP 4 LECT 1 TERM REFE -0.20794E+00 TOLE 1.E-2 ! EPS-ZZ
     CONT COMP 1 LECT 1 TERM REFE  0.13863E+12 TOLE 1.E-2 ! SIG-XX
     COUR 50                 REFE  0.91461E+11 TOLE 1.E-2 ! FX-SUM
FIN
```

q4gss5.epx

```
Q4GSS5
ECHO
!CONV WIN
TRID LAGR
GEOM LIBR POIN 4 Q4GS 1 TERM
 0 0 0  1 0 0  1 1 0  0 1 0
 1 2 3 4
COMP EPAI 1.0 LECT 1 TERM
MATE VMIS PARF RO 8000 YOUN 2.E11 NU 0.3 ELAS 4.E8
          LECT 1 TERM
LINK COUP BLOQ 1 LECT 1 4 TERM
          VITE 1 1.0 FONC 1 LECT 2 3 TERM
FONC NUM 1 TABL 2 0.0 1.0
                  1.0 1.0
INIT VITE 1 1.0 LECT 2 3 TERM
ECRI COOR DEPL VITE ACCE FINT FEXT FLIA FDEC CONT EPST ECRO FREQ 5000
     FICH ALIC FREQ 50
OPTI NOTE PAS UTIL CSTA 0.5E0
     LMST
CALC TINI 0 TFIN 1.0 PASF 2.E-5 NMAX 50000
SUIT
Post-treatment
ECHO
RESU ALIC GARD PSCR
SORT GRAP
AXTE 1.0 ’Time [s]’
COUR  1 ’dx_1’ DEPL COMP 1 NOEU LECT 1 TERM
COUR  2 ’dx_2’ DEPL COMP 1 NOEU LECT 2 TERM
COUR  3 ’dx_3’ DEPL COMP 1 NOEU LECT 3 TERM
COUR  4 ’dx_4’ DEPL COMP 1 NOEU LECT 4 TERM
COUR  5 ’fx_1’ FLIA COMP 1 NOEU LECT 1 TERM
COUR  6 ’fx_2’ FLIA COMP 1 NOEU LECT 2 TERM
COUR  7 ’fx_3’ FLIA COMP 1 NOEU LECT 3 TERM
COUR  8 ’fx_4’ FLIA COMP 1 NOEU LECT 4 TERM
COUR 11 ’s1_1’ CONT COMP 1 ELEM LECT 1 TERM
COUR 12 ’s2_1’ CONT COMP 2 ELEM LECT 1 TERM
COUR 13 ’s3_1’ CONT COMP 3 ELEM LECT 1 TERM
COUR 14 ’s4_1’ CONT COMP 4 ELEM LECT 1 TERM
COUR 15 ’s5_1’ CONT COMP 5 ELEM LECT 1 TERM
COUR 16 ’s6_1’ CONT COMP 6 ELEM LECT 1 TERM
COUR 21 ’e1_1’ EPST COMP 1 ELEM LECT 1 TERM
COUR 22 ’e2_1’ EPST COMP 2 ELEM LECT 1 TERM
COUR 23 ’e3_1’ EPST COMP 3 ELEM LECT 1 TERM
COUR 24 ’e4_1’ EPST COMP 4 ELEM LECT 1 TERM
COUR 25 ’e5_1’ EPST COMP 5 ELEM LECT 1 TERM
COUR 26 ’e6_1’ EPST COMP 6 ELEM LECT 1 TERM
COUR 50 ’fx_sum’ FLIA COMP 1 ZONE LECT 2 3 TERM
TRAC 1 2 3 4 AXES 1.0 ’DISPL. [M]’ YZER
TRAC 5 6 7 8 AXES 1.0 ’FORCE [N]’ YZER
TRAC 11 12 13 14 15 16 AXES 1.0 ’STRESS [PA]’ YZER
TRAC 21 22 23 24 25 26 AXES 1.0 ’STRAIN [-]’ YZER
TRAC 11 AXES 1.0 ’STRESS [PA]’ XAXE 21 1.0 ’STRAIN [-]’ YZER
QUAL EPST COMP 1 LECT 1 TERM REFE  0.69315E+00 TOLE 1.E-2 ! EPS-XX
     EPST COMP 2 LECT 1 TERM REFE -0.34657E+00 TOLE 1.E-3 ! EPS-YY
     EPST COMP 4 LECT 1 TERM REFE -0.34657E+00 TOLE 1.E-2 ! EPS-ZZ
     CONT COMP 1 LECT 1 TERM REFE  0.40000E+09 TOLE 1.E-2 ! SIG-XX
     COUR 50                 REFE  0.20000E+08 TOLE 1.E-2 ! FX-SUM
FIN
```

List of input files

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JRC Mission

As the Commission's
in-house science service,
the Joint Research Centre's
mission is to provide EU
policies with independent,
evidence-based scientific
and technical support
throughout the whole
policy cycle.

Working in close
cooperation with policy
Directorates-General,
the JRC addresses key
societal challenges while
stimulating innovation
through developing
new methods, tools
and standards, and sharing
its know-how with
the Member States,
the scientific community
and international partners.

Serving society
Stimulating innovation
Supporting legislation

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